An Abstract Bibliography

of

Statistical Methods

in

Grassland Research

MISCELLANEOUS PUBLICATION NO. 1030
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

An Abstract Bibliography

of

Statistical Methods

in

Grassland Research

Compiled by

Meredith J. Morris

Principal Biometrician,

Rocky Mountain Forest and Range

Experiment Station

Miscellaneous Publication No. 1030 **April 1967**

Forest Service **U.S. Department of Agriculture**

PREFACE

This bibliography was prepared for scientists concerned with the problems of defining and measuring biotic parameters, and of sampling populations in grassland communities. References on the applications of statistics to these problems, or on underlying statistical theory, are found in a great variety of publications, some limited in distribution. This is a collection of such references with abstracts and should be useful in designing new studies of grassland problems. Literature of the world through 1963 was searched; some references were undoubtedly omitted, although not deliberately.

Many of the abstracts, which are included with most of the references, were taken from various abstracting sources. The source in such cases is noted at the end of the abstract. The references are arranged alphabetically by author within each subject matter class. Since the classes are not unique, cross references are listed by number at the end of each.

Abbreviations for titles of publications generally follow USDA Miscellaneous Publication 337, Abbreviations Used in the Department of Agriculture for Titles of Publications, issued in 1939. The list of complete titles wherever possible follows Library List 75, Serial Publications Indexed in Bibliography of Agriculture, issued annually by the Department's National Agricultural Library. The full list and abbreviations of titles used in the citations are given at the end of the bibliography. Abbreviations for single words in the abstracts and added notes are also listed.

CONTENTS

THE MEASUREMENT OF VEGETATION

GENERAL REVIEWS

AHLGREN, H. L. 1

1947. A comparison of methods used in evaluating the results of pasture research. Amer. Soc. Agron. Jour. 39(3): 240–259.

The nature and complexity of probs. assoc. with pasture res. and the many variations in vegetative cover due to differences in soil, climate, topog., and elevation within and between regions have resulted in the devlpmt. of many widely different methods, all for the evaluation of pasture res. Sixteen methods or techniques that have been or are being used are reviewed, and their advantages and limitations are considered. Seven—hay wts., yields of DM of immature forages, photographs, surveys, bot. comp., chem. comp., and duration of grasses—do not involve the use of livestock; nine—profit, prod. of milk, cattle and sheep wts., pilot plots, TDN, carrying capacity, palatability trials, digest. trials, and biol. assays with small animals—are based on results provided by livestock. Although fewer, methods of measurement not involving livestock are more common than those based on livestock. Those not based on the use of livestock are probably less accurate than those involving livestock, but are often necessary in initial phases of pasture invests. where, of necessity, many variables are included. Additional studies are needed to determine relations between chem. comp. and biol. assays with small animals and large farm animals. Results from trials involving livestock are more readily expressed as cash values than are those obtained by other procedures.

AHLGREN, H. L., BOHSTEDT, G., AND AAMODT, O. S. 2

1938. Problems in evaluating pastures in relation to other crops. Amer. Soc. Agron. Jour. 30(12): 1020–1029.

Thirteen methods used in east. U.S. in evaluating pasture crops are reviewed. The need for, and desirability of, developing a satisfactory standardized technique for evaluating various types of pasture crops in relation to each other and to other harvested feed crops is discussed.

ALEHIN, V. V., AND URANOV, A. A. 3

1933. Methods of steppe analysis. Sovet. Bot. [Moskva] 1933 (2): 44–46.

Steppes, usually regarded as forage and pasture lands, possess special features affecting the methods of their invest. The most typical are (1) the abundant floral comp. gradually decreasing southwards from 70–50 spp. to 12 spp. per sq. m., (2) the complexity of the comp. of horizontal tiers of swards, (3) characters of ecotypes and sinusium, and (4) the frequency of phenological changes. In conjunction, the appl. and size of sampling and the methods of recording assocs. and frequency of spp. in the swards are discussed in detail.

ALL-UNION SCIENTIFIC RESEARCH INSTITUTE FOR FODDERS, U.S.S.R. 4

1959. [Methods for evaluating natural forage lands.] 110 pp., illus. Moscow: Academy of Agricultural Sciences. [In Russ.]

Information is given on: the classification of the meadows and pastures of the Soviet Union into 25 categories; field work for evaluating sward cover; technique for lab. study of the material; a scheme for ecol. work on a regional basis; classification of pastures in the forest/steppe, steppe, and west. Cis-Caspian areas; coefficients of util. of herbage swards; coefficients of wastage through converting the green crop to hay; and the need of green feed for cattle.—Herb. Abs.

BECKING, RUDY W. 5

1957. The Zürich-Montpellier school of phytosociology. Bot. Rev. 23(7): 411–488, illus.

The auth. holds that insufficient attention has been paid in the U.S.A. to the views and techniques of the European phytosociol. school. With a view to prompting an inquiry into the value of European methods for studying vegetation in the U.S.A., a detailed description is given of the views and methodology of European phytosociol. schools, particularly the Zürich-Montpellier school. The Physiognomic-Ecol., the Russ., and the Uppsala schools are discussed briefly. Aspects of the methodology of the Zürich-Montpellier school reviewed include: general vegetation concepts, plot analysis, the synthesis of vegetation units, phytosociol. nomenclature, the use of statis. in vegetation analysis, and some viewpoints on, and criticisms of, the Zürich-Montpellier system. —Herb. Abs.

BROWN, B. A. 6

1937. Technic in pasture research. Amer. Soc. Agron. Jour. 29(6): 468–476.

Three expt. stations in northeast. U.S.A. have found close correlation of "grazed" and "cut" 5-yr. pasture yields. But at 2 stations continuously clipped areas have been less productive than grazed areas clipped only once or for 1 season. Cutting, weighing, and analyzing pasturage may not furnish data for accurate evaluation of its feeding value. Important factors affecting yields and chem. and bot. comp. of a pasture are: frequency and closeness of grazing (or cutting), soil fertility or fertil., spp. seeded on cultivated fields, and weather. Methods of sampling herbage and soil of grassland and determining bot. and chem. comp. of vegetation are discussed briefly.

BROWN, DOROTHY. 7

1954. Methods of surveying and measuring vegetation. (With a chapter on the theory of sampling, by Jolly, G. M.) Commonwealth Bur. Pastures and Field Crops Bul. 42, 223 pp., illus. Reading, England: Bradley and Son, Ltd.

This book is a thorough rev. of the methods and techniques used in quantitative ecol. studies of vegetation for the past 20–30 yrs. The methods are classified under 3 phases of vegetation surveys, namely, bot. analysis, productivity, and util. The methods described are chiefly those applicable to the many types of grazing land throughout the world.

CAIN, STANLEY A., AND CASTRO, G. M. DE OLIVEIRA. 8

1959. Manual of vegetation analysis. 325 pp., illus. New York: Harper and Bros.

Discusses, on the basis of an extensive literature, the chief concepts and methods of vegetation analysis, with special regard to the probs. of the tropics, under the following main headings: floristics; the community-synusial structure of vegetation; major vegetation types of the world, with the tropical rain forest as an example; analysis of vegetation—reconnaissance, primary, and intensive survey, sampling systems, etc.; probs. of no.—abundance and density; probs. of pattern—frequency; probs. of dominance—coverage; size of sample units; the combination of community characteristics; concepts important in synthesis—presence and constance, fidelity, exclusiveness; and life form and leaf size. The examples, mostly taken from the West. Hemisphere, include original work by the auth. on the vegetation of Brazil.—Forestry Abs.

CAMPBELL, R. S. 9

1937. Problems of measuring forage utilization on western ranges. Ecology 18(4): 528–532, illus.

Suitable methods for the expression of util. standards for the many key spp. and for actually measuring util. in terms of such standards are required by the practical range administrator, and depend on the fundamental results of res. Range forage util. must be measured more accurately and proper util. must provide for maintenance of all the services of the land, not only forage for domestic livestock and wildlife, but also watershed protection and timber reproduction.

CAMPBELL, R. S. 10

1940. Range management research methods in the Western United States. Imp. Bur. Pastures and Forage Crops, Herbage Rev. 8(3/4): 121–138.

The range res. prob. is to determine how the highest continued productivity and use of the vast native forage resource can be maintained in harmony with econ. livestock prod. and the conserv. of other resources. The organ. and scope of work in the west. domain, initiated by the Forest Service, has been described in Herbage Rev. 5: 1–13, 1937. The present work indicates some of the more important expt. methods for: mangt. studies on semidesert ranges; pasture studies on north. shortgrass plains; cattle pasture expt. in the annual plant type; sheep grazing; ecol. studies on high mountain summer ranges; and correlation of grazing and timber reproduction.

CAMPBELL, R. S. 11

1943. Ecology.—Progress in utilization standards for western ranges. Wash. Acad. Sci. Jour. 33(6): 161–169, illus.

Recent advances in inform. needed by managers in currently judging forage util. and relative cond. of ranges in West. U.S.A. are summarized. Range cond. or state of productivity is related mainly to stage of plant succession. Trend of cond. relates to direction of plant change. A sum. of 7 yrs.' study of factors influencing cattle util. of *Bouteloua eriopoda* in south. N. Mex. is given. Several methods of establishing proper util. of important forage spp. are compared and methods of estimating degree of forage util. are considered.—Biol. Abs.

DASMANN, WILLIAM P. 12

1948. A critical review of range survey methods and their application to deer range management. Calif. Fish and Game 34(4): 189–207.

The basic prob. of deer mangt. is to balance the no. of deer with the carrying capacity of the range. The stocking levels should be adjusted to a level at which the vegetative cover and soil mantle will not be damaged. Observations on the intensity of cropping key plant spp. in key areas supplemented by observs. on general range conds. are the best methods of checking range util.—Biol. Abs.

DASMANN, WILLIAM P. 13

1951. Some deer range survey methods. Calif. Fish and Game 37(1): 43–52, illus.

As events necessitate more intensive herd mangt., inventories become essential to determine vegetation and soil cond. trends on deer ranges. The line-point and line-interception methods of sampling vegetation cover are used in Calif. where intensive survey methods appear necessary. When coupled with checks on shrub and tree form and age classes, and on forage util., either method will inform about present cond. of deer range and indicate current trend as influenced by forage util. Also, either method will provide a base with which future measurements may be compared to determine periodic trend and to show ecol. changes in vegetation cover. Two browse util. check methods, the twig measurement and the visual estimate method, are used in Calif. deer range surveys. Several suggestions regarding technique are given in the paper. A simple growth index based on av. seasonal twig length is described.

DAVIES, J. GRIFFITHS, AND TRUMBLE, H. C. 14

1934. Grassland research in Australia: Notes on the technique of pasture investigations. Imp. Bur. Plant Genet., Herbage Plants Bul. 14, pp. 23–32.

Determination is discussed for: (1) bot. comp.; (2) yield of herbage; (3) productivity in terms of the grazing animal and its products; and (4) chem. comp. Some excellent points are discussed for carrying capacity and ocular estimation.

DAVIES, WILLIAM. 15

1931. Methods of pasture analysis and fodder sampling. Welsh Plant Breeding Sta., Aberystwyth, Rpt. 1, 29 pp., illus.

Methods of pasture analysis and of hay sampling in use among res. workers, more especially at Aberystwyth, are discussed. The analyt. work upon which the paper is based is described under 6 headings, the 1st 3 dealing with the analysis of pastures [(a) the single plot of mixed herbage, (b) an acre of pasture, and (c) the pure sp. plot] and the last 3 with the analysis of cut herbage [(d) the fodder sample for air drying, (e) the fodder sample from a plot sown with a single sp., and (f) the fodder sample from a plot sown with mixed grasses and clovers]. Among the main points stressed, the following are of interest. In bot. analysis of pasture plots, 10 samples should be taken at random per plot of 1/100-acre or less to obtain a reliable mean result for the proportion of each constituent sp. All plots should be replicated 5 times in critical field trials and detailed ecol. studies of plant communities. Instead of the usual % frequency method involving lifting and teasing out of turfs, it is suggested that an eye estimation should be made of the no. of tillers of each sp. and their proportion to the whole that occur within the mark. A scale of 0–10 is used, 10 being the total marks allotted for each reading. For hay analysis, a 1 lb. green hay sample drawn after careful sampling is sufficient for a reliable result. This can be reduced to a minimum of 6 oz. when only 1 or 2 spp. are present. A representative 2 lb. green sample is of sufficient bulk to give a reliable indication of the loss of moisture during air-drying. These smaller samples are taken in the first place from large "field samples" of about 10 lbs. green wt. For calculation of the % productivity of constituent spp. of a hay sample, the lab. sample is divided into 10 subsamples and a total of 10 marks is allotted to each subsample, the proportion of each sp. being expressed on a scale 0–10. The summated results in report of the 10 subsamples give the estimated % productivity of the whole sample. The point quadrat method of pasture analysis is described and it is suggested that a modification might be suitable for analysis of cut herbage.—Herb. Abs.

DAVIES, WILLIAM. 16

1960. Betesavkastningens värdering. [The evaluation of pasture.] Nord. Jordbrugsforsk. [Stockholm] Sup. 2, 94–103.

An exposition is given of modern trends in grazing technique and in the use and mangt. of perm. grassland, temporary leys, and rough grazings in Gr. Brit., with special ref. to influence upon yield. There is no 1 expression which denotes in an entirely satisfactory way pasture yield and its value. Figures denoting starch units, DM, CP, etc. have their drawbacks, because the end product comprises an animal product (meat, milk, wool). Evaluation on a bot. basis offers a good point of departure, as does analysis of chem. comp., but seasonal variation, soil, and, above all, the grazing

animal must be taken into acct. Despite much study of evaluation probs. in many countries, progress has been slow and little has yet emerged which can be put into practice. Evaluation must be approached as a study in ecol. Environment comprises not only climate and other natural factors over which there is no control, but also soil, animal, and pasture. The 3 last-named are inseparable parts of a whole, and ultimately have to be considered thus, however much they may be studied individually.—Herb. Abs.

DAVIES, WILLIAM, HEDDLE, R. G., ROBINSON, D. H., AND OTHERS. 17
1933. Methods of pasture analysis. Agr. Prog. [Cambridge] 10: 223–252, illus. (Fenton, E. Wyllie, Horne, F. R., Roberts, R. Alun, Jones, Martin G., and Thomas, J. O., joint auth.)

Davies gives resume of history of quantitative pasture invests. and summarizes the % tiller estimate method by which, with a 6×6 in. grid, the no. of tillers in the turf is estimated by eye and checked from time to time by lifting the turf and counting the tillers. Heddle discusses specific frequency method, the same as Raunkiaer's. Robinson outlines % frequency method, in which the units are nos. of plants or tillers, counts being made on a 6×6 turf which is removed and examined in the lab. A possible defect might be that units would continually be modified in light of experience. Percent productivity method is the same, except that the units are wts. Fenton discusses % area method by which a 10×10 in. grid, subdivided by brass wires into sq. in., is estimated by eye. It is said not to be applicable when vegetation is long. He also discusses the point quadrat method, for which, instead of a frame, he uses a hollow aluminum tube with clamp and butterfly nut for fastening to a walking stick. "The point quadrat method must have a strong appeal for all those who desire statis. material unaffected by the personal factor. It does eliminate the personal factor in estimation." Horne discusses the transect method using a coil of insulated aerial wire 500 ft. long marked to show each ft. For perm. work pegs are driven every 50 ft. A 6×6 in. grid is used, in which 6 squares are painted white (at random) in which tillers are counted. After adjusting the line the worker walks from 0 ft. until he notes a distinct change in bot. composition . . . "Four random samples are then obtained within this distance, the grid being laid on the N. or E. side of the line, . . ." He also suggests estimating area rather than counting tillers. Each 100 ft. takes approximately 1 1/2 hrs. when the spp. are familiar to observer. Roberts discusses % productivity method in which turves are taken up and green parts weighed after drying between 98°–105° C. for 24 hrs. and cooled in dessicator. He suggests not going above 100°. Jones and Thomas discuss estimated productivity method. A sq.-ft. frame is used, subdivided into 10 pts. Proportional wts. are estimated and checked by weighting every 20th green sample in the field.

DONALD, C. M. 18
1946. Pastures and pasture research. 117 pp., illus. Sydney: Univ. of Sydney Press.

This book is a concise and comprehensive sum. of Australian pasture probs. and viewpoint. Experimental results from domestic and foreign sources are drawn upon freely for illus. Ch. I, The Role of Pastures in Land Use Planning, includes effects of pastures upon soil structure, fertility, and resistance to erosion. Effects of overgrazing in semiarid regions and of rotations, spp., and legume effects in humid and subhumid regions are discussed. Ch. II, Pasture Competition and Seeds Mixtures, includes ecol. and competitive relations of pasture spp. for water, nutrients, and light and compounding of seeds mixtures. Ch. III is concerned with spp. and strains of pasture plants, plant introduct., the ecotype in relation to breeding, breeding of strains, and varietal maintenance. Ch. IV is concerned with pasture mangt. and influences of grazing on performance. Season, frequency, and severity of grazing, selectiveness of grazing animals, and return of nutrients are related to mangt. Ch. V, The Nutritive Value of Pastures, is a review of factors influencing nutritive value and the effect of animal selectivity on the diet. The relations of seasonal factors, protein quality, energy constituents, mineral and vitamin content, and nutritive defects are considered. Ch. VI is devoted to the technique of pasture experimentation. Aspects emphasized are general principles, criteria of evaluation, expt. design, and determination of yield. In studying bot. comp., density, foliage cover, and basal area analyses are described.

GIÖBEL, G., LUNDBLAD, K., SAKSHAUG, B., AND OTHERS. 19
1940. Technique of grassland experimentation in Scandinavia and Finland. Imp. Bur. Pastures and Forage Crops Bul. 28, pp. 7–47. (Foss, H., Bogh, H., Hansen, H., and Charpentier, C. A. G., joint auth.)

The Sw. Grassland and Peat Assoc.'s origin and expt. work are reviewed. Techniques both for quantitatively measuring grass prod. and for stock grazing trials are described. Measurement of grass prod. involves use of control cages and plot trials under specified

cutting and grazing systems. Stock grazing trials involve recording of dates of manuring, times of pasturing, animal prod., and data on grazing capacity and palatability of the sward. The methods employed for determining the bot. comp. of the sward in Sweden are field methods (notably coverage estimation by the Hult-Sernander procedure) and lab. methods involving sampling after cutting, separating, and weighing the different spp. When uncultivated, but otherwise productive soils are grazed in Norway, the most effective methods of util. are studied in cultivation expts. Yield is determined in fodder units on the basis of no. of grazing days and the amount of milk produced on different plots. The value of new strains for different regions of Norway is determined from bot. analyses and yield of DM. Grassland bot. comp. in Denmark is determined by (a) P. Nielsen's method, (b) Raunkiaer's method, and (c) bot. wt. analysis. Methods used in Finland since 1924 for evaluating grassland productivity include direct and indirect estimates. Productivity is estimated directly with control cages, generally 4×4 or 5×5 m., which are moved to new areas in the plot after each harvest of forage. It is estimated indirectly from livestock wt. gains or losses and products livestock produce while on pasture.

GOODALL, D. W. **20**
1952. Quantitative aspects of plant distribution. Cambridge Phil. Soc. Biol. Rev. 27(2): 194–245.

A rev., covering the random or aggregated distrib. of individuals, the relation between frequency and density, spp.-area and frequency-distrib. curves, the logarithmic series and index of diversity, interspecific correlations, vegetational homogeneity, minimal area, and the classification of vegetation based on quantitative measurements.—Biol. Abs.

GOODALL, DAVID W. **21**
1962. Bibliography of statistical plant sociology. Excerpta Bot. [Stuttgart], Sect. B, 4: [253]–322.

Grassland Research Institute, Hurley. **22**
1961. Research techniques in use at the Grassland Research Institute, Hurley. Commonwealth Bur. Pastures and Field Crops Bul. 45, 167 pp., illus. Farnham Royal, Bucks: Commonwealth Agricultural Bureaux.

Director William Davies and members of his staff have performed a great service to all grassland scientists by outlining in detail the res. techniques used at the Institute. The auth. are to be commended for their efforts to impress upon the grassland res. worker the importance of careful planning, the wise use of statis., and the adoption of suitable techniques. Much of the philosophy concerning grassland res. will be helpful to, and should be heeded by, both the young and the experienced investigator. The description of techniques and methods is presented under 6 main heads: Expt. design and interpretation; Herbage plant invests.; Animal invests.; Plant soil studies; Extension trials; Special lab. equipment and its use. Within the confines of this book grassland specialists working in humid regions will find techniques for making most of the measurements they are likely to undertake. While the methods used by the staff at Hurley have been selected only after careful evaluation, the auth. recognize that their uniform adoption in other regions may not be possible or desirable. It is the intent of the auth. to provide a ready ref. on grassland res. techniques which will permit other investigators to avoid the time-consuming task of developing a "new" technique. Even if the procedure described is not completely satisfactory in another environment it can frequently provide a valuable point of departure. Probably no 2 investigators would agree upon all of the techniques described, but on the other hand it is doubtful whether they would disagree on many. The book presents ideas as well as methods and the grassland specialist will find that it is a valuable addition to his library.—Herb. Abs.

GREIG-SMITH, P. **23**
1957. Quantitative plant ecology. 198 pp., illus. New York: Academic Press.

Practical potentialities of various methods and techniques in quantitative study of plant communities, including statis. analyses, are assessed. The book is mainly a guide to profitable means of obtaining and handling quantitative data. Successive ch. deal with probs. of description of comp., structure, and classification of communities, such as: describing vegetation in qualitative terms, positioning and no. of samples to be used, comparison of sets of samples, patterns of random distrib. and techniques of detection and analysis of departure from random patterns, correlations between vegetation and environmental factors, and delineation and classification of communities. A final ch. discusses the contribs. to the ecol. theory that can be made by the quantitative approach, including the few integrating principles of plant ecol. (succession, climax, and the community as a quasi-organism). It concludes that the quantitative approach

can assess relative stability in vegetation better than preexisting methods, and that the individualistic viewpoint in plant ecol. is closer to reality than the organismal concept, and the continuum than the discrete assoc.—Biol. Abs.

HANSON, HERBERT C. 24
1938. Ecology of the grassland. Bot. Rev. 4(2): 51–82.

Methods and criteria in ecol. study, especially of grassland, are discussed.

HANSON, HERBERT C., AND CHURCHILL, ETHAN D. 25
1961. The plant community. 218 pp., illus. New York: Reinhold Publishing Corp.

The cent. theme of this book is the formation and nature of the plant community. The devlpmt. of the theme begins with a discussion of the properties of spp. and populations, i.e., of the relations of plants and animals to their physical environment and to one another. It is then demonstrated how these properties lead to the formation of various kinds of groupings and communities. This discussion is followed by an analysis of community characteristics and their use in description and classification, and of the changes, or dynamics, that occur in plant communities. Numerous illustrative examples are provided in order to clarify concepts and to assist in the solution of specific probs., particularly as they are encountered in the field. This book is intended as a text for semester or quarter courses in plant ecol.; as a supp. to textbooks in general ecol. which usually do not deal adequately with the formation and nature of the plant community; or as an adjunctive text for courses in animal ecol., forestry, range mangt., wildlife mangt., conserv., and agr. It is also intended to serve the general reader who desires to be better informed about the nature of vegetation and its potentialities. A bibliog. and subj. index are included.—Biol. Abs.

HEADY, HAROLD F. 26
1949. Methods of determining utilization of range forage. Jour. Range Mangt. 2(2): 53–63.

Techniques of measuring range forage util. are reviewed. Methods based upon estimates and measurements are compared and the advantages and limitations of each are discussed. Forty-five refs. are listed.

HUMPHREY, R. R. 27
1949. An analysis of forage utilization methods and a proposal for utilization surveys by range condition classes. Jour. Forestry 47(7): 549–554.

Forage util. survey methods are reviewed and some of their shortcomings for field use given. A method of making util. surveys on a range-cond. basis is proposed. Different cond. classes should be grazed at different intensities. A rate for grazing each of 5 cond. classes of range is proposed. To obtain wider acceptance of util. data by ranchers and technicians, specific recoms. are made for simplifying recording. An ability to designate the key forage spp. and to determine the cond. of the range is essential. Utilization on key areas is observed and recorded directly on a map of the ranch. No data are tabulated on forms.

IVINS, J. D. (ed.) 28
1959. The measurement of grassland productivity. 217 pp., illus. New York: Academic Press.

Unlike most arable crops, grass is a most difficult crop to measure for its production. This is because it is grown to feed livestock and its ultimate value consequently rests on its effects on animal production. The normal grazed sward is also a mixture of plants—grasses, clovers, and herbs—each sp. making a particular demand on its environment. Measurement techniques were the main concern of the 6th (1959) Easter School in Agr. Sci. where the following papers were presented: The evolution of grassland res. techniques, by William Davies; Twenty years of grassland recording on the expt. farm at Rengen, by E. Klapp; The ley in relation to crop productivity, by T. E. Williams; The preliminary classification of herbage vars., by R. P. Hawkins; Varietal characteristics of herbage plants in relation to their agronomic assessment, by Ll. I. Jones; Analysis of the distrib. of foliage area in grassland, by J. Warren Wilson; The measurement of herbage prod., by J. O. Green; The value of herbage estimates in animal prod. expts., by C. Line; Experiences in the measurement of herbage consumption by livestock, by J. Davison; A rev. of herbage prod. and consumption yield measurement techniques adopted in N. Ireland, by J. Lowe; Pasture expts. with animals, by F. E. Alder; The relationship between grazing intake and animal prod., by W. Holmes; Studies of herbage prod. and consumption and the prod. of dairy cows in various grazing conds., by D. S. MacLusky; A critical rev. of pasture evaluation via the Falke-Geith Method, by P. Boeker; The interpretation of animal prod. data in grassland evaluation, by J. D. Ivins; The nutritive value of herbage, by W. F. Raymond; Ruakura experiences with

the chromium-faeces nitrogen method, by R. J. Lancaster; The digestibility of herbage by dairy cows, by J. Davison; The measurement of grassland productivity on dairy farms in England and Wales, by J. Clark; and Sixteen years experience of grassland recording on a farm scale, by Rex Paterson.

JOINT COMMITTEE OF AMERICAN SOCIETY OF AGRONOMY, AMERICAN DAIRY SCIENCE ASSOCIATION, AND AMERICAN SOCIETY OF ANIMAL PRODUCTION. **29**

1943. Preliminary report on pasture investigations technique. Jour. Dairy Sci. 26(4): 353–369.

Committees of the 3 Societies have proposed tentative procedures and methods of expressing pasture yields as a guide for res. workers. The rpt. is primarily designed for the humid and irrig. sects. of the country. The procedure employed may vary with the type of expt. conducted, whether it be a measure of growth response to particular fert. treatments, a comparison of different systems of grazing mangt., or some other important pasture prob. In some cases merely adaptations of some of the suggestions of procedure will be necessary. Items covered are: location of plot or paddocks; soil types and comp. changes; size, shape, and fencing of pasture, and no. of animals; kind, sex, size, and uniformity of animals; mangt. of pasture, and of animals; determination of yields by calculating amount of TDN required by grazing animals; determining comp. of herbage; digest. trials; use of pilot plots; palatability determinations; cooperative demonstrations; study of pasture flora; duration of expt.; use of fertil. and soil amendments; animal parasites; insects and rodents; determination of costs; contingent or contributing data; and photography.—Biol. Abs.

JOINT COMMITTEE OF AMERICAN SOCIETY OF AGRONOMY, AMERICAN DAIRY SCIENCE ASSOCIATION, AMERICAN SOCIETY OF ANIMAL PRODUCTION, AND AMERICAN SOCIETY OF RANGE MANAGEMENT. **30**

1952. Pasture and range research techniques. A report. Agron. Jour. 44(1): 39–50.

This rpt. makes current recommended procedures and methods for pasture and range res. Numerous refs. are given. Suggestions as to the no. of pastures per treatment, no. of animals per pasture, and size of pasture for grazing expts. are given, and the selection and allotment of pastures and animals specially considered. Procedures recommended for determining prod. of a pasture and forage quality are discussed, and those for studying pasture flora, soils, and climatic factors are reviewed briefly.

JOINT COMMITTEE OF AMERICAN SOCIETY OF AGRONOMY, AMERICAN DAIRY SCIENCE ASSOCIATION, AMERICAN SOCIETY OF ANIMAL PRODUCTION, AND AMERICAN SOCIETY OF RANGE MANAGEMENT. **31**

1962. Pasture and range research techniques. 242 pp., illus. Ithaca: Comstock Publishing Associates.

This is a rev. of more brief rpts. appearing in the Jour. of Dairy Sci. in 1943, and in the Agron. Jour., 1952. It contains an introduct. to numerous methods and a guide to over 400 pubs. describing res. methods useful in studying pastures, grazing animals, herbage quality and yield, and bot. analysis of pastures and ranges. Additional and complementary factors are treated briefly: plant diseases and pests, root and soil studies, irrig., climate, small plot techniques, econ. evaluation, and photography.—Biol. Abs.

KLAPP, E. **32**

1935. Methods of studying grassland stands. Imp. Bur. Plant Genet., Herbage Plants, Herbage Rev. 3(1): [1]–8. [Transl. of article in Third Internatl. Grassland Cong., Zürich, Rpt. 1934: 193–202.]

From 6 yrs.' comparative observs., the auth. rev. the factors in prod. of accurate and correct analyses. The following methods are not advisable: (a) purely qualitative method, (b) counts or % estimates of individual plants or shoots, and (c) area estimations and projection surveys. Methods aiming at the determination of the % yield are best for accuracy and comparison of results. The following may be used: (a) regular analyses by weighing the yield after cutting, (b) mass estimations in pasture expts. and on other areas, and (c) methods using less accurate estimations for surveying larger areas and supplementing plant sociol. study.

KLEČKA, A., AND FABIAN, J. **33**

1934. [Scientific bases for the study of meadows and pastures.] [Czechoslovakia] Min. Zeměděl. Sborn. 117: 182. [Ger. sum.]

The study of meadows and pastures must be carried out from the point of view of plant sociol. and synecology. From the history of plant-growth devlpmt. in cent. Europe the auth. show that nearly all grassland except the mountain meadows, etc., is of artificial origin, the forest climax assoc. preponderating. Sociological methods must be

appl. in the study of grassland plants. After a detailed criticism of other methods the auth. reach the concl. that the best method for studying abundance is that of judging according to a 5-point system. The density is tested by measuring the distances between individual plants of the same sp. Similarly the dominance is given by the av. area of single plants of one sp. Repartition, sociability, frequency, vitality and periodicity in the grass cover, together with competition of spp. are points discussed. The influences of climate and soil are described in detail with many examples. Finally the changes caused by human activities are discussed. In the last ch. the auth. give recoms. for carrying out expts. on grassland and for laying out plots, harvesting, etc.—Herb. Abs.

Konjuškov, N. S., Rabotnov, T. A., and Cacenkin, I. A. **34**
1961. Methods for experimental work on meadows and pastures. 287 pp., illus. Moscow: State Publications for Agricultural Literature. [In Russ.]

This book is a new version of a collection of articles originally prepared by the V. R. Williams All-Union Sci. Res. Inst. Fodders and published in 1935. The majority of the articles have been rewritten. The book is in 2 pts. In the 1st pt., general methods are dealt with. The 2nd pt. is devoted to programs, methods and systems, of value for rational use and impr. of natural meadows and pastures. Examples of subjs. dealt with in the 1st pt. are: terminology; choice of expt. plots; calculation of yields of meadows and pastures in standardized expts.; the study of structures of herbage stands; the effect of mowing and grazing. Subjects discussed in the 2nd pt. include: the study of fodder-meadows in rotations; the choice of high productive pasture grass/legume mixtures for wooded zones; increasing the legume content in grass stands of sown and natural meadows and pastures; the use of ferts.; impr. of meadows and pastures by irrig.—Herb. Abs.

Lindsey, Alton A. **35**
1956. Sampling methods and community attributes in forest ecology. Forest Sci. 2(4): [287]–296.

Substantial progress has been made recently in the devlpmt. of improved ecol. sampling techniques for analysis of forest communities. The vegetational attributes constituting the objectives of sampling methods are redefined and their interrelationships indicated by means of a symbolic system presented in tabular form. The recent expansion of quantitative methods and concepts suggests the usefulness of symbols and formulae, particularly in the teaching of ecol. Two new sum. expressions, prevalence and predominance, which integrate the role of cover with other parameters, are introduced. Two general groups of methods, detailed versus rapid survey methods, are distinguished. Detailed sampling techniques include the quadrat method involving surveyed boundaries, and the line-strip method—which combines a linear unit and an areal strip but in which only the line is surveyed. Rapid methods include distance or spacing methods such as the random-pairs and the preferable quarter method, and the Bitterlich variable-plot-radius method. The various methods are evaluated, and a new method, involving use of instruments from 1 point to combine variable-radius sampling with the quadrat, is suggested.—Auth. sum.

Linehan, P. A. **36**
1956. Methods of pasture evaluation. European Grassland Conf., Paris, Sum. 1954: 110–112.

Mainguy, P. **37**
1958. Les herbages tropicaux. Revue synoptique des principes des méthodes d'étude. Application à l'échantillonnage de la végétation. [Tropical grasslands. Synoptical review of principles concerning methods of study. Application to the sampling of vegetation.] Rev. d'Élevage et de Méd. Vét. des Pays Trop. [Paris] 11(3): 305–338, illus.

This rev. is concerned with the qualitative and quantitative study of grassland vegetation, in particular with: nomenclature and classification of plant environments proposed by J. L. Trochain for French Negro Africa; phytogeographical classification proposed by specialists of the Sci. Council for Africa of the Sahara; classification of grasslands; biol. units of study; sampling; bot. analysis.—Herb. Abs.

Medin, Dean E. **38**
1960. References on methods of measuring production and utilization of range and pasture forage. A selected annotated list. Colo. Dept. Game and Fish Tech. Bul. 6, 43 pp.

Moore, R. M., Barrie, Nancy, Kipps, E. H., and others. **39**
1946. Grazing management: Continuous and rotational grazing by Merino sheep. 1. A study of the production of a sown pasture in the Australian Capital

Territory under three systems of grazing management. Appendix: The measurement of pasture yield under grazing. 2. The effect of continuous and rotational grazing on the infestation of sheep with internal parasites. 3. A note on pasture management. Austral. Council Sci. and Indus. Res., Bul. 201, 104 pp. (McIntyre, G. A., Gordon, H. McL., Turner, Helen Newton, and Davies, J. Griffiths, joint auth.)

A perm. pasture mixture of *Phalaris tuberosa, Trifolium subterraneum, Medicago sativa,* and *Dactylis glomerata* was seeded in 1939 at Canberra and grazed by Merino wethers from June 1940 to Oct. 1944 under 3 grazing systems: continuous, 4-wk. rotation, and 8-wk. rotation. The 3 systems were compared in pasture yield and comp. and in live wt., wool prod., and health of grazing sheep. Carrying capacity varied from 2 to 4 sheep per acre, averaging 2.84 per acre over the 4 years. *P. tuberosa* and *T. subterraneum* yields were not affected by the method of grazing. But *M. sativa* had almost completely disappeared at the end of the 4 years under continuous grazing. Under the 4-wk. rotation the stand was much reduced. Under the 8-wk. rotation, a productive stand was maintained. Sheep live wt. was equal under the 3 treatments except during the summer and autumn drought of 1942. Wool quality and quantity were equal except in the 1941–42 season. Because of the 6 mos. drought in this season, sheep on the 8-wk. rotation produced fewer tender fleeces and slightly more wool than sheep on the other 2 treatments. It is recommended that lucerne be grown as a separate crop. Yield cannot be expected to increase under rotational as compared with continuous grazing without adjusting stocking rate to the carrying capacity of the pasture. Chemical analyses were made of the 4 pasture spp. under the 3 grazing systems. The usual seasonal variations and variations due to available moisture were noted. The overall picture showed little difference between the 3 systems. To see if there was correlation, pasture yield under each was also measured and bot. comp. and density studied.

National Research Council. Agricultural Board. Subcommittee on Range Research Methods. **40**

1962. Basic problems and techniques in range research; a report of a joint committee of the American Society of Range Management and the Agricultural Board. Natl. Acad. Sci.-Natl. Res Council Pub. 890, 341 pp., illus.

Although intended primarily for use in the range areas of N. Amer. the book should be a useful ref. and guide for pasture workers in any country with natural grasslands. Within the broad spectrum of range res. methodology the book fulfills its objectives of discussing the inherent problems, assembling the various methods used for different phases, and describing their use, limitations, and suitabilities. After an outline of the rational approach to range research, emphasis is put on the need to define and appraise the problem, planning and interpretation of experiments, and application of results. Range research complexities, selection of expt. facilities, and methods are discussed. These matters inherent in any good res. cannot be stated too emphatically to the student and to the res. worker-in-training. Subsequent ch. deal with the control of habitat factors, study of vegetation, measuring of forage util., livestock selection and mangt., and watershed studies. A ch. is devoted to econ. res. in range mangt. Two ch. are devoted to sampling methods and expt. design. These will be especially useful to the embryo res. worker applying his basic statis. training to the design and analysis of pasture and large-scale grazing expts. The final ch. covers the range of probs. that might be expected in applying res. techniques in range mangt. Subjects covered include range resowing, range fertil., brush- and weed-control, expt. grazing, big-game mangt., and fire.

Poore, M. E. D. **41**

1955. The use of phytosociological methods in ecological investigations. I. The Braun-Blanquet System. Jour. Ecol. [London] 43(1): 226–244.

The divergence that has arisen between the phytosociologists of Continental Europe and Anglo-Amer. ecol. is discussed. An attempt is made to interpret the devlpmt. and aims of the Zürich-Montpellier school of sociologists. The reasons for certain features of the system which they use are analyzed, as well as the use of floristics as the basis of a classification of vegetation, the abs. nature of the Assoc., the value of various criteria (fidelity, dominance, constancy) for characterising Assocs., and their view of succession. Techniques for the field description of vegetation and for the constructing of assoc. tables are explained. The article is interpretative rather than critical. "Faithful species" is proposed to transl. the German "Charakterart."

Poulton, Charles E. **42**

1948. Sampling technique in range forage volume inventory. Northwest Sci. 22(3): 108–115.

Methods of range reconnaissance, wt. inventory, and forage yield are evaluated. Present inventory methods are not wholly satisfactory.

RENNER, F. G., CRAFTS, EDWARD C., HARTMAN, THEO C., AND ELLISON, LINCOLN. 43
1938. A selected bibliography on management of western ranges, livestock, and wildlife. U.S. Dept. Agr. Misc. Pub. 281, 468 pp.

SCHULTZ, VINCENT. 44
1961. An annotated bibliography on the uses of statistics in ecology—a search of 31 periodicals. U.S. Atomic Energy Comn. Off. Tech. Inform. TID–3908, 315 pp.

U.S. FOREST SERVICE. 45
1959. Techniques and methods of measuring understory vegetation. Proceedings of a symposium at Tipton, Georgia, October 1958. U.S. Forest Serv. South. and Southeast. Forest Expt. Stas., 174 pp., illus.

This rpt. is divided into the following sects.: (1) Measurement of herbage prod. and util., (2) measurement of plant cover and comp., (3) related probs. in the measurement of understory vegetation, and (4) statis. probs. in measurement of understory vegetation. In addition, each sect. has a committee rpt., and an overall rpt. is included for the symposium.

U.S. FOREST SERVICE. 46
1963. Range research methods. A symposium—Denver, Colorado—May 1962. U.S. Dept. Agr. Misc. Pub. 940, 172 pp., illus.

The proceedings of this symposium, sponsored by the Division of Range and Wildlife Habitat Res., Forest Service, include sects. for: (1) Introductory session, (2) vegetation measurement and sampling, (3) range site measurement and evaluation, (4) measurement and evaluation of range use by livestock and game, and (5) design and conduct of grazing expts. In addition, each sect. has a committee rpt.

VRIES, D. M. de. 47
1937. Methods used in scientific plant sociology and in agricultural botanical grassland research. Imp. Bur. Pastures and Forage Crops, Herbage Rev. 5(4): 187–193.

VRIES, D. M. de. 48
1949. Übersicht über die bestandes- untersuchungsmethoden von grünland. [Survey of methods of botanical analysis of grassland.] Fifth Internatl. Grassland Cong., Wageningen, Rpt. 1949: 143–153.

WAGNER, R. E. 49
1952. Weight estimation and other procedures for measuring the botanical composition of pastures. Sixth Internatl. Grassland Cong., State College, Proc. 1952: 1315–1321.

WILLIAMS, C. B. 50
1954. The statistical outlook in relation to ecology. Jour. Ecol. [London] 42(1): 1–13.

Presidential address surveying the effect of the math. outlook on experimentation and outlook on field ecol., and particularly the changeover from the idea of over-simplification to more complex forms of experimentation and observ. Examples—chiefly from the author's own work—are given of the effect of weather conds. on insect activity and insect nos., phenology of birds, relative abundance of insect spp., the no. of genera with different nos. of spp., the no. of parasites on individual hosts, the relative distrib. of plants in quadrats, the measurement of diversity in animal and plant populations, and its appl. to the study of intrageneric competition. There is a bibliog. of 23 pubs. by the auth. dealing with the special probs. in more detail.

CLIPPED OR MOWED PLOTS

AUSTENSON, H. M. 51
1958. Use of a field chopper for harvesting forage plots. Agron. Jour. 50(4): 231–232, illus.

A commercial rotary forage harvester was adapted for harvesting and weighing hay and pasture plots. In comparison with the conventional method of cutting with a sickle bar mower, raking and carrying to a scale, the chopper required half as many man-hrs. per plot and the C.V. was reduced by half. Ground surface must be smooth for effective operation.—Biol. Abs.

Brown, B. A., and Munsell, R. I. 52
1945. Deterioration of clipped caged areas in permanent pastures. Amer. Soc. Agron. Jour. 37(7): 542–548.

In each of 3 differently fertilized, grazed perm. pastures, caged areas, clipped with grass shears for 11 yrs., had decidedly less grass, many more weeds, much more bare ground, and consistently smaller yields including the weeds, than nearby areas caged for only 1 yr. Except for K, there were no important differences between the chem. analyses of the vegetation from the fixed and moved cages. The 10-yr. av. difference in total yields between continuously caged, clipped areas and those caged and clipped for only 1 season was greatest (61%) on the unfertilized pasture, medium (33%) under LPK fertil., and least (16%) where, in addition to LPK, a liberal amount of N was applied annually in Apr. For the differently fertilized pastures, the av. grazed yields varied from 71% to 119% of the yields from the fixed cages and from 58% to 74% of the yields from the moved cages. Although the yields of the fixed cages were closer to the grazed yields than those from the moved cages, the markedly greater prevalence of weeds under continuous clipping throws much doubt on the applicability of that method as a substitute for grazing in measuring the prod. of pastures.—Auth. sum.

Campbell, Robert S., and Cassady, John T. 53
1949. Determining forage weight on southern forest ranges. Jour. Range Mangt. 2(1): 30–32, illus.

Some south. (U.S.A.) forest ranges have a pine litter of 6–10 tons per acre. They yield only a fraction of the forage produced by open forest ranges. Forage wt. is determined by a modification of the method of Pechanec and Pickford developed for west. ranges. Forage is clipped and weighed in g. from a plot 3.1 ft. sq. The g. wt. times 10 equals lbs./acre. Litter (pine and oak leaves), old growth (previous season's herbage), weeds, and grass are harvested and weighed separately. The method has proven satisfactory on ranges whose prod. varied from 10 to 5,000 lbs./acre.

Cassady, John T. 54
1941. A method of determining range forage utilization by sheep. Jour. Forestry 39(8): 667–671, illus.

The method consists of clipping and weighing individual samples of several important forage spp. shortly before grazing and repeating the process soon after grazing. Each specific sample consists of several observs. (wt.-records) obtained from several mechanically located points on the area chosen as representative. An observ. is composed of a predetermined no. of plant units (stem, leaf, twig) of the sp. involved.

Cowlishaw, S. J. 55
1951. The effect of sampling cages on the yields of herbage. Brit. Grassland Soc. Jour. 6(3): 179–182.

An expt. showed that the yields of green and DM were significantly greater under sampling cages than on unprotected areas. The implication of differences for measurement of herbage yields in grazing expts. is discussed.

Culley, M. J., Campbell, R. S., and Canfield, R. H. 56
1933. Values and limitations of clipped quadrats. Ecology 14: 35–39.

There are several points of difference between clipping and actual grazing by livestock which prevent direct and unqualified appl. of the results in range mangt.: (1) in clipping, the vegetation is cut uniformly at a given ht., whereas the grazing animal breaks off the stems and leaves at a convenient ht.; (2) the natural preferences of livestock are not simulated in clipping studies; (3) with plots as small as one m. sq. there is some question as to the accuracy of the results which is, of course, reduced by replication; (4) the trampling factor is not present; (5) the accumulation of litter on clipped quadrats differs from that on a grazed range. If properly conducted, however, it may show the following relationships: (1) forage yield each yr. over a period of yrs.; (2) variation in yield between spp.; (3) relation of yield to soil moisture; (4) relation of tuft area or plant cover to soil moisture; (5) relation of both yield and tuft area to frequency and degree of harvesting; (6) relation of ht. growth, leaf length, no. of flower stalks, and tuft area to yield; (7) relation of nutritive and mineral values of clipped materials to soil moisture and to frequency and degree of harvesting; (8) probable trends in plant succession under different degrees of cutting. Author claims the method has proven valuable in showing the proper degree of util.—Herb. Abs.

Elliott, I. L., and Lynch, P. B. 57
1958. Techniques of measuring pasture production in fertiliser trials. New Zeal. Jour. Agr. Res. 1(4): 498–521.

A description is given of a series of expts. at the Rukuhia Soil Res. Sta. where the

responses of pasture to a no. of ferts. were measured by several different techniques. The techniques are compared as follows: (1) as measures of total pasture prod.; (2) as measures of responses to fert. treatment; (3) errors of estimation attached to each technique; (4) effects of techniques on the spp. comp. of the sward; (5) effects of techniques on the chem. status of the soil; and (6) labor and land requirements of each technique. For trials where stock prod. data are required in addition to pasture prod. data and where it is considered essential that treatments be compared under normal grazing mangt. by stock, the "cage" technique as operated by the Extension Division is considered to be the most useful and reliable method. For small-plot trials where the primary aim is an estimation of fert. response by pastures, and where an accurate measure of total pasture prod. is not required, the "mowing and clippings returned" technique is satisfactory. Certain limitations to the "mowing and clippings returned" technique are discussed.—Auth. sum.

FRENCH, M. H., AND RODRÍGUEZ, C. S. **58**

1960. Variaciones en los rendimientos de diferentes pastos en los Trópicos. [Variations in the yields of different forage species in the Tropics.] Agron. Trop. [Maracay] 10(2): 77–86. [Eng. sum.]

This prob. was studied with *Chloris gayana* and *Cynodon plectostachyus* in Kenya, and with *Panicum purpurascens* (*Brachiaria mutica*), *P. maximum*, and *C. plectostachyus* in Venezuela. Great variations were found in the yields from small test plots. Dry-matter yields from such plots varied with the plant sp. and the soil type but variations between individual small plots were greater than in temperate regions.—Herb. Abs.

GLENDAY, A. C. **59**

1959. Mathematical analysis of growth curves replicated in time. New Zeal. Jour. Agr. Res. 2(2): 297–305.

Alternative math. models for the analysis of growth curves replicated in time are fitted and their efficiencies in a field growth study compared. Modifications of the models necessary for their appl. to data where the time replication interval is greater than the recording interval are described. The magnitude of bias in the parameters fitted because of systematic errors in the prelim. cutting of the plots, is determined. An example of the math. procedure is also given.—Auth. sum.

HEADY, HAROLD F. **60**

1957. Effect of cages on yield and composition in the California annual type. Jour. Range Mangt. 10(4): [175]–177, illus.

Comparisons were made of the growth of annual grass vegetation in Calif. under wire-netting cages (1.5-in. mesh) and in the open. The cages were 3.5 ft. in diam. and 2.5 ft. high. From 8 Nov., 1955, to 3 Mar., 1956, the av. oven-dry wt. of herbage from a caged site was 3.46 g. per sq. ft., compared with 2.33 g. on an adjacent uncaged area; the prod. of grass under a thin tree canopy was 2.38 g. per sq. ft. under cages and 1.88 g. on an uncaged area. These differences were both significant at the 0.01% level. Where the cages were in place from Nov. to May, or Mar. to June, forage yields under cages did not differ significantly from that of adjacent uncaged areas. It is concluded that on this type of vegetation in Calif., cages result in small, but significant, increases in growth during the winter season, but the differences soon disappear when temps. rise enough to permit rapid growth. The use of cages had no detectable effect on bot. comp. or soil surface conds.—Herb. Abs.

HEBBLETHWAITE, P., AND HUGHES, M. **61**

1959. Estimating the soil content of herbage collected by forage harvester. Brit. Grassland Soc. Jour. 14(3): 169–171, illus.

A method is described for estimating soil contamination in herbage collected with a forage harvester. Handcut samples of herbage are used as a control. To avoid subsampling errors a relatively large sample is used. It is ovendried and then compressed to facilitate ashing. Acid-insoluble ash ("silica") content is used as a measure of contamination. The statis. examination of the data is discussed briefly.

JAGTENBERG, W. D., AND BOER, T. A. DE. **62**

1957. De bruikbaarheid van graskooien voor opbrengstbepalingen. [The usefulness of grazing cages in pasture yield determinations.] Landbouwvoorlichting [Hague] 14(12): 622–623, illus.

The effect of cages on grass prod. in ungrazed pasture was investigated in the wet summers of 1952, 1953, and 1954 in 9 trial plots, 6 of which were on clay soil, 2 on sandy soil, and 1 on peaty soil; 5 cuttings at intervals of 35 days were made each season. Under the cages, DM content of the grass was always lower than in the open field. Dry-matter prod. under cages on clay soil was up to 15% greater than in the open

field, but on the other soils no significant difference was observed. When rainy conds. prevailed, the cage-effect was smaller. A high correlation was found between the DM content of the grass and increased yield (on clay soils) under the cages. On Netherlands clay soils, grazing cages were found to be unsuitable for accurate res. on grass yields.—Herb. Abs.

JAGTENBERG, W. D., AND BOER, T. A. DE. 63
1958. De invloed van graskooien op de grasopbrengst. [The influence of grazing cages on grass yield.] Landbouwk. Tijdschr. [Wageningen] 70(12): 879–889, illus. [In Dutch with Eng. sum.]

Full numerical data are given of expt. work on grazing cages, an acct. of which appeared in Landbouwvoorlichting [Hague] 1957, 14, No. 12.—Herb. Abs.

JONES, LL. I. 64
1958. Technique studies on herbage assessment. Welsh Plant Breeding Sta., Aberystwyth, Rpt. 1950–56: 111–113.

When different cocksfoot swards were defoliated simultaneously and at the same frequency, their relative herbage prod. varied with the mode of defoliation. The S strains were more productive than Dan. when grazed by sheep, and Dan. was more productive when mown. In a comparison of cutting methods, Dan. yielded 1,136 lbs./acre when cut with hand shears and 977 lbs./acre when autoscythed, while S143 yielded 1,226 lbs./acre when cut with hand shears and 482 lbs./acre when autoscythed.—Herb. Abs.

KLINGMAN, DAYTON L., MILES, S. R., AND MOTT, G. O. 65
1943. The cage method for determining consumption and yield of pasture herbage. Amer. Soc. Agron. Jour. 35(9): 739–746.

When estimating the consumption of pasture herbage by the difference method it was found that it is more efficient to choose the 1st 4×4 ft. area at random and its mate similar to the 1st, than to choose both at random. After the two 4×4 ft. areas are located, the 1 to be caged should be chosen at random. Each of 4 operators working independently greatly increased his precision by selecting the 2nd 4×4 ft. area to be similar to the 1st. It is more efficient to place cages singly than in groups. For estimating herbage consumption and prod. of pastures with equal variability, the same no. of cages is needed for equal precision regardless of the size of the pasture. In the pasture studied, nearly as many cages would have been needed for a 2-acre area as for the entire 12 acres.—Biol. Abs.

LYNCH, P. B. 66
1947. Methods of measuring the production from grasslands. A review of the techniques employed by the Fields Division, Department of Agriculture. New Zeal. Jour. Sci. and Technol. Sect. A 28(6): 385–405.

Special techniques need to be developed for measuring grassland prod. Some of those in use are discussed and evaluated. For small plots, mowing and grazing trials, clipping with clippings returned, and other approaches are discussed.

NEVENS, W. B. 67
1945. A comparison of sampling procedures in making pasture yield determinations. Jour. Dairy Sci. 28(3): 171–185.

Standard errors are smaller in the direct harvest plan of sampling grass pastures than in difference plans, and coefficients of variability are lower. Tests of the variance of the data obtained in this invest. by 4 plans of sampling show significant *F* values for the direct harvest plan in a no. of instances where expected, but no such values for the other plans. Where grazing is delayed because of a rotation plan of pasturing or other reasons, the direct harvest plan is advantageous in showing period yields and in computing yields. These advantages and its simplicity make it highly suitable as the 1 plan of sampling where only yield determinations of grass pastures are desired. The difference plans provide a valuable check. They are much more satisfactory than the direct harvest plan in determining yields of crops such as soybeans and sweet clover, which may either be killed or greatly retarded by frequent close cutting, and are also valuable in computing by period herbage consumed in grazing. Difference plan No. 2, in which open pasture yields of the previous sampling date are subtracted from the protected area samples, is proposed as an improved plan of calculating yields over difference plan No. 1, in which open pasture yields are subtracted from the protected area yields of the same date. The amount of live wt. maintained per acre is one of the valuable measurements of pasture yield.

SCHECHTNER, G. 68
1959. Zur technik der probenahme bei grünlandversuchen. [Sampling technique for grassland experiments.] Grünland [Hannover] 8(7): 44–46, illus.

Besides a brief rev. of known herbage-sampling techniques, 2 instruments developed at Gumpenstein, Austria are described. The 1st is a fodder borer used in sampling mown hay for DM content and chem. analysis. The spiral cut of this instrument increases the no. of plants represented in the sample. The 2nd instrument is a pair of grass-cutting shears which, to reduce effort, has the opening and closing mechanism perpendicular to the plane of cutting. The grass is cut in 1 strip, and since the shears give a narrow cut, the strip is long, and the sample therefore satisfies the requirement of including as many plants as possible. With skill in handling, the herbage can be cut with plants lying side by side.

VRIES, D. M. DE. 69
1937. Methods of determining the botanical composition of hayfields and pastures. Fourth Internatl. Grassland Cong., Aberystwyth, Rpt. 1937: 474–480.

Two methods are described: 1. Weight (actual air-dry wts.); 2. Sociol. (specific) frequency. Samples (25 sq. cm.) of sward are taken into the lab., after which (a) sp. occurrence is listed, and (b) the order (1st, 2nd, or 3rd only) in vol. in each sample is estimated.

VRIES, D. M. DE. 70
1948. Method and survey of the characterization of Dutch grasslands. Vegetatio [Hague] 1(1): 51–57.

The author's plant sociol. specific frequency plus % wt. method of classifying grassland using 0.25 sq. dm. plots is outlined. Sixteen main types distinguished for the Netherlands are each characterized by a sp. that is sufficiently frequent, significant from agr. viewpoint (indicating a good, fair, or bad sward), or a useful indicator ecologically. Value of the main-type and type-forming spp. and reasons for choosing them are discussed, and a key to the 16 main types, in order of priority, is given.

WACKER, F. W. 71
1943. Vergleichende prüfung von landwirtschaftlich brauchbaren verfahren der grünlandbestandes-untersuchung. [A comparison of methods for the investigation of green-land associations, practicable in agriculture.] Pflanzenbau [Leipzig] 19(11): 328–348; 19(12): 349–363, illus.

A no. of analyses with the several methods of studying plant assocs. were made to find the best one for determining the comp. of the green-land. The most complete list of spp. was obtained by total analysis of the crop (cutting all plants in a definite area and determining the % (wt.) of the several spp.). Comparative methodology is further discussed.

WAGNER, R. E., HEIN, M. A., SHEPHERD, J. B., AND ELY, R. E. 72
1950. A comparison of cage and mower strip methods with grazing results in determining production of dairy pastures. Agron. Jour. 42(10): 487–491.

Two techniques of determining prod. of dairy pastures were compared 1 with another and with results obtained from grazing over the 3-yr. period, 1946–48, at Beltsville, Md. The data show a high correlation (r=0.94) between yields of pasture as determined by the mower strip and cage methods. Cage yields, however, were generally somewhat higher than strip yields and considerably higher than grazing results. From the standpoint of mean yields by individual pastures and mean yields of all pastures for all 3 yrs., strips gave a closer indication of grazing results than cages in these studies. The general level of cage yields was somewhat higher relative to grazing results than that of the strip yields. However, the correlation between cage and grazing yields was greater than between strips and grazing, on a basis of individual season yields from all pastures, indicating more variability in the strip results. Much of the difference between the 2 methods in this respect occurred on the bluegrass pasture. In fact, while both methods were more accurate on the orchard grass than on the bluegrass pasture, there was some indication that strips estimated grazing yields of the orchard grass with slightly less variability than the cage method. On the other hand, the cage method was considerably less variable on the bluegrass pastures.—Auth. sum.

WILLIAMS, STELLA S. 73
1951. Microenvironment in relation to experimental techniques. Brit. Grassland Soc. Jour. 6(4): 207–217.

The effects of sampling cages, hurdles, and fences on the enclosed microenvironment were investigated. Wind was measured with an Air Meter type of anemometer under all 3 types of protection and in the open field. Temperature and humidity were measured with thermistors inside both a cage and a hurdle and compared with readings in the open. Some temperature records were also taken with thermometers. The light under a cage and outside were compared. Evidence is given that wind force is greatly cut

down by all 3 types of obstruction. Temperature and relative humidity were higher inside a hurdle than outside; this may be explained as the direct result of the wind reduction. Evidence is also given that the microenvironment under a cage is controlled by the balance of the reduction of both wind force and solar radiation. The relative humidity is higher under a cage than in the open. But the temp., although variable, is most frequently lower. Reference is made to the recognition of these results in expt. techniques.

See also **6, 7, 15, 19, 32, 46, 146, 213, 219, 233, 241, 243, 244, 262, 275, 319, 372, 621, 633, 674, 687, 738, 740, 741, 745, 747, 749, 751–754, 757, 758, 760, 761, 763, 765–767, 774, 958, 1074, 1075, 1115.**

LINE INTERCEPT

ANDERSON, KLING L. **74**

1942. A comparison of line transects and permanent quadrats in evaluating composition and density of pasture vegetation of the tall prairie grass type. Amer. Soc. Agron. Jour. 34(9): 805–822, illus.

Randomized line-transects were compared to perm. m.-sq. quadrats for sampling of density and spp. comp. of 2 pastures of the tall grass prairie type near Manhattan, Kans. In the quadrats, clumps of vegetation were charted in sq. cm. at the ground surface; individual culms were given a value of 1 sq. cm. In the transects, all vegetation that came into contact with a 10-m. length of 3/32-in. steel cable stretched as near the ground level as possible was recorded. Clumps were recorded in cm. along the wire; individual culms were given a value of 1 cm. Assuming the sampled strip to be 1 cm. wide, these culms were considered as sq. cm. of area occupied to permit direct comparisons. General agreement between the 2 methods was fairly close. The quadrats failed to accurately estimate spp. which were not uniformly distributed over the pasture, due, undoubtedly, to insufficient sampling. The quadrats were found likely to fail to sample widely scattered, though sometimes dense areas of a particular sp., but they occasionally fell directly on such an area and unduly emphasized a particular sp. The transect method is more rapid, and a larger no. of samples may be taken in a given period. Furthermore, the samples are taken at random and are not subj. to the personal bias that might be encountered in the selection of representative areas for the estab. of perm. sampling plots. In addition to providing a better comparison between pastures, the line-transect method gives a better estimate of the variability within pastures as the area is sampled by a greater no. of more widely distributed points.

BAUER, HARRY L. **75**

1943. The statistical analysis of chaparral and other plant communities by means of transect samples. Ecology 24(1): 45–60.

A comparison of transect and quadrat methods of sampling vegetation was made and, also, a comparison of 3 different concepts of quantitative relations, namely, (1) coverage, (2) numerical abundance, and (3) frequency. The lab. tests consisted of measurements of simulated plant communities of known comp. These "communities" consisted of colored cardboard discs assembled in various combinations. Where the discs were all the same size, transect and quadrat sampling were about equally accurate. Transect sampling, however, requires much less time. Where discs were various sizes (the usual situation in nature), the transects were decidedly more efficient than quadrats where the results were expressed as coverage. The % of the transect line covered more accurately indicated the true areal coverage than did % of the area covered within the quadrat samples. The advantages of coverage data, rather than numerical abundance or frequency data, are discussed. A field test in a dense Calif. chaparral indicated that, in this type of vegetation, transect sampling may save time without loss of accuracy. Transect sampling deserves much wider use than has been made of it in the past. It is likely that, by proper adaptations, it can be used to determine most of the ecol. relations for which quadrats have generally been used.

BUELL, M. F., AND CANTLON, J. E. **76**

1950. A study of two communities of the New Jersey pine barrens and a comparison of methods. Ecology 31(4): 567–586.

The forest communities in the pine barrens region of N. J. were studied, using the quadrat and the transect methods of community analysis. The quadrat method was used to obtain density, frequency, and basal area for the tree layer. The transect method (modified from Bauer 1935) was used to obtain cover, numerical abundance, frequency, and basal area of the tree layer, and to obtain frequency and cover in the shrub layer. A new instrument was designed for obtaining accurate crown projection for studying cover of the tree layer. The results obtained by the 2 methods are compared and an attempt is made to evaluate the methods.—Auth. sum.

CANFIELD, R. H. 77
1941. Application of the line interception method in sampling range vegetation. Jour. Forestry 39(4): 388–394, illus.

Estimates of density, comp., and ecol. structure involve only linear measurements of the intercept of plants along the line. The taking of stubble hts. along the line permits an estimate of grazing use and the clipping and weighing of plants along a narrow belt transected by the line permits an estimate of forage crops. The method is efficient for both large and small areas, is economical, and has a sound statis. basis.—Biol. Abs.

CANFIELD, R. H. 78
1942. Sampling ranges by the line interception method. Plant cover—composition —density—degree of forage use. U.S. Forest Serv. Southwest. Forest and Range Expt. Sta. Res. Rpt. 4, 28 pp., illus.

The line interception method was used for sampling density and comp. of range vegetation over such varying areas as small expt. plots, expt. range pastures, and 2 large National-Forest allotments. Special attention was given to forage-plant inventory and the measurement of forage use. The 1st pt. of the paper gives instructions for sampling range vegetation. The 2nd pt. deals with compilation of results and statis. treatment of the data.

CANFIELD, R. H. 79
1944. Measurement of grazing use by the line interception method. Jour. Forestry 42(3): 192–194, illus.

Three yrs.' field experience indicates that transect lines 50–100 ft. long are adequate as units of sampling. The range is divided into blocks of a given size, and equal nos. of sample lines are distributed at random in each block. Methods of recording and summarizing the data are described and illus.—Biol. Abs.

HORMAY, A. L. 80
1949. Getting better records of vegetation changes with the line interception method. Jour. Range Mangt. 2(2): 67–69.

This discussion directs attention to factors that make for efficient use of the technique.

KINSINGER, FLOYD E., ECKERT, RICHARD E., AND CURRIE, PAT O. 81
1960. A comparison of the line-interception, variable-plot and loop methods as used to measure shrub-crown cover. Jour. Range Mangt. 13(1): 17–21, illus.

Three methods for estimating shrub crown cover were compared by 3 observers at 4 locations in NW. Nev. The line-interception method gave shrub cover values comparable to "line cover" calculated by the ellipse-formula method. Values obtained by the loop and variable-plot methods were significantly higher than "true cover." Among-plot variation was significant at all locations with the loop and line-interception methods, but it was significant at only 1 location with the variable-plot method.

MCINTYRE, G. A. 82
1953. Estimation of plant density using line transects. Jour. Ecol. [London] 41(2): [319]–330, illus.

An examination is made of various methods of estimating no. of plants per unit area from intercepts on line transects either directly or with the assistance of supplementary data. The use of these methods is illus. by sampling an artificial population of irregular figs. The methods are likely to be of greatest interest when basal area is regarded as the primary measure and density only auxiliary.

NAVARRO, J. A. 83
1955. A mathematical appraisal of rapid sampling methods including line-intercept coverage method. (Unpublished Ph.D. thesis in mathematics, Purdue Univ., Lafayette, Ind.)

PARKER, KENNETH W., AND SAVAGE, D. A. 84
1944. Reliability of the line interception method in measuring vegetation on the Southern Great Plains. Amer. Soc. Agron. Jour. 36(2): 97–110, illus.

Tests of the accuracy and reliability of the line interception method as used in sampling the vegetation on expt. pastures showed this method to be admirably suited for the accurate determination of density and floristic comp. of native vegetation, but the need is stressed for careful standardization and repeated checking of field procedure. —Biol. Abs.

WHITMAN, WARREN C., AND SIGGEIRSSON, EINAR I. 85
1954. Comparison of line interception and point contact methods in the analysis of mixed grass range vegetation. Ecology 35(4): 431–436.

Point contact methods were found to produce overall higher density evaluations for most spp. and groups in mixed grass range vegetation than did the line interception method. The all-contacts variation of the point method was about equal to the line transect method in indicating the presence of spp. on the study area at the intensities of sampling used, but the basal-contact variation of the point system was notably poorer in this respect. When used to secure density estimates of equal accuracy for the major components of the vegetation, the point contact methods were not much more rapid than the line interception method. Variability in spp. or group densities was high. The principal spp. and groups which made up over 70% of the vegetation on the study area showed variabilities in excess of 30% of their mean densities. Sampling to secure sampling errors not in excess of 5% of mean density at the 68% level of probability for all spp. and groups as used in this study, while not impossible, would be a task of considerable magnitude with any of the methods studied. In intensive studies it would be practical to sample the principal spp. at 5% accuracy and the most important secondary spp. and groups with sampling errors not to exceed 10%. For survey work in vegetation of this type and density a minimum working basis of 23 line transects, 1,400 all-contacts points, or 3,600 basal-contact points is suggested. This would provide for estimates of the 3 major components of the vegetation, needle-and-thread (*Stipa comata*), blue grama grass (*Bouteloua gracilis*), and the sedges (composite group of 3 *Carex* spp.) with sampling errors of 10% or less, and most of the other important spp. and groups with sampling errors somewhere between 10% and 20%.—Auth. abs.

See also **7, 13, 86, 93, 95, 184, 962, 975.**

POINT

Brun, Jorge M., and Box, Thadis W. **86**

1963. A comparison of line intercepts and random point frames for sampling desert shrub vegetation. Jour. Range Mangt. 16(1): 21–25, illus.

In (a) a sagebrush (*Artemisia tridentata*)/grass community, consisting of approx. 55% shrubs, 15% forbs and 30% grasses, a 50-ft. line intercept gave results for bot. comp. similar to those of a 10-point frame, but in (b) a sagebrush/shrub community containing approx. 90% shrubs, the line intercept tended to overestimate shrubs at the expense of forbs and grasses. The point frame, however, gave higher values for ground cover than did the line intercept. The efficiency of the point frame, in terms of time required to obtain results of a predetermined accuracy, was 1.4 times greater than the line intercept in (a) and 1.85 times greater in (b).—Herb. Abs.

Cook, C. Wayne, and Box, Thadis W. **87**

1961. A comparison of the loop and point methods of analyzing vegetation. Jour. Range Mangt. 14(1): 22–27, illus.

In a sagebrush (*Artemisia tridentata*) and snowberry (*Symphoricarpos vaccinoides*) community, estimates of canopy cover (1st hit) and ground cover were made along twelve 100-ft. transects. The "point" consisted of the tapered point of a 36-in. length of 0.125-in. thick welding rod used either singly (line point transect) or mounted 6 in. apart in a frame of 10 (point frame quadrat). The loop consisted of a ring, 0.75 in. diam., attached (at right angles) to the base of a 36-in. welding rod. A hit was recorded when 50% or more of the loop was covered. Reset, or replacement, readings were made after a few days. The line point gave a significantly higher overall canopy cover than the loop, but for ground cover there was no such difference; assembly of the points in a frame merely reduced the C.V. Browse plants (shrubs) were overestimated by the loop and grasses considerably underestimated when compared with the point or point frame, whilst forbs were in reasonably close agreement. Reset readings showed no appreciable difference by either method for canopy and ground surface cover, but only 68% of the hits were of the same spp. The auth. conclude that rereading the same transect is preferable to resampling and that the point frame is, of the 3 methods used, the quickest and most precise.—Herb. Abs.

Crocker, R. L., and Tiver, N. S. **88**

1948. Survey methods in grassland ecology. Brit. Grassland Soc. Jour. 3(1): 1–26.

The point quadrat method of cover analysis of pasture swards has been used for grassland surveys in the SE. of S. Australia, and has proved both objective and rapid. Three to five hundred point samples per unit area (field or paddock) are usually enough for reliable analysis of a pasture. Providing that edaphic variability is not great, uniformity of treatment is more significant than most other factors, especially area, in determining bot. variation, and the size of paddock is not very important for the no. of point samples required. For general ecol. studies on grasslands under S. Australian conds., the most satisfactory time to make the analyses is in mid-late

spring. This enables the ann. facies of the sward to be assessed in relation to the perens. that provide the more stable framework of assocs. in the better pastures. Many of the pastures in S. Austrialia, however, are almost all anns. Where more inform. is required, the bot. comp. of the grasslands can of course be assessed by the same method at regular intervals or as frequently as desired throughout the yr. Although most spp. contribute their maximum to coverage just before maturity, spp. in a pasture assoc. unfortunately do not mature at the same time. When comparisons are to be made in subsequent yrs., it is important to record the stage of maturity of different spp. Providing such observs. on stage of maturity are made and the comp. determined at a similar stage (not necessarily the same date) each yr., the point technique makes a relatively simple matter of the study of the effect of variable climatic factors from season to season on the dynamics of pasture communities. Where a sp. has a growth habit differing markedly from that of the remainder of the grassland, it is better omitted from the point analysis, and its frequency determined in some other manner. This was found necessary with thistles, for example, which in late spring reach a ht. beyond the possibilities of the point apparatus. Relative abundance of thistles was determined by counting the individuals in a no. of quadrats, each 2 1/2 links by 5 links in area, randomly placed over the pasture. The chief value of grassland surveys is in defining pasture types and their edaphic and climatic relations. Surveys can also be used to assess the major successional trends resulting from various types of field husbandry and to define probs. in pasture establishment, development, and maintenance. A no. of examples are given to indicate the type of inform. that can be obtained, though no attempt has been made to consider the operation of all the ecol. factors in results. The examples are primarily to demonstrate the wide no. of uses and value of the point quadrat technique.

Evans, Raymond A., and Love, R. Merton. **89**

1957. The step-point method of sampling—a practical tool in range research. Jour. Range Mangt. 10(5): 208–212, illus.

The step-point method was investigated as a means of determining the total ground cover and % cover of herbaceous plants; the procedure in this case was a combination of (a) the point transect method, and (b) estimation of the % area in quadrats along the same transect. Equally spaced transects were laid across the test area and sampling points were equally spaced along each transect. Sampling points were established as follows: the sampler held his boot with the heel on the ground and the sole inclined at 30° to the vegetation; a sampling pin was lowered perpendicular to the sole and guided by a definite notch in the toe of the boot. The 1st plant struck by the pin was recorded. If no plant was struck the plant directly in front of the pin was recorded. Coverage was estimated with a sq.-ft. frame with a cross-bar which was aligned with the notch. Using 300–500 points and 20 frame readings, this method compared favorably in accuracy with established methods, and was more rapid.—Herb. Abs.

Fayle, D. C. F. **90**

1959. The point contact method as a three-dimensional measure of ground vegetation. Forestry Chron. [Canada] 35(2): 135–141, illus.

A measure of the quantity of vegetation competing with yellow birch seedlings on 1/4-milacre study plots was needed to provide a comprehensive picture of seedling devlpmt. The point-contact method of sampling vegetation was chosen because with modifications to the technique, the structure, distrib., and comp. could be measured to provide data on the competing vegetation. Basically, the method involves dropping a rod (point) vertically through the vegetation and recording the plants touched (contacts) by the rod at a large no. of these points. Features of the method, considerations in appl., and the technique developed for this particular study are discussed.—From auth. sum.

Goodall, D. W. **91**

1952. Some considerations in the use of point quadrats for the analysis of vegetation. Austral. Jour. Sci. Res. Ser. B 5(1): [1]–41, illus.

The use of vertical pins or point quadrats in the analysis of vegetation, and the statis. treatment of results obtained with them, are discussed on the basis of data collected in different parts of Victoria. Results are expressed in terms of the proportion of the ground covered by each sp. ("% cover"), the av. no. of layers of foliage covering each point of ground ("cover repetition"), and the proportion of each sp. in the vegetation as a whole ("% of sward"). It is shown that pin diam. affects the results markedly, except those for % of sward. Percentage cover and cover repetition both tend to be overestimated by pins. Equal distrib. of points over the area under study is advocated, rather than random distrib. of individual points or groups of points. Where changes in the vegetation are the main subj. of interest, successive observs. should be

made at the same points. The use of transformations in the statis. treatment of the data is discussed. It is shown that the no. of contacts of a pin with a given sp. can generally be fitted by a negative binomial distrib. if the no. of points at which there is no contact be ignored. Subjective factors may lead to consistent differences between observers recording the same vegetation by the point-quadrat method, but these differences are small compared with those occurring with many other ecol. techniques.—Auth. sum.

GOODALL, D. W. 92

1953. Point quadrat methods for the analysis of vegetation. The treatment of data for tussock grasses. Austral. Jour. Bot. 1(3): [457]–461, illus.

An improved estimate of the mean cover repetition in the centers of tussocks may be obtained by fitting a negative binomial distrib. by successive approx.—Auth. sum.

JOHNSTON, A. 93

1957. A comparison of the line interception, vertical point quadrat, and loop methods as used in measuring basal area of grassland vegetation. Canad. Jour. Plant Sci. 37(1): 34–42.

The methods were compared on selected, uniform areas of 3 range types: *Festuca/Danthonia, Agropyron/Stipa,* and *Bouteloua/Stipa.* In each range type, records were taken along 10 transects, each of 100 ft. Only plant crowns were recorded; the results therefore represent basal area. Line-intercept measurements were made to the nearest 0.01 ft.; point readings, with pins of 3/32 in. diam., were taken at 1-in. intervals along each 100 ft. transect; and in the loop method, the crowns of vegetation appearing within a 0.75 in.-diam. loop which bisected the transect were recorded. The av. % basal area of vegetation determined by the loop method was 2 to 3 times that determined by the point method which was a little higher than that by the line intercept. The loop method was the most rapid to use in the field; it detected the fewest spp. and gave the most variable data, especially when the dominant plants were single-stemmed spp., e.g., *Agropyron smithii,* or grasses of the open bunch type such as *Danthonia parryi,* but it was a useful method for *Bouteloua gracilis* and grasses of a similar growth habit. The line-interception method was the most time-consuming; it detected more spp. than either the loop or the point and gave data which were slightly more variable than the point method. The point method gave the least variable data, and in general, seemed the most satisfactory for characterizing the vegetation of the range types studied. Sampling intensities required at 4 locations to sample the dominant spp. (by 3 methods) and the secondary spp. (by 2 methods) within ±10% of their respective means, using basal areas, are tabulated.—Herb. Abs.

JOHNSTON, A. 94

1958. Note on personal error in estimates of basal area when using the vertical point method. Canad. Jour. Plant Sci. 38(3): 382–383.

KARMANOVA, I. V. 95

1960. Nekotorye priemy opredeleniya obiliya vidov travyanokustarnichkovogo yarusa taezhnykn lesov. [Some methods of determining the abundance of species in the herb and shrub layer of Taiga forests.] Bot. Zhur. [Moscow] 45(2): 238–248. [In Russ. with Russ. sum.]

Methods compared for accuracy are ocular estimation, the quadrat method, the point method, and the line interception method. For determining the percentages of different spp., the last 2 methods were found the most practical, giving sufficient accuracy with less expenditure of time than quadrats (the most accurate method if enough quadrats are laid out).

KEMP, C. D., AND KEMP, ADRIENNE W. 96

1956. The analysis of point quadrat data. Austral. Jour. Bot. 4(2): [167]–174.

The type of distrib. followed by point quadrat %-cover data has been studied. The hypergeometric type IIA distrib. with constant n has been deduced from theoretical considerations and found to give a good fit to data published by Goodall in 1952. The parameters of this distrib. assist the study not only of the overall % cover but also of the patchiness of the vegetation. The assumption of this type of distrib. does not preclude the use of the angular transformation; this remains the appropriate transformation for stabilizing the variance. Theoretical considerations have been put forward in support of the policy of reducing the no. of pins per frame. However, if this is done, the no. of necessary locations is increased; only by practical experimentation can the optimum no. of pins per frame be determined.—Auth. sum.

LEVY, E. BRUCE. **97**
1933. Technique employed in grassland research in New Zealand. 1. Strain testing and strain building. Imp. Bur. Plant Genet., Herbage Plants Bul. 11: [6]–16, illus.

LEVY, E. BRUCE, AND MADDEN, E. A. **98**
1933. The point method of pasture analysis. New Zeal. Jour. Agr. 46(5): [267]–279, illus.

MULLER, P. J. **99**
1963. A stave-point apparatus for vegetation survey and measurement on steep and rock-strewn hill slopes. So. Afr. Jour. Agr. Sci. 6(2): 339–343, illus.

A spring-loaded, single-point sampling device is described. It moves in a vertical plane and is supported by 2 guides attached to a stouter stave held upright by 1 operator with its lower end on the ground. A 2nd operator records hits by the moving point. The method is suitable for rocky, sloping terrain on which the wheel point method is unsuitable. In a test to compare these 2 methods, no significant difference between them in % spp. comp. or total cover was disclosed.—Herb. Abs.

ROBINSON, P. **100**
1955. The estimation of ground cover by the point quadrat method. Ann. Bot. [London] (n.s.) 19(73): [59]–66.

In studying pasture comp. it has been found that with certain spp. the nos. of individual plants per sample quadrat followed the negative binomial distrib. Others, however, where the isolation of individuals is difficult, such as grasses showing a creeping type of growth, did not appear to follow this distrib. Another method of pasture analysis is therefore required, and the paper describes an examination of a pasture in Kenya by the point method described by Levy and Madden. It is suggested that for pastures less uniform than those normally found in Gr. Brit. there should be a greater distance between the points of the apparatus for it to be efficient.—Auth. sum.

SPEDDING, C. R. W., AND LARGE, R. V. **101**
1957. A point-quadrat method for the description of pasture in terms of height and density. Brit. Grassland Soc. Jour. 12(4): 229–234, illus.

This paper is a contrib. to the concept of ht. of a dense sward. The concept takes into acct. the distrib. of herbage density throughout the ht. range of a sward. The method described measures the proportion of a sward which attains a series of hts. at 1-in. intervals. To do this, a point-quadrat apparatus is used. The point quadrat is mounted on one side of a tripod frame (for stability); the pins are slender, solid cylinders, graduated in in., and have blunt ends. Herbage density at each in. level is regarded as being proportional to the no. of hits obtained at that level. The apparatus is placed in the pasture according to some accepted method of random sampling. The pins are lowered to ground level and every hit by some part of a plant within each in. band is recorded. For each sp. and for each 1-in. ht. band, the readings are converted into the no. of hits per 100 points. When this series of nos. is plotted against ht., a curve is obtained which shows the relation between ht. and density of the sward. Mean density is calculated as the total no. of hits in all ht. bands divided by the maximum ht. The ht. on the curve which corresponds with the mean density is the ht. index. This is regarded as the effective ht. of a sward. The method has been used to follow the devlpmt. of swards under different treatments and to provide an objective measurement of the sward in terms of ht. and density.—Herb. Abs.

TINNEY, FRED W., AAMODT, O. S., AND AHLGREN, HENRY L. **102**
1937. Preliminary report of a study on methods used in botanical analyses of pasture swards. Amer. Soc. Agron. Jour. 29(10): 835–840, illus.

Six methods for making bot. analyses of pastures, namely, string, vertical, and inclined point quadrat, specific frequency, % frequency, and % area, were tested for accuracy and practicability. On the basis of relative *F* values, labor, and accomplishment, the specific frequency and % frequency methods used with a grid are not favored. If the inform. either provides is desired, 1 of the 2 point quadrat methods or the string method may be used instead. The 2 point quadrat methods show the greatest merits for rapidly and reliably determining the comp. of a pasture and, in addition, indicating productivity. The inclined point quadrat method covers the greater area per reading and consequently increases the accuracy, and is more easily used in tall vegetation. More experience and data are necessary to evaluate accurately the merits of the respective methods and under what purposes and conds. each is best.

WATSON, E. V. **103**
1960. A quantitative study of the bryophytes of chalk grassland. Jour. Ecol. [London] 48(2): 397–414.

Bryophytes along perm. transect lines on 4 nature reserves are studied, and results with point contact and quadrat methods compared. Each gives the same picture of status of principal spp. New light is shed on the relative importance of different spp. in chalk grassland. The importance of angle and aspect of slope, turf character, and land use history is discussed. Species of N.- and S.-facing slopes are contrasted. The survey followed drastic reduction of rabbits through myxomatosis, and the influence of this on bryophyte incidence is considered.

WILSON, J. WARREN. **104**

1959. Analysis of the spatial distribution of foliage by two-dimensional point quadrats. (With appendix on derivation of formulate by Reeve, J. E.) New Phytol. [London] 58(1): 92–101, illus.

The quantitative method for estimating grassland cover described by Levy and Madden [Herb. Abs. 3, p. 185, 1933] is criticized and a modified method is advocated from which summated data provide an estimate of the total area of foliage per unit area of ground (LAI).—Herb. Abs.

WILSON, J. WARREN. **105**

1960. Inclined point quadrats. (Appendix on derivation of formulae by Reeve, J. E.) New Phytol. [London] 59(1): [1]–8, illus.

"Relative frequency" recorded by point quadrats measures not the actual area of foliage but the area projected in the direction in which the quadrat lies. Accordingly the relative frequency varies both with the slope of the foliage and also—when inclined quadrats are used—with the inclination of the quadrat. A theoretical study reveals that variation in relative frequency resulting from foliage angle differences is greatest in vertical quadrats, is much reduced when (as suggested by Tinney, Aamodt, and Ahlgren) quadrats incline at 45°, and is least when quadrats incline at 32.5°. Accordingly the usual, vertical position for point quadrats is the worst possible, since it results in the most erroneous estimates of % contrib. (area basis). With quadrats inclined at 32.5° errors are greatly reduced and are of an order acceptable in general survey work.

WILSON, J. WARREN. **106**

1963. Estimation of foliage denseness and foliage angle by inclined point quadrats. (Appendix by Reeve, J. E.) Austral. Jour. Bot. 11(1): 95–105.

Compared with a combination of vertical and horizontal quadrats, the accuracy of point quadrat estimations of foliage denseness and LAI is improved by using 1 quadrat inclined at 32.5° to the horizontal, and improved still further by using 2 quadrats inclined at 13° and 52°. Inclined quadrats, however, gave less accurate estimates of foliage angle. Practical details of the use of the method are given.

WINKWORTH, R. E. **107**

1955. The use of point quadrats for the analysis of heathland. Austral. Jour. Bot. 3(1): [68]–81, illus.

A brief theoretical examination of the relations between the orientation of leaves on a plant and the area of their projections is made and it is then shown how, for heathland spp., inclined point quadrats give appreciably different and usually higher estimates of % cover than do vertical point quadrats. The use of inclined point quadrats for estimation of % contrib. to the vegetation is examined and found to have no real advantage since no increase in precision is obtained with their use. Errors caused by the thickness of point quadrat pins are found to be large for the estimation of % cover in the microphyllous heathland vegetation. These can be minimized by the use of a cross-wire sighting tube, but an expt. shows that caution must be exercised in using this device because of the intertangling of the foliage of the various spp. Estimates of % contrib. were hardly affected by pin size. When pins were randomized independently over the test area, considerably lower variance for both % cover and contrib. estimates were obtained compared with pins held in frames of 10.—Auth. sum.

WINKWORTH, R. E., PERRY, R. A., AND ROSSETTI, C. O. **108**

1962. A comparison of methods of estimating plant cover in an arid grassland community. Jour. Range Mangt. 15(4): 194–196, illus.

Percent cover in an arid tussock grassland in cent. Australia was estimated by 5 sampling methods. While the line intercept method was in doubt, for all practical purposes the 5 methods gave statistically similar and equally reliable estimates. The point method and an ocular estimate in a small circular quadrat appeared to be faster than either ocular estimates in larger quadrats or the line intercept method.

See also **7, 15, 17, 28, 46, 85, 114, 129, 203, 218, 231, 241, 243, 251, 264, 275, 279, 392, 752, 1077.**

ARENS, R. 109

1958. Zur frage der anwendung der ertragsanteilschätzung bei weidebestands-untersuchungen. [The application of the weight-estimate method to the botanical analysis of pastures.] Ztschr. f. Acker- u. Pflanzenbau [Berlin] 105(1): 44–49.

The reliability of estimations was tested against actual analysis by wt. of herbage (dried to 100° C.). The test was made on a 4-yr.-old sown pasture, the herbage of which had attained a ht. of about 15 cm. The estimates were made on 7 plots each 2 sq. m., distributed evenly over an area of 0.6 ha. Agreement of results by estimating and weighing was remarkably good, even when inexperienced assistants estimated. Any divergencies in results were regular, e.g., *Festuca pratensis* and *F. rubra* showed consistently higher, and *Poa pratensis* a consistently lower, estimated wt. than actual proportion by wt. Differences between estimators were also consistent.—Herb. Abs.

BERULDSEN, E. T., AND MORGAN, A. 110

1934. Grassland research in Australia: Notes on botanical analysis of irrigated pasture. Imp. Bur. Plant Genet., Herbage Plants Bul. 14: 33–43.

The "% estimation method" of bot. analysis, as here described, is synonymous with the "% productivity method." As far as a single estimation is concerned, the method possesses the advantages of (a) rapidity, and (b) requisite accuracy when a good growth of herbage is present, and the disadvantages of (a) inaccuracy when growth is poor, and (b) inaccuracy on herbage of which the component spp. are very intimately mixed. In watering and manurial trials, it is practicable in most cases to take a sufficient no. of readings per plot and a sufficient no. of replications to show that differences of 20% in the values of the major spp. are significant. Where total grasses or total clover are estimated, differences of less than 20% are significant. On grazing trials, particularly where grasses very similar in general appearance are preferentially grazed, the method is more accurate than observational methods. With suitable lay-out, the no. of estimations per plot and the no. of replications may be adjusted largely to suit practical convenience without materially affecting the accuracy of the results.—Auth. sum.

BLACKMAN, G. E. 111

1932. An ecological study of closely cut turf treated with ammonium and ferrous sulphates. Ann. Appl. Biol. [London] 19(2): 204–220, illus.

The plot under observation was 10×10 ft. A grid 6×6 in., containing 9 smaller squares (2×2 in.), is thrown down 10 times at random on the plot, and areas covered by weeds and grasses are estimated at each throw. "To test the accuracy of this method of random sampling, a hundred grid estimations were made on the same plot during a period of 2 days. When the samples were summed in groups of 10, the resulting figs. agreed within a small margin." Ammonium sulphate and ferrous ammonium sulphate reduced the weeds, including *Achillea* and *Trifolium*, and increased the grasses.

COSTELLO, DAVID F., AND KLIPPLE, GRAYDON E. 112

1939. Sampling intensity in vegetation surveys made by the square-foot density method. Amer. Soc. Agron. Jour. 31(9): 800–810, illus.

The no. of 100 sq.-ft. plots required for a reliable statis. sample in range surveys varies within a vegetation type and between different types. The no. required bears little relation to area of the type. Sampling a given area by means of a composite sample requires fewer plots than sampling the area on the basis of range cond. classes. Sampling intensity is influenced by seasonal and yearly fluctuations in floristic comp. Either prelim. surveys or samples taken periodically from survey data provide a basis for determining the intensity of sampling required in different vegetation types.

DAVIES, WILLIAM. 113

1934. Pasture sampling with particular reference to methods used in Great Britain for determining the botanical composition of grasslands. Third Internatl. Grassland Cong., Zurich, Rpt. 1934: 203–207.

Sampling for bot. comp. of pasture is discussed. Techniques fall into 3 main groups, (a) frequency, (b) productivity, and (c) % area covered. Estimation methods for frequency and productivity are outlined. The basis of these methods is that (a) an adequate number of samples be drawn from properly replicated plots, and (b) estimates of frequency and productivity be made on each sample in place of detailed counts or weights respectively of separated spp.

ELLISON, LINCOLN. 114

1942. A comparison of methods of quadratting short-grass vegetation. Jour. Agr. Res. 64(10): 595–614, illus.

Three methods of quadratting *Bouteloua gracilis* and *Buchloe dactyloides* vegetation —the pantograph-chart, density-list, and point-analysis methods—were tested on 3 typical short grass quadrats of low, intermed., and high density. Five trained observers used the first two methods 4 times on each quadrat and the point method 6 times. Although absolute values differed, the methods, on the average, reflected similarly the marked differences between quadrats. Grass areas tended to be 50% greater by the chart method than by the others. Areas were similar by the list and point method. The chart method proved generally least consistent and most time-consuming of the 3; its net efficiency varied from 1/2 to less than 1/50 the others. The list method tended to give the most consistent results; its net efficiency was much higher than that of the other methods except on the high-density quadrat where net efficiency of the point method was greatest. Consistent differences between observers were most evident on the quadrat where grass was the densest and most matted. Interactions were demonstrated between observers and methods. Inconsistencies, sometimes large, appeared within the work of a given observer. For estimating area of short-grass vegetation on perm. quadrats, the density-list method, carefully standardized, should be appl.; the point-analysis method may be used for training and standardizing observers in the list method; the chart method should be reserved for those studies in which the greatest need is a detailed graphic record of the vegetation.

GOEBEL, CARL J., DEBANO, LEONARD, AND LLOYD, RUSSELL D. 115

1958. A new method of determining forage cover and production on desert shrub vegetation. Jour. Range Mangt. 11(5): 244–246, illus.

An improved method for estimating forage cover and prod., using a subdivided 25-sq.-ft. quadrat frame, was tested on 2 pure vegetation types, shadscale (*Atriplex confertifolia*) and winterfat (*Eurotia lanata*) in NW. Utah. A significant correlation was found between plant cover and current forage prod., but the accuracy in estimating plant density was dependent on inherent growth characteristics. Results for shadescale, which has a regular plant outline, were more consistent than for the irregularly defined winterfat.—Herb. Abs.

HALL, THOMAS D., AND MURRAY, S. M. 116

1935. The botanical analysis of intensively grazed pastures. So. African Jour. Sci. 32: 189–196, illus.

The results of a comparison of the % area method with a modification of the % productivity method made on the same areas on intensively grazed pastures under various fert. treatments are recorded. Data obtained at 3 centers, on 2 veld and 1 sown pasture expts., were consistent, and showed that the modified productivity method gave more reliable results for grazing or carrying capacity than the % area method. The disadvantages of the suggested new method are outlined. A suggestion as to its possible util. is given, whereby yield data and rapidly made estimations might be combined to give accurate bot. analyses.—Auth. sum.

HANSON, W. D., AND HUNT, O. J. 117

1957. A statistical technique for the evaluation of visual estimates involving components of forage mixtures. Agron. Abs. 49: 70.

LARIN, I. V., SOSNOVSKAJA, N. N., AND SLJAPNIKOVA, N. D. 118

1933. [A simplified method for determining proportion by weight of species in the swards of meadows and pastures.] Sovet. Bot. [Moskva] 1933 (3/4): 267–270.

A sample of 100 g. is divided into 5–10 approx. equal subsamples, each of which is roughly divided further into 2 (grasses and others) or 3 (grasses, sedges, and others) groups; their relation to the subsample is eye-estimated in % or marks. The groups are then classified into constituent spp. and the % contrib. of each sp. within its group is eye-estimated. The accuracy of this method was compared with that of the common method of % estimation by wt. by analysing 6 samples, 4 of 35 spp., and 2 of 40 spp. It was found that either method gave the same practical and fodder estimation of these samples. The total working hrs. required for estimating 6 samples by the common and simplified methods are calculated as 75 hrs. and 13 hrs. respectively. —Herb. Abs.

MALMSTEN, H. E. 119

1930. Combination of list and chart quadrat methods for grazing studies. Ecology 11(4): 749–751.

After the quadrat has been subdivided into units, the density of the vegetation on

each unit is estimated ocularly to the nearest 1/10, or when necessary to the nearest 1/20; the plant spp. are recorded in order of abundance and according to % of area each occupies; and the boundaries of important turf forming plants are carefully charted. The advantages over the list or chart methods are that less time is required to make the record, and data is in a form permitting ready computation of range impr. or deterioration in terms of forage acre factors or carrying capacity. With training and careful work, the error due to ocular estimating should not exceed 10%.

MURRAY, S. M., AND GLOVER, P. **120**
1935. Some practical points regarding the detailed botanical analysis of grassveld or other pastures by the list quadrat method. Jour. Ecol. [London] 23: [536]–539, illus.

NISSEN, ØIVIND. **121**
1949. The use of visual estimates in place of separation analysis in experiments with hay crops. Norges Landbrhogskole. Meld. [Oslo] 29: 225–256.

PAATELA, JUHANI, AND LAINE, LALLI. **122**
1953. Heinänurimien botaanisen koostumuksen määrittämisestä silmävarasisesti. [On visual estimation in determination of the botanical composition of tame-hayfields.] Acta Agr. Fenn. [Helsinki] 80(2): 1–24.

In comparison with wt. analysis, visual estimation generally gave a fairly accurate picture of the bot. comp. of the investigated tame-hayfields at 3 different stages. The bot. comp. of a tame-hayfield may vary widely even during a short time. Thus estimations of the bot. comp. of tame-hay should be made immediately before harvesting. For the 4 persons conducting this invest., subjectivity was of slight importance in estimations of abundance. But they distinctly differed in their observations on frequency of spp. Because differences, however, were greatest with the lowest proportion (0.1%), they could not have any remarkable influence on the av. abundance of spp. Thus, division of abundance into small groups (0.1, 0.5, 1.0, 2.5, 5, 10. . . . 95, 100%) seems justified.—From auth. sum.

PECHANEC, JOSEPH F., AND PICKFORD, G. D. **123**
1937. A weight estimate method for the determination of range or pasture production. Amer. Soc. Agron. Jour. 29(11): 894–904.

A wt. estimate method for determining grazing capacity was designed during summer 1936 after grazing capacity calculated from plant cover density was found to differ widely from that determined in grazing trials in prelim. intensive pasture and open range studies on sagebrush-wheatgrass range. The method was so designed that it might be substituted for density estimates in the point-observ.-plot method. By this method, productivity of spp. of classes is estimated on perm. or temporary plots purely randomized or located in a gridiron or patternized arrangement. Yield and floristic comp. are recorded by wt. Estimates can be made on plots of any size or shape. In tests on grass and weed vegetation types in the Upper Snake River plains of Idaho, wt. method estimates proved definitely superior to sq.-ft. density estimates in accurately indicating yield of different spp. and different types of the same sp. Error in density estimates was found in the relation of density and herbage yield. As such, it cannot be readily corrected. Wt. estimates are accurate, indicative of yield, subj. to actual mechanical check, rapid, and thus suited to use with replicated mechanically or randomly located plots, and the technique is easily learned with minimum instruction. The wt. estimate method may be excellent for studying vegetation on plots of any limited size or shape located in patternized mechanical arrangements or purely randomized. Its use should be considered where vegetational changes due to climate or grazing are being recorded or carrying capacity is being studied.

REID, ELBERT H., AND PICKFORD, G. D. **124**
1944. An appraisal of range survey methods. Jour. Forestry 42(7): 471–479, illus.

A comparison was made of (1) single ocular estimates of the av. density and comp. of vegetation on each forage subtype (reconnaissance method) and (2) estimates of the density of each sp. on regularly-spaced plots 100 sq. ft. in area, numbering 20–36 per sq. mile (sq.-ft.-density method). Five men used each method twice on the same 27-sq.-mile area, once with (A) type-boundary mapping from parallel survey lines 1/2 mile apart, and once with (B) mapping of types directly on aerial photographs in the field. Where aerial photographs and base maps are already available, combination 1B is recommended. In unphotographed areas, combination 1A is usually cheaper, considering the cost of photographing, and is nearly as accurate. Method 2 gave satisfactory results with B, but was not accurate enough with A.

SHOOP, M. C., AND MCILVAIN, E. H. 125
1963. The micro-unit forage inventory method. Jour. Range Mangt. 16(4): 172–179, illus.

A simple and rapid technique is described for measuring forage prod. and disappearance on rangeland. A quadrat of 11.5×24 in. is laid at randomly chosen sites. The frame has 1 side open so that it can be pushed through plants at ground level. Within each quadrat, the wt. of herbage contributed by discrete plant units is estimated separately for each sp. From time to time, these estimates are checked by clipping and weighing. The method compares well with clipping where herbage is sparse but tends to underestimate standing herbage as density increases.

SMITH, ARTHUR D. 126
1944. A study of the reliability of range vegetation estimates. Ecology 25(4): 441–448.

Estimates of vegetation by range reconnaissance methodology were studied for reliability and variability. Eight men, all experienced, estimated on 3 vegetation types for 7 days. To determine variability and effect of training, plots previously estimated were reworked on 3 days. Analysis of variance showed differences between both men and days were highly significant. Further, training failed to overcome variation between men. After training, estimates still varied from 71.24% to 139.81% of the group av. Clipped forage yield from these plots, used as a prod. standard, varied greatly per estimated sq. ft. of density both within and between spp. For example, g. yield per sq. ft. was 35 for *Agropyron smithii* and 369 for *Atriplex confertifolia.* These studies do not show density estimates to be a highly reliable measure of range value. The studies support a current tendency to rely less on density estimation in determining grazing capacity and more on comparison with ranges of known productivity, and upon a general ecol. analysis of soil and plants followed by % adjustments in current stocking rates.

STEWART, GEORGE, AND HUTCHINGS, S. S. 127
1936. The point-observation-plot (square-foot density) method of vegetation survey. Amer. Soc. Agron. Jour. 28(9): 714–722, illus.

The point-observ.-plot method is much more accurate, easier to learn and to apply, and provides much greater consistency in the forage-vol. estimates made by individual estimators than does either the chart quadrat or the large-estimate plot hitherto used for this purpose. The method is so distinctly timesaving as to make possible 10- or 20-fold replication; its system of randomizing plot locations at mechanical intervals obviates "selecting" plots, the ordinary procedure in former vegetation studies. The plots are circular and of 100 sq. ft. area. One or more series of plots in a line or in a gridiron arrangement are used to supply representative samples so highly useful for forage inventories, comparative surveys, perm. study plots, and erosion surveys. The method has been widely tried and found suitable for providing quantitative data in range, agronomic, and ecol. invests.—Biol. Abs.

TANNER, J. W., GAMBLE, E. E., AND TOSSELL, W. E. 128
1960. Determination of botanical composition of two-component forage mixtures. Canad. Jour. Plant Sci. 40(2): 225–234.

Alfalfa, grown in mixed stands with each of 6 vars. of timothy, was mown for hay on 2 dates in 1958 and an aftermath cut to simulate grazing was also taken. The bot. comp. of the swards at the time of cutting was determined by means of (a) hand separation, (b) visual estimation of the comp. of the unmown stand by 3 observers. The percentages of alfalfa in the stand obtained by the 2 methods were significantly correlated. Method (b) gave less variable results and greater precision per unit cost than method (a). The differences between results using the 2 methods depended on the stage of growth of the sward. Both methods were more precise for the aftermath cut than for the hay cut. The precision of method (b) was increased to a greater extent by employing an additional observer than by an additional replicate or sample.—Herb. Abs.

VANKEUREN, R. W., AND AHLGREN, H. L. 129
1957. A statistical study of several methods used in determining the botanical composition of a sward: II. A study of several forage mixtures. Agron. Jour. 49(11): 581–585.

A further study was made of several methods used in determining the bot. comp. of a sward. Additional evidence was presented that the inclined point quadrat method and the visual estimates of the standing forage provided satisfactory measures of the % comp. of the swards studied when compared with hand-separation. The inclined point quadrat method, however, required the use of factors to correct for underestimation of alfalfa and medium red clover, and overestimation of Kentucky bluegrass. The correc-

tion factor based on yield per hit gave more satisfactory results than did the factor based on the regression coefficient. The use of the regression equations to provide estimates of yield of forage by the inclined point quadrat method did not give satisfactory results, although the estimates obtained for alfalfa, medium red clover, and Kentucky bluegrass were close enough to the actual yield to indicate that the procedure may have merit. —Auth. sum.

WEST, OLIVER. **130**

1937. An investigation of the methods of botanical analysis of pasture. So. African Jour. Sci. 33: 501–559, illus.

Raunkiaer's law of the distrib. of frequencies, the "Minimal Area" and "Constant Sp." concepts are reviewed and the applicability of the methods to the analysis of grass veld in S. Africa investigated. Adaptations to meet local conds. are suggested and a new method, the "% area transect method," is described. Investigation of the relation between size and no. of quadrats in the % area method showed that the use of a comparatively small quadrat greatly reduces the amount of work necessary for accuracy. The 25 sq. dm. quadrat proved the most suitable size for use in the frankewald purple veld. In the case of the rare spp. in the veld, a random distrib. was obtained for all quadrat sizes from 1 sq. dm. upwards; the distrib. of the abundant bunchy spp. was not random for quadrat sizes less than 25 sq. dm., but was random when the quadrat was 25 sq. dm. or larger.—Biol. Abs.

WEST, OLIVER. **131**

1938. The significance of percentage area determinations yielded by the percentage area or density list method of pasture analysis. Jour. Ecol. [London] 26(1): [210]–217.

The % area method is discussed. The difficulty of using estimated % area results for the detection of change in pasture or grassland is pointed out. Although a strong correlation exists between the estimations made by different observers on the same quadrat, each observer estimates differently and the results of several observers cannot be compared until reduced to the same scale. It is proposed that the measurements of area covered made by means of pantograph be used as a constant scale, that all observers correlate their estimations with pantograph measurements at regular intervals, and that they reduce all estimated % area results to the pantograph scale. In deciding on the significance of change shown in results obtained by different observers at different times, it is necessary to reduce all observs. to the same scale, to compute the standard deviation of the difference of the means, and to compare the difference with its standard deviation, or with the derived value, the probable error.—Auth. sum.

See also **7, 13–15, 17, 19, 32, 46, 89, 95, 150, 177, 230, 251, 262, 268, 269, 277, 279, 356, 965.**

RANKING OR RATING

BURTON, GLENN W. **132**

1944. Estimating individual forage plant yields. Amer. Soc. Agron. Jour. 36(8): 709–712.

This study is an appraisal of a yield estimate method which consists of rating the yields of spaced plants from 1 to 5 or 1 to 10 by visual examination. Several hundred spaced plants in strain tests of Dallis and Bahia grass were rated and the results were analyzed statistically. Individual A, who had had considerable experience with the estimate method, was able to duplicate yield ratings of Dallis grass on consecutive days with sufficient accuracy to make the variation assoc. with duplicate ratings of individual plants insignificant when compared with the other sources of variation in the strain test. This estimate method gave significantly different strain means which correlated well with the actual yield means. Three individuals differed significantly in their ability to correctly rate the yield of Bahia grass plants and to improve with training. The accuracy of each individual was significantly improved by comparing his yield estimates with actual yields before rating a group of plants.—Biol. Abs.

DIX, R. L. **133**

1959. The influence of grazing on the thin-soil prairies of Wisconsin. Ecology 40(1): 36–49.

A study, using paired plots, was made of the effect of grazing on the vegetation of the thin-soil prairies of south. Wis. The paired plots were selected for similarity to each other in all respects, except that 1 was subject to grazing and the other was not. The frequency method was used to sample the plant stands. A formula was evolved to indicate in terms of nos. on scales of 1 to 10 and −1 to −10, the behavior of given spp. under grazing, based on their comparative densities on the paired plots. Grazing susceptibility nos. are given for 78 spp. These grazing susceptibility nos. were used to

evaluate the status of plant communities in regard to their behavior under grazing. The advantages of using grazing susceptibility nos. as an index of range cond. is discussed. —Herb. Abs.

HERCUS, J. M. 134
1963. Botanical sampling as a means of identifying the components of sheep's diet in tussock grassland. New Zeal. Jour. Agr. Res. 6(1/2): 83–89.

The technique samples an area with a 1 ft. diam. ring, all spp. inside the ring being recorded and each rated by its degree of defoliation.

HOVEYN, C. A. WAARNEMINGEN. 135
1960. Observations. Wageningen Inst. v. Biol. en Scheik. Onderz. van Landbgewassen. Jaarb. 1960: 193–197. [Eng. sum.]

The distinctions between appreciation, appraisal, and measurement are discussed. Appreciation is a qualitative means of observ. and always subjective, while the other 2 methods are quantitative, and objective or nearly so. It is argued that properties with several dimensions cannot be quantitatively evaluated in terms of order of rank.—Herb. Abs.

KAPUR, M. N. 136
1957. Some investigations on the problem of ranking of varieties. (Abstract.) Indian Council Agr. Res. Statis. Newslet. 7(2): 16.

McINTYRE, G. A. 137
1952. A method for unbiased selective sampling, using ranked sets. Austral. Jour. Agr. Res. 3(4): [385]–390, illus.

A new method of sampling is described. Take the largest in the 1st of n sets, each of n random items, the 2nd largest in the 2nd set, and so on to the smallest in the nth set. The sample of n items selected in this way is an unbiased sample of the population. For typical unimodal distribs. the mean of such a sample is slightly less than $\frac{(n+1)}{2}$ times more efficient than the mean of n items taken at random. The appl. of the ranked sample method to pasture measurement is discussed.—Auth. sum.

McINTYRE, G. A., AND WILLIAMS, R. F. 138
1949. Improving the accuracy of growth indices by the use of ratings. Austral. Jour. Sci. Res. Ser. B 2(4): 319–345, illus.

A statis. procedure is developed whereby the precision of estimation of growth increments and various growth indices is greatly increased, especially where the variability of the plant material is great. The procedure takes acct. of the fact that the difference between the mean wts. of 2 successive harvests includes the difference between the sample means at the time of the 1st harvest. The importance of this factor is reduced by the use of ratings of both samples taken at the time of the 1st harvest. Weight comparisons are made by ref. to the mean rating at this time or, where a succession of harvests is involved, to a suitable estimate of this mean rating. The procedure is appl. to a study on growth of tomatoes on a range of soil treatments and using simple chains of leaf area ratings. It is exemplified in detail from the control series of that expt. The data are examined critically to see whether they satisfy the assumption inherent in the devlpmt. of the theory. It is found that the variables of the bivariate distribs. are highly correlated, with no evidence of a departure from a linear trend. Under these conds., bias introduced from small departures from normality in the marginal distribs. will be negligible. Estimates of total wt., leaf wt., and leaf area based on maximum likelihood estimates of mean rating are more precise than are those based on mean rating at 1st harvest. Gains in precision in estimates of relative growth rate and net assimilation rates are quite substantial, but there is little advantage in the use of maximum likelihood estimates in place of mean rating at 1st harvest for this purpose. For estimates of wt., leaf area, and growth indices, the gain in inform. using ratings is as great for the absolute as it is for the logarithmic data. General considerations relevant to the appl. of the procedure are discussed, and its merits and limitations are indicated.—Auth. sum.

MICHELSON, L. F., LACHMAN, W. H., AND ALLEN, D. D. 139
1958. The use of the "weighted-rankit" method in variety trials. Amer. Soc. Hort. Sci. Proc. 71: 334–338.

The weighted-rankit method allows for the numerical classification of strain and var. descriptions. Each trait is weighted according to its relative importance and integrated with other weighted characteristics. The data are subjected to variance analysis, which then permits a final quantitative comparison among all the items within the test.—Herb. Abs.

MORRIS, M. S. **140**

1943. A method of rating forage plants for use in range surveys. (Abstract.) Mont. Acad. Sci. Proc. 1942–43 (3/4): 23–24.

TORRIE, J. H. **141**

1957. Evaluation of general and specific combining ability in perennial ryegrass (*Lolium perenne* L.). New Zeal. Jour. Sci. and Technol. Sect. A 38 (10): 1025–1035.

Specific combining ability estimates calculated from visual yield scores at different seasons were highly correlated with each other and with those for spring forage yield. The correlation between autumn and winter visual yield scores was significantly greater than either autumn or winter with spring scores. A highly significant correlation was obtained between visual yield estimates and green forage yield.—Herb. Abs.

VESTAL, A. G. **142**

1943. Unequal scales for rating species in communities. Amer. Jour. Bot. 30 (4): [305]–310, illus.

After a brief rev. of published scales having unequal divisions, a progression to serve as a basis for new scales is described. In a total range of 100 units, the 1st of 10 intervals is 2.5, the last is 20.9. Two of 4 cognate scales using these intervals have larger divisions at the top (they are called V scales); the others have smaller divisions above (A scales); both 10-parted and 5-parted forms of these are given. In an appl. to frequency percentages for occurrence in plots of leading forest-tree spp., A 10, A 5, and equal 5-class scales are compared. Another example uses the V 5 scale to help distinguish dominant and subdominant groups of spp. Classes in this scale are 62–100, 36–61, 18–35, 7–17, 0–6.—Biol. Abs.

VRIES, D. M. DE. **143**

1933. De rangorde-methode. Een schattingsmethode voor plantkundig graslandonderzoek met volgorde-bepaling. [The rank-order method. An estimation method for botanical investigation of grassland with determination of serial order.] Verslag. van Landbouwk. Onderzoek. der Rijkslandbouwproefsta. [Hague] 39A: 1–24. [In Dutch]

The author proposes a new method of bot. analysis adapted from Davies' method of % frequency. Designated as the "rank" method, it is conducted on a 1 m. quadrat; the precedence in bulk of each sp. is determined and recorded. The auth. concludes that results agree with those from the air-dry wt. analyt. method.

See also **15, 33, 46, 334, 503.**

COUNT

ANSCOMBE, F. J. **144**

1949. The statistical analysis of insect counts based on the negative binomial distribution. Biometrics 5 (2): 165–173.

This note summarizes results of a math. invest. into sampling theory of the negative binomial distrib. Insect counts in the field (and other population counts) are often fitted fairly well by a negative binomial distrib. described by the mean m and the exp. k. Methods for estimating k from a single large sample and from several samples are illus. by a numerical example (counts of eggs of *Aphis fabae* on hedgerow shoots).

GYSEL, LESLIE W. **145**

1956. Measurement of acorn crops. Forest Sci. 2 (4): 305–313, illus.

Acorn prod. is much greater in the pt. of a tree crown exposed to full sunlight than in the unexposed pt. Acorn crops can be measured by complete counts of acorns or by sample tallies, using glasses or spotting scopes. This method is best adapted to studies of individual trees. Prod. can be estimated from periodic collections from seed traps or open quadrats on sample areas on the ground beneath the trees. Differences between samples collected in seed traps and on adjacent open quadrats were generally small.—From auth. sum.

HANSON, HERBERT C., AND LOVE, L. DUDLEY. **146**

1930. Comparison of methods of quadratting. Ecology 11: 734–748, illus.

Pantograph-chart, count-list, density-list, area-list (basal area), and wt.-list methods of determining vegetative changes were studied. Results of each method differ. To determine proportion of each sp., the wt.-list method is best with temporary quadrats but not practical with perm. quadrats. To determine changes from yr. to yr. for single stalked or even-sized clump spp., combining pantograph-chart and count-list methods is

most desirable. For mixtures, combining pantograph-chart and area-list methods is most desirable. In mixed prairie or irrigated pastures, area-list and count-list methods appear more accurate and faster than the pantograph-chart method.

HEADY, HAROLD F. 147

1958. Vegetational changes in the California annual type. Ecology 39(3): 402–416.

Vegetational changes were studied on 3 sites located on the Hopland Field Sta. in Mendocino Co., Calif., during 5 successive growing seasons, 1951–56. The nos. of plants by spp. on 2,400 quadrats of 1 sq. in. in size constitute the data. The seasonal growth pattern proceeds from germination, usually in Nov., through a short period of moderate growth, then a longer winter period when growth is slow, and finally ends with about a mo. of fast growth in Apr. and May. Average no. of plants per sq. in. varied between 3.3 and 35.0 with different situations. All spp. decreased in nos. per unit of area from Dec. to June, but *Bromus mollis, B. rigidus,* and *Erodium botrys* decreased less than the others and thus increased in % spp. comp. The nos. of plants per unit of area varied greatly between yrs. as also did the various spp. For example, 1953 was a yr. when grasses clearly dominated the vegetation. *E. botrys* constituted a larger portion of the vegetation in 1955 than in other yrs. Changes in the ann.-type vegetation due to such items as grazing, seeding, fertil., and fire are reviewed and the influence of mulch on % bot. comp. is illus. The results are discussed as illus. of seasonal, ann., and successional changes in ann.-type vegetation.—Biol. Abs.

LANGER, R. H. M. 148

1958. Changes in the tiller population of grass swards. Nature [London] 182 (4652): 1817–1818.

From a study of the no. of living tillers/sq. ft. in S215 *Festuca pratensis* and S48 *Phleum pratense* during Mar. to Aug. under 2 treatments: (a) cutting for hay and aftermath; and (b) cutting every 4 wks. beginning in early Apr., there was evidence that both spp. maintained a greater population of tillers under (b). Under both treatments tiller nos. tended to be high early in the yr., but declined after mid-Apr. This seasonal variation in tiller nos. was accompanied by changes in the proportion of new and dead tillers. In both spp., cuts for hay after ears had emerged resulted in heavy mortality among tillers, but new tiller growth was rapid and was roughly proportional to losses. Similar changes occurred under frequent cutting. Thus, the comp. of the tiller population of swards in Aug. differed from that earlier in the yr. The significance of this in regard to DM yields is recorded. The decline in prod. during summer, attributed to changes in the tiller population, is discussed in the light of selection.—Herb. Abs.

MANNER, R. 149

1957. Några synpunkter på undersökningsmetodiken i fråga om gräsmattor. [On the methods for investigating lawns.] Hammenhög Gullåkers Växtförädlingsanst. Meddel. 14: 29–33. [Eng. sum.]

As an index of lawn sward density, the Gullåker Plant Breeding Inst. has, since 1955, used the no. of shoots per sq. m. The no. of shoots in four 10×10 cm. quadrats, sited at random on a given plot, is counted. In a series of observs. made in 1955, the no. of shoots per sq. m. for 5 selections of *Agrostis stolonifera* ranged from 4,000 to 10,000, for 3 of *A. tenuis* from 15,000 to 19,000, and for 1 of *A. canina,* 45,000. For *Cynosurus cristatus* the no. was 7,400, for *Festuca rubra* 22,200, and for *F. ovina* 50,000. For 5 selections of *Poa pratensis* it ranged from 5,000 to 10,000, for 2 of *P. palustris* it was 25,000 and 14,000, and for both *P. nemoralis* and *P. compressa* was 20,000. The relation between shoot density and degree of vegetative cover is discussed. It appeared that a summer shoot density of 5,000–6,000 per sq. m. in *A. stolonifera* and *P. pratensis* corresponded to a cover of about 50% and also with a shoot density of 8,000–10,000 in *C. cristatus* and 20,000 in *P. palustris, P. nemoralis,* and *P. compressa.* A shoot density of 20,000 per sq. m. in *A. tenuis* corresponded to a 90% cover and to shoot densities of 25,000 in *F. rubra* and about 50,000 in *A. canina* and *F. ovina.*—Herb. Abs.

PEARSE, KENNETH. 150

1935. An area-list method of measuring range plant populations. Ecology 16(4): 573–579, illus.

The method depends on measurement, by a special scale, of the projectional area of every plant in a 25 sq. m. sample plot. Compilation of the measurements provides inform. on (1) total density, (2) spp. density (comp.), and (3) the no. of all plants on the plot, by spp. and size classes. Compared with other methods (chart quadrats, list quadrats, and ocular estimates) the area-list method is rapid and accurate, and promises to be applicable to a wide range of field conds.

SHIMADA, Y. **151**

1958. [Statistical studies on the design of yield survey and field experiment in natural grassland. Part 2. Estimation of number of bracken, *Pteridium aquilinum* (L.) Kuhn, in the *Miscanthus* grassland.] Tohoku Univ. Sci. Rpts., Ser. D, 9(2): 131–135, illus.

The object was to determine the most efficient size and shape of sampling unit and sample size for estimating the no. of bracken plants in *Miscanthus* grassland. The lay-out of the plots, which were 1×1 to 64×8 sq. m., and the manner of charting results were similar to those used for estimating the productivity of *Miscanthus*. The distrib. of plants in the sq. m. plot followed neither the Poisson nor the Polya-Eggenberger distrib.; but in plots larger than 2×2 sq. m. there was good agreement with the negative binomial distrib. The C.V. decreased slightly with increase in size of sampling unit. A large sample was required for a reliable estimate of the bracken population.—Herb. Abs.

See also **17, 32, 46, 88, 164, 165, 231, 262, 372, 416, 436, 447, 452, 963, 967, 1077, 1115.**

DISTANCE MEASURE

BAUERSACHS, EWALD. **152**

1942. Bestandesmassenaufnahme nach dem mittelstammverfahren des zweitkleinsten stammabstandes. Forstwiss. Centbl. [Berlin] 64(8): 182–186.

At fixed intervals on parallel strips the nearest tree is calipered and its distance from the 2nd-closest tree measured. (This is said to give more accurate results than distance from the closest tree in irregularly spaced stands.) For estimating number of trees in the stand when the area is known, about 50 such measurements give an average distance. For a close estimate of total volume of the stand, average tree volume computed from 50–100 caliper and height measurements is multiplied by number of trees.

BLACKITH, R. E. **153**

1958. Nearest-neighbor distance measurements for the estimation of animal populations. Ecology 39(1): 147–150.

Two published expressions linking density of organisms distributed at random in the field and comparing av. distances between nearest neighbors. One is shown to give densities some 4 times higher than the other. Practical trials of these formulae using populations of Brit. and Fr. grasshoppers, estimated by capture-recapture methods, favor 1 expression, but empirical tests with random points favor the other. Nonrandom dispersal of organisms seems to introduce errors which are much less than discrepancy between population estimates as given by the 2 expressions.—Biol. Abs.

CATANA, A. J., JR. **154**

1955. The wandering quadrant—a new ecological sampling method utilizing interspace measurements. Ecol. Soc. Amer. Bul. 36: 88.

CATANA, ANTHONY J., JR. **155**

1963. The wandering quarter method of estimating population density. Ecology 44(2): 349–360, illus.

The method was developed for use in plant populations not necessarily randomly distributed. Within the area, observs. are made along 2 sets of parallel transects at 90° to each other. For each transect a point is chosen at random and measurements are begun from the nearest plant under study within a 90° angle bisecting the transect direction. Successive plants, up to 24, are located from each other in a similar way, and the distance between them measured. Details of the calculation, which also assesses degree of randomness or aggregation, are given. This method is an adaption of the point-centered-quarter method.

CLARK, PHILIP J., AND EVANS, FRANCIS C. **156**

1954. Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology 35(4): [445]–453.

Degree to which 2-dimensional distrib. of individuals in a population of known density departs from random expectation can be ascertained from ratio $R=\bar{r}_A/\bar{r}_E$, where $\bar{r}_A$ is observed mean distance between nearest neighbors and $\bar{r}_E$ is mean distance expected if distrib. were random. This ratio ranges in value from 0 for a distrib. with maximum aggregation, through 1.0 for a random distrib., to 2.1491 for a distrib. which is as evenly and widely spaced as possible. Methods are given for calculation of $\bar{r}_E$, its standard deviation, significance of departure from random expectation, and significance of difference between values of R from 2 or more populations. Sensitivity of measure is demonstrated by appls. to synthetic and actual distribs. of various patterns. Problems which

arise in its use are discussed briefly and an extension of method to utilize additional spatial relationships is described. An app. to paper gives derivation of formulas used in devlpmt. of measure.—Biol. Abs.

COTTAM, GRANT, AND CURTIS, J. T. 157
1949. A method for making rapid surveys of woodlands by means of pairs of randomly selected trees. Ecology 30(1): 101–104, illus.

Pairs of trees instead of quadrats are used to furnish data for calculating frequency, density, and dominance. At predetermined intervals along a compass line, measurements are made on 2 nearby trees that bear certain spatial relations to each other. Results with this pairs method agree well with results with the regular quadrat method.

COTTAM, GRANT, AND CURTIS, J. T. 158
1956. The use of distance measures in phytosociological sampling. Ecology 37(3): 451–460, illus.

Four distance methods, 2 point-to-plant and 2 plant-to-plant, were used on 3 mapped stands and on an artificial population. The data were compared with results with the quadrat method and known population parameters. Although all distance methods were found capable of yielding accurate results when an adequate sample was used, size of an adequate sample varied with the method. The closest individual method has the advantage of simplicity. Only 1 tree and 1 distance are measured at each point. An additional advantage is that the math. characteristics of the method have been worked out, and observed distance need only be multiplied by a factor of 2.0 to give sq. root of mean area. Disadvantages are the extreme variability of results, which necessitates the sampling of many points before an adequate sample is obtained, and susceptibility to subjective bias. The nearest neighbor method gives less variable results than the closest individual method, but still requires more sampling points than random pairs or quarter methods. It, too, is simple, requiring only that the tree nearest the sampling point be located and the distance to its nearest neighbor measured. Results do not agree with math. theory, largely because the method of sampling is not random, but tends to undersample trees close together. This results in a correction factor of 1.67 rather than the theoretical 2.00. The method does, however, yield consistent results in all stands where used. The random pairs method with an 180° angle of exclusion is less variable than the 2 previously discussed. It has been more widely used than the other methods. One disadvantage is that the math. theory has not been worked out. The quarter method gives the least variable distance determinations, provides more data on tree spp. per sampling point, and is least susceptible to subject bias. The math. characteristics are known. It requires no correction factor, the mean of the distances equaling the sq. root of the mean area. The apparent disadvantage of requiring more time per point is compensated for by the need to sample fewer points. The auth. consider the quarter method superior in most respects to the other distance methods studied, and recommend it.

COTTAM, GRANT, CURTIS, J. T., AND CATANA, ANTHONY J., JR. 159
1957. Some sampling characteristics of a series of aggregated populations. Ecology 38(4): 610–622, illus.

Aggregation of populations is defined in terms of 3 interrelated variables, and 3 indices for measuring aggregation, using distance methods, are discussed.—Herb. Abs.

COTTAM, GRANT, CURTIS, J. T., AND HALE, B. WILDE. 160
1953. Some sampling characteristics of a population of randomly dispersed individuals. Ecology 34(4): 741–757, illus.

An artificial population was sampled by both area methods and distance methods using exclusion angles. The population consisted of 1,000 individuals located on a map by rectangular coordinates from a random nos. table. Data on frequency, relative (%) density, and area density were obtained. All methods indicated that random populations give highly variable results, and that larger than usual samples are needed to measure the frequency and density of the spp. in such populations. The appls. to the measurement of plant communities is discussed.

DICE, LEE R. 161
1952. Measure of the spacing between individuals within a population. Mich. Univ. Lab. Vert. Biol. Contrib. 55, 23 pp., illus.

For measuring the spacing between the individuals in any given population which is distributed over a single plane the following method is proposed: (1) A certain no. of individuals in the population are taken at random as points of origin for the measurements. (2) From each such point of origin the distance is measured in each surrounding sextant to the nearest other individual in the same population. (3) The sq. roots of these measurements of spacing are treated statistically to derive means, variances, and

other statis. The frequency curve of the sq. roots of the measurements of the spacing between individuals taken according to the above described method, approaches normality when the distrib. of the population is random. When the individuals are clumped, the curve is skewed toward the left. When the distrib. is more even than random, the curve is skewed toward the right. The significance of any irregularity of distrib. may be evaluated by the g_1 and g_2 statis. These statis., moreover, give a measure of the degree of departure of any distrib. from randomness. The relation between mean population density per unit area (P) and the mean spacing between the individuals (S) measured by sextants should be given by the formulas:

$$P = \frac{1.155}{S},\ S = \sqrt{\frac{1.155}{P}}.$$

These formulas seem to apply with fair precision when the distrib. of individuals in a population is approx. random or is more even than random but they give erroneous values when the individuals occur in aggregations. The sq. roots of the measurements of spacing between the individuals of 1 sp., taken at random as points of origin, to the nearest individuals of another sp. in each surrounding sextant should approach a normal frequency curve when there is no assoc. between the 2 spp. The curve is expected to be skewed to the left when there is assoc. between members of the 2 spp., or to the right when there is repulsion between them. The significance of any tendency toward assoc. or repulsion can then be measured by the g_1 statistic. The frequency curves of the sq. roots of the measurements of the spacing between 2 spp., each of which is clumped in distrib., however, exhibit negative kurtosis. The measurement of spacing between individuals should be of general usefulness for describing the structure of populations and communities in quantitative terms. Its particular merit is that the measurements obtained are not affected by sample size.—Auth. sum.

DIX, RALPH L. **162**

1961. An application of the point-centered quarter method to the sampling of grassland vegetation. Jour. Range Mangt. 14(2): 63–69, illus.

Distances are measured from an objectively established point to the nearest living shoot in each of 4 quadrants. The absolute density of each sp. is calculated from these distances. The relative density and relative frequency of each sp. are derived from the no. of shoots representing them and the no. of sampling points at which they occur. The sum of relative density and relative frequency gives an importance value. It is suggested that a grassland sp. is adequately sampled when it is represented by 30 shoots or more; and sampling efficiency can be greatly increased by the technique of multiphase sampling, if information on importance values is not required. This method is quicker than the line intercept or point quadrat.—Herb. Abs.

HOPKINS, BRIAN. **163**

1954. A new method for determining the type of distribution of plant individuals. Ann. Bot. [London] (n.s.) 18(70): 213–227, illus.

The principle of the method is that if I is the distance from an individual chosen at random to its nearest individual, and P is the distance from a point chosen at random to its nearest individual, then A, the coefficient of aggregation, (defined as $\Sigma(P^2)/\Sigma(I^2)$ where the no. of observs. of P and I are equal) equals unity if the individuals are distributed independently and at random. If the individuals are aggregated, A is greater than unity and vice versa for individuals regularly distributed. Results with this method compare favorably with those with the current quadrat methods when tested on synthetic and natural populations. The method is quicker than the quadrat methods and is especially useful for analyzing the distrib. of trees. For methods used in determining the significance of observed deviations of A from unity, a math. proof is given in the app.

HUTCHINGS, S. S., AND MORRIS, M. J. **164**

1959. Use of distance measurements for determining plant density in semidesert vegetation. (Abstract.) Ninth Internatl. Bot. Cong., Montreal, Proc. 2: 174.

Discusses the relation of distance measurements to spatial distribution of plants. Nearest neighbor, closest individual, and point-centered-quarter methods for measuring plant density and spatial distrib. were tested on stands of small desert shrub vegetation and compared with plant counts.

MOORE, P. G. **165**

1954. Spacing in plant populations. Ecology 35(2): 222–227.

The usual methods of statis. examination of plant populations have been concerned with the idea of sampling by quadrats. In this paper attention is focussed on the use of the spacing in plant populations as a basis for the examination of probs. concerning

(1) the estimation of the density of a particular plant in a community and obtaining confidence limits for the estimate, (2) the comparison of the densities of 2 plants or of the same plant in 2 communities, and (3) the randomness or otherwise of the occurrence of plants in some community. Tests are derived and illus. for these probs. and a comparison of the accuracy of the methods based on quadrats and those based on spacing is made.—Auth. abs.

MORISITA, MASAAKI. 166
1954. Estimation of population density by spacing method. Kyushu Univ., Faculty Sci. Mem. Ser. E 1(4): [187]–197, illus.

Though capable of yielding greater returns per man hr. than the quadrat method (Cottam et al. 1953), spacing methods have not been studied as much, the main reason apparently being an absence of math. foundation. This paper presents such a foundation for future studies. When the distrib. of individuals is random, the theoretical equations presented permit easy calculation of the probability of finding the closest individual between the distances r' and r from the sample point or from the individual taken as the point of origin. The equations are appl. to the quadrant, sextant, etc., methods, and also to the "order method," newly proposed, in which distances are measured from the sample point or from the individual taken as the point of origin to the 1st, 2nd, 3rd, etc. closest individual. Using equations given, the density of population is easily estimated by any method. Thus, it is known that by the shortest method the theoretical mean distance is a half of the sq. root of the mean area, and by the quadrant method equal to it as suggested by Cottam et al. (1953). When the distrib. of individuals is not random, the departure from randomness will be measured by comparing the observed values of mean and variance with the theoretical ones, instead of measuring g_1 and g_2 statistics used by Dice (1952). This is because the theoretical curve is by no means a normal one in strict sense even if the sq. root transformation of measurements of distance is performed. Though the equations given are not applicable directly to the nonrandom distrib., the estimation of population density may be possible if adequate transformations of the equations are performed. These probs., including that of accuracy of the estimated value of population density through the use of spacing methods, are left for future invests.—From auth. sum.

MORISITA, MASAAKI. 167
1957. A new method for the estimation of density by the spacing method applicable to non-randomly distributed populations. Physiol. and Ecol. [Japan] 7(2): 134–144. [In Jap. with Eng. sum.]

Even if T individuals are distributed irregularly over an area (A), the area may be divided into several small fractions (A_i, i=1, 2, 3, . . .,) on which the individuals contained will be distributed randomly or uniformly. By placing N sample points randomly on the total area A, dividing the circle of infinite radius surrounding each sample point into k sectors, and measuring the distance (r) to the nth nearest individual in each sector from the sample point, formulae can be derived when the individuals are distributed at random on A. These formulae are given. The auth. considers that regular sampling is also available for density estimation by this method unless the individuals are distributed regularly on A. Results of the estimation by this method are given for various artificial populations. The method can be put to practical use at least when k=4 and n=3 are used.—Biol. Abs.

PENFOUND, WILLIAM T. 168
1963. A modification of the point-centered quarter method for grassland analysis. Ecology 44(1): 175–176.

The modification consists in cutting at ground level, for subsequent weighing, the ref. culm in each quadrant (the culm nearest the cross-point in each of 4 quadrants derived from 2 bars joined at their centers at 90°). The method is then able to record parameter frequency, density, and wt. An example is given in which assessment of sp. dominance is markedly affected by adopting the wt. parameter.

PIELOU, E. C. 169
1959. The use of point-to-plant distances in the study of the pattern of plant populations. Jour. Ecol. [London] 47(3): [607]–613.

The most straightforward method of assessing the degree of nonrandomness, if any, of a plant population is to collect a sample of distances from random points to the plant individuals nearest them. A knowledge of the density of the individuals, independently determined, is also necessary. As an index of nonrandomness, $a=\pi D\overline{w}$ is suggested, where D is density and $\overline{w}$ is the mean of the squares of the point-to-plant distances; a is equal to, less than, or greater than $(n-1)/n$ according as the population is random, regular, or aggregated. The significance of a departure of a from

this value is easily found since $2na$ is distributed like χ^2 with $2n$ degrees of freedom. Observed values of a from 2 nonrandom populations may be compared by a t-test. The advantage of using this index is that it will reveal all the nonrandomness present and not merely the smallest scale of nonrandomness as would an index based on plant-to-plant distances. Also, no distances need be measured from randomly chosen plants; the selection of truly random plants is exceedingly laborious and a biased sample is useless as it is likely to give most misleading results. Owing to point-to-plant distances sometimes having the same frequency distrib. in random, regular, or aggregated populations, the observed distrib. of this variate will not necessarily, by itself, reveal nonrandomness.

PIELOU, E. C. **170**
1962. The use of plant-to-neighbour distances for the detection of competition. Jour. Ecol. [London] 50(2): 357–367, illus.

In an aggregated plant population, the pattern within high density patches may be regular owing to competition. But tests for pattern appl. to the whole population will usually indicate only the overall aggregation and will not reveal the localized regularity. Evidence as to whether or not a population exhibits such "within-clump" regularity may be obtained by collecting a sample of plant-to-neighbor distances that are less than some chosen value. The use of a sample thus truncated permits detailed study of the spatial patterns within the high density patches. Denoting the sq. of plant-to-neighbor distance by w, the frequency function of w in a noncompeting population is monotonically decreasing from a finite value at $w=0$. If competition among the plants is causing them to be regularly spaced where their density is high, the distrib. of w will have a mode at some $w > 0$. The modal value of w is proportional to the area preempted by each plant. A test for within-clump regularity is described. Also, a method is proposed for estimating the modal value of w in populations exhibiting such regularity. Results from 5 natural populations of forest trees serve as examples.—Biol. Abs.

See also **33, 35, 46, 185, 359, 409, 440, 443, 447, 511.**

VARIABLE RADIUS

ADAMS, LOWELL. **171**
1962. The variable-plot tree stem count versus the photocanopymeter as a measure of overstory. Jour. Forestry 60(8): 567.

Overstory measurements by the 2 methods had a correlation coefficient of 0.51, too low for predicting 1 measurement from the other. The correlation coefficients for overstory-understory relations were —0.37 for the variable plot and —0.19 for the photocanopymeter methods. These coefficients are not significantly different, so apparently the 2 methods are measuring the same relation.

BORGESON, A. E., COLCLOUGH, D. M., AND YOUNG, H. E. **172**
1958. A field test of the Bitterlich variable plot cruising method in Maine. Maine Univ. Forestry Dept. Tech. Note 48, 4 pp.

Tests were made in 50 stands of varying comp., structure, and density (data tabulated) and the results compared with tape measurements of trees on a 1/5-acre plot in each stand. Time for the Bitterlich method averaged 13.3 mins. and for tape measurements 31.6 mins. For all 50 plots combined, basal area as measured by the Bitterlich method was 10% higher, the difference on separate stands varying from +87.5% to −24.5%.

COOPER, CHARLES F. **173**
1963. An evaluation of variable plot sampling in shrub and herbaceous vegetation. Ecology 44(3): 565–569, illus.

Variable plot estimates of shrub cover are faster than those with any other accepted method. Individual samples can be made quickly, and fewer are required because of the low sample-to-sample variability. For the divisor used to reduce sample counts to a cover estimate, the term "cover % factor" is suggested. The relative uniformity of variable plot samples is due to the large area integrated in each. This makes the method relatively insensitive to minor variations in individual shrub spacing or pattern. The angle gage should be calibrated specifically for each user. Accuracy is slightly increased by correcting for the eye intercepting a chord closer to it than the true diam. Difficulty is usually encountered in determining the exact margin of every shrub, particularly in crowded stands. For precise work, it is almost essential that an assistant outline each plant. The method is not usable where cover exceeds about 35%. When the slope exceeds 10%, the count should be multiplied by the secant of the av. slope angle. Any deviation in shrub outline from a circle biases estimates upwards. For an

ellipse, with a ratio of minor to major axis of 0.9, the bias amounts to about 0.5%; for one with a ratio of 0.6, the bias amounts to 13%. A frequency distrib. of size classes can be constructed from variable plot counts. Although an index of dispersion can be used to detect deviations from randomness, the variable plot method is not suited to detailed analysis of the nature and scale of pattern. Likewise, the method is not suited to herbaceous cover other than bunchgrasses. If its limitations are recognized, variable plot sampling is fast and efficient for gathering inform. on the ground cover of shrubs and bunchgrasses.

DAFAUCE RUIZ, CARLOS. **174**

1958. Un nuevo método de medición rápida de espesura de rodales y de aprecición de volúmenes (el prisma dasométrico). [A new method for rapid measurement of volume and growth of timber stands.] Montes [Madrid] 14(80): 113–118, illus.

Suggestions are made for reducing errors in use of the "wedge prism" in the "point sampling" method, and for automatic reduction of sample data to horizontal values.—Biol. Abs.

DANIEL, T. W., AND SUTTER, HAROLD. **175**

1955. Bitterlich's "spiegelrelaskop"—a revolutionary general-use forest instrument. Jour. Forestry 53(11): 844–846.

An excellent description of an instrument for making measurements as plotless survey of timber resources is given.

FINCH, H. D. S. **176**

1957. Plotless enumeration with angle gauges. Forestry [London] 30(2): 173–192, illus.

The basic method and theory for determining basal areas with angle gages are explained. Limitations in use are pointed out, and modifications and developments discussed. An explanation is given of the use of the angle-gage principle for determining ht. and vol. Next, the instruments themselves are discussed and finally the Spiegelrelaskop and its wide range of uses. For the future, the auth. considers consolidation of ideas more likely than any very startling new developments. A full list of refs. to literature is given.—Auth. sum.

FISSER, H. G. **177**

1961. Variable plot, square foot plot, and visual estimate for shrub crown cover measurements. Jour. Range Mangt. 14(4): 202–207, illus.

Of the 3 methods described, it was concluded that transects of 1 sq.-ft. plots were of little value in estimating shrub cover (the spp. tested were *Atriplex nuttallii, Artemisia tridentata,* and *Sarcobatus vermiculatus*), visual estimates required intensive training and continued checking for reliable results, and that the variable-plot method, with suitably standardized field procedure, appeared to be a suitable tool for range survey.—Herb. Abs.

GALLARDO MARTIN, JOSÉ, AND GARCIA-GUTIÉRREZ, GONZÁLEZ ANTONIO. **178**

1957. Muestreo puntual en el cálculo de extencias. [Point sampling for calculation of forest stands.] Montes [Madrid] 13(78): 405–410, illus.

The theory and appl. of the point-sampling method, with wedge prism, for determining basal area and vol. of forest stands are described.—Biol. Abs.

GROSENBAUGH, L. R. **179**

1958. Point-sampling and line-sampling: Probability theory, geometric implications, synthesis. U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 160, 34 pp., illus.

This paper explains new theory of sampling forest trees with probability proportional to some element of tree size, gives underlying statis. and geometric bases, discusses possible sources of bias and how to avoid them, and synthesizes theories into techniques for efficient appl.

GROSENBAUGH, L. R. AND STOVER, W. S. **180**

1957. Point-sampling compared with plot-sampling in southeast Texas. Forest Sci. 3(1): 2–14.

This exploratory study demonstrated how comparisons between point-sampling and plot-sampling estimates should be analyzed. Point-sampling estimates of basal area and vol. per acre were found to be unbiased with respect to plot-sampling estimates when precautions were observed. Local cost inform. was not secured for 1/4-acre plot-sampling, so relative efficiencies cannot be estimated, although certain advantages of point-sampling were quite obvious (possibility of 1-man crews, growth and error calculations). Coefficients of correlation and variation in SE. Tex. may not be valid

for other areas, but they are at least indicative of the comparative magnitudes and trends apt to be exhibited elsewhere, and may be useful in sampling design. A rough estimate of optimum cluster-size indicated that 3 points per cluster would have been slightly better than 2, but this conclusion might be modified if crew, grid, gage, or conveyance is changed. Finally, a technique was developed for reducing bias in basal-area estimates when tree frequency only has been tallied by rather broad d.b.h. classes (2 ins. or more).—Auth. concl.

HIRATA, T. **181**
1958. [Precisions of variable plot methods (WZP.)]. Tokyo Univ. Forests Bul. 54, 17 pp. [In Jap. with Eng. sum.]

Compares in detail the precision of results obtained by Bitterlich himself in his original Winkelzahlprobe, by Strand in his "variable rectangular plot" method (with relascope), and by random sampling for determining mean ht., mean diam., and no. of stems/ha.

HUSCH, BERTRAM. **182**
1955. Results of an investigation of the variable plot method of cruising. Jour. Forestry 53(8): 570–574, illus.

Within recent yrs. a new approach has been developed which promises to speed up timber vol. estimation. The variable-plot method, proposed by W. Bitterlich in 1948, consists of establishing sampling points in the tract to be inventoried. All those trees whose diameters appear larger than an angle gage are counted at each point. The mean no. of trees per point is multiplied by a constant to obtain av. basal area per acre. Other timber survey statis. can be developed by varying the procedure. Four contiguous 10-acre tracts were sampled using 3 critical angles; 52.09, 104.18, and 208.38 mins. A complete tally of all trees was made of the same area for comparison. Basal area and vol. estimates were then calculated. The 208.38 min. angle proved most accurate and efficient. The results of the estimates with the 52.09 min. angle were much less accurate. The estimates with the 104.18 min. angle gave results between the other 2. Results indicate that the variable-plot cruising method works best with a large critical angle used at the maximum no. of estimating points.—Auth. abs.

HUSCH, BERTRAM. **183**
1956. Comments on the variable plot method of cruising. Jour. Forestry 54(1): 41.

HYDER, D. N., AND SNEVA, F. A. **184**
1960. Bitterlich's plotless method for sampling basal ground cover of bunchgrasses. Jour. Range Mangt. 13(1): 6–9, illus.

This method was compared with Canfield's line-interception method for measuring the basal ground cover of tussock grasses. At equivalent sampling intensities, the plotless or angle method required only one-ninth the time and gave 40% higher ground-cover estimates, larger differences among spp., and a more consistent order of spp. dominance than did the line-interception method. The time advantage would probably have been less when sampling in scrub areas where the angular frame would become cumbersome. The difficulties in the use of the method for spp. growing in irregularly shaped clumps is discussed.

LINDSEY, ALTON A., BARTON, JAMES D., JR., AND MILES, S. R. **185**
1958. Field efficiencies of forest sampling methods. Ecology 39(3): [428]–444, illus.

A large scale map of an undisturbed 20-acre stand of white oak—beech—sugar maple was sampled intensively by 9 forest sampling methods. The no. of units and no. of trees required for 15% standard error were computed. Each method was timed in the actual stand to determine time per tree. The total no. of stems of all spp. required for 15% standard error for a selected dominant sp. multiplied by the time per stem gave a total time-at-units fig. for each method. To this was added the time required to make the circuit of the required no. of sample units; the sum is the field time, the inverse of field-statis. efficiency. For sampling the density and basal area of either sugar maple or beech with not more than 15% standard error, the methods ranked in the following order of field time—(1) combination of the rangefinder circle and the Bitterlich method, 2.04 hrs.; (2) 1/10-acre rangefinder circle, 3.41 hrs.; (3) 1/5-acre strip, 3.65 hrs.; (4) full Bitterlich, 3.66 hrs.; (5) quarter method, 4.36 hrs.; (6) 1/5-acre square, 5.17 hrs.; (7) 1/10-acre square, 5.81 hrs.; (8) 1/40-acre circle, 6.85 hrs.; and (9) 1/40-acre square, 9.84 hrs.—Biol. Abs.

PALLEY, MARSHALL N., AND HORWITZ, LEAH G. **186**
1961. Properties of some random and systematic point sampling estimators. Forest Sci. 7(1): 52–65.

The unbiasedness of forest basal area and vol. estimates with Bitterlich's method

of sampling is shown. An expression for the true variance of these estimates is derived, and a bias-free estimator of it is demonstrated. Formulas appropriate to systematic point samples with 1 or multiple random starts are presented. The bias of the double-sampling procedure of Bell and Alexander is evaluated, and an estimator for the mean sq. error of this quantity is suggested. Examples of computations are given.

SPURR, STEPHEN H. **187**
1962. A measure of point density. Forest Sci. 8(1): 85–96, illus.

A precise measurement of stand density affecting a specified point within a forest stand may be obtained from the summation of the angles subtended by the surrounding trees. The formulas and computation procedures are given by which basal area per acre is computed at a given point rather than over a given area. The angle-summation technique here developed is based upon the same principles as the angle-count method of Bitterlich, but is more precise in that the size and relative position of each tree bole within the sample contribute to the basal-area estimate, rather than simply the no. of trees subtending an angle greater than a given arbitrary minimum. The angle-summation technique is not designed to provide a measure of av. stand density, but is useful in silvicultural and ecol. invests. where it is desired to evaluate stand density at a given point rather than over a given area. For instance, a statistically significant correlation was obtained between point density and the current ann. basal-area increment of trees at the sample points in a 35-yr.-old stand of New Zeal. Douglas-fir, thinned to 3 different intensities.—Biol. Abs.

THOMSON, GEORGE W., AND DEITSCHMAN, GLENN H. **188**
1959. Bibliography of world literature on the Bitterlich method of plotless cruising, 1947–1959. Iowa Agr. and Home Econ. Expt. Sta. [unnumbered pub.], 10 pp.

See also **35, 46, 81, 447.**

FOLIAGE AND LINEAR MEASUREMENTS

ACKLEY, W. B., CRANDALL, P. C., AND RUSSELL, T. S. **189**
1958. The use of linear measurements in estimating leaf areas. Amer. Soc. Hort. Sci. Proc. 72: 326–330.

ALEKSEENKO, L. N. **190**
1959. [Method for determining leaf area of herbage plants.] Vsesoyuzn. Akad. Sel'sk.-Khoz. Nauk Dok. [Moscow] 24(9): 27–28. [In Russ.]

The method described is based on the assumption that the area of 1 g. of the crude leaf (or of 1 g. of leaf in an air-dry cond.) is constant for a given sp. This assumption is substantiated as follows. In each herbage sp. the area is determined (11 to 35 times) of 1 g. of the crude or dry leaves at different stages of plant devlpmt. Whole plants from the expt. plots are cut and all the green leaves are quickly removed, weighed, and imprinted on light-sensitive paper which, after being developed, shows the leaves in clear contour. These contours are cut from the prints and weighed, comparison being made with the weight of 100 sq. cm. of paper. Thus the area of leaves in a given sample is determined and the no. of sq. cm. in 1 g. crude leaf is calculated. At the stage of maximum devlpmt., the leaf area per 1 sq. m. of soil calculated by this method is (in sq. m.): for *Phleum pratense* 4.85; for *Festuca pratensis* 4.88; *Dactylis glomerata* 10.62; *Bromus inermis* 12; *Trifolium pratense* 9.68; and *Medicago sativa* 17.5. To determine the accuracy of this coefficient (i.e. leaf area in sq. cm. as derived from 1 g. of the leaf's crude or dry wt.), the data have been statistically analyzed and this shows that the % error does not exceed 2.15. It is concluded that utilizing this coefficient as obtained for conds. in the NW. zone of U.S.S.R., or determining it by this method for plants grown in other climatic conds., is a quick process (with an accuracy within 1.5 to 2% in field conds.) by which crude wt. of the leaves can be used to determine leaf area. To relate leaf area with a unit of soil surface, the leaf wt. is considered with any given area of soil.—Herb. Abs.

ANIKIEV, V. V., AND KUTUZOV, F. F. **191**
1961. A new method for determining leaf surface area of cereals. Fiziol. Rast. [Moscow] [Transl.] 8(3): 293–295, illus. [Transl. from Fiziol. Rast. [Moscow] 8(3): 375–377.]

APPADURAI, R. R. **192**
1961. The importance of leaf area as a determinant of yield in pastures. The measurement of leaf area in pasture plants. Trop. Agr. [Ceylon] 117(2): 77–88.

BEDELL, THOMAS E., AND HEADY, HAROLD F. 193
1959. Rate of twig elongation of chamise. Jour. Range Mangt. 12(3): 116–121, illus.

Chamise plants (*Adenostoma fasciculatum*), the tops of which had been removed, produced sprouts which grew more rapidly than did twigs of either grazed or ungrazed mature plants. Twig elongation began on approx. 24 Mar. for mature plants and the hedge-like, grazed plants, and slightly later in the case of topped plants. Twig elongation on mature plants ceased on 23 June, while on hedged plants it ceased on 24 July. Topped plants continued growth until late autumn. Removal of terminal buds from twigs of mature plants caused reproductive or vegetative axillary growth and leaf enlargement. The greatest amount of vegetative axillary growth occurred when buds were removed in spring, at which time the growth rate of the plant was at a maximum—Herb. Abs.

BREDEMEIER, L. F. 194
1958. Measurement of time and rate of growth of range plants with application in range management. Jour. Range Mangt. 11(3): 119–122.

Aerial length measurements of grasses were made over 2 years. *Agropyron smithii* and *Stipa comata* made some growth during the winter. The main growth of these grasses and of *Bouteloua curtipendula*, *Andropogon scoparius*, and *Calamovilfa longifolia* began at roughly the same time and was made within 3 mos., so that maximum elongation was reached at about the same time. Seasonal variations in amount and time of rainfall had little influence on linear growth.—Herb. Abs.

CHATTERJEE, B. K., AND DUTTA, P. K. 195
1961. A simple method of determining leaf area in *Mentha arvensis* L. (Abstract) Jour. Sci. and Indus. Res. [Delhi] 20C(12): 359–360.

COCHRAN, W. G., AND WATSON, D. J. 196
1936. An experiment on observer's bias in the selection of shoot heights. Empire Jour. Expt. Agr. 4: 69–76, illus.

Samples picked by randomization must be representative of the population and give an unbiased estimate of the quantity measured. Of 12 observers with some training in sampling, none picked a sample that could be called representative, and all but 3 had large biases in their estimate of shoot-ht. Biases in both shoot-ht. and relative variance show large differences from individual to individual and were not consistent for each individual throughout the expt. but increased regularly as the mean ht. of the sampling unit decreased. This invest. supplies further evidence that the only sure way to avoid bias is for selection to be random. Although observer bias has been said to be unimportant provided the same observer makes all estimates, this invest. shows that observer bias is not constant. Even if it were constant, uses for an observer's results are limited. Percentage differences or regression coefficients based on his results would be biased in different ways. No one can forseee the results to which data might be appl., and differences between observers would come into play in studies of long duration.

COOPER, ARTHUR W. 197
1960. A further application of length-width values to the determination of leaf-size classes. Ecology 41(4): 810–811.

The formula, 2/3 length $\times$ width, has been used to assign leaves of tropical rain forest spp. to Raunkiaerian size-classes with reasonable accuracy. A study was made of leaf-size classes of 228 spp. in oak-hickory woodland on the E. S. George Reserve in southeast. Mich. Comparison of classes determined on an actual area basis and by the 2/3 *LW* rule showed that little error was introduced by using the latter rule. The errors which did occur were generally in the direction of an increase in leaf area. Most frequent errors were in classification of lobed leaves, 18% of these being misclassified, all to a larger class. These errors suggested the use of other correction factors. For lobed leaves with shallow or narrow sinuses a factor of 1/2 gave adequate results and for leaves with deep or wide sinuses a factor of 1/3 gave a more accurate estimate.—Biol. Abs.

DAVIDSON, J. L., AND DONALD, C. M. 198
1958. The growth of swards of subterranean clover with particular reference to leaf area. Austral. Jour. Agr. Res. 9(1): 53–72, illus.

An expt. was conducted to study the growth of *Trifolium subterraneum* sown at 4 different densities (1, 4, 14, and 50 plants/sq. link [link=7.9 in.]); the control swards were not defoliated, while others were subjected to a single defoliation at various dates, 2–4 mos. after sowing. During the final mo. the rate of DM prod. (tops only) increased to a maximum when the LAI (the ratio of the area of the leaves to

the area of the ground surface) was about 4–5, falling by about 30% as the LAI increased to 8.7. The rate of leaf prod. was greatest at about LAI 4–5, falling to 0 at LAI 8.7. Climatic conds. during the growth influenced the relationship of LAI to growth; as conds. became more favorable the values of the optimum LAI for growth and of the ceiling LAI progressively rose. Irrespective of the density, all swards tended towards a common ceiling LAI and yield by the end of the season. The effect of defoliation depended on the LAI at which defoliation occurred, on the value to which the LAI was reduced, and on current climatic conds. If swards near the ceiling LAI were defoliated, total DM prod. was slightly increased and there was a great increase in leaf prod. Defoliation of swards from about the optimum LAI to very low LAI values led to a substantial reduction in both DM and leaf prod. It is suggested that all these effects depend on the light relationships within the sward and their influence on the balance of photosynthesis and respiration. Pasture at the optimum LAI will give greater prod. than swards of lower or higher LAI; defoliation can give greatly increased leaf prod., unless LAI is reduced to very low values.—Herb. Abs.

DEALY, J. EDWARD. **199**

1960. The densiometer for measurement of crown intercept above a line transect. U.S. Forest Serv. Pacific Northwest Forest and Range Expt. Sta. Res. Note 199, 5 pp., illus.

Measurement of crown intercept with the spherical densiometer appears to be an effective method for ecol. studies in tall shrubs and small trees. It provides precise and accurate estimates of crown cover, requires little instrumentation, and is simple and rapid in operation. Tests reported here and later field trials indicate that it could be easily adapted to other vegetation types containing plant spp. of intermed. ht.

DONOVAN, L. S., MAGEE, A. I., AND KALBFLEISCH, W. **200**

1958. A photoelectric device for measurement of leaf areas. Canad. Jour. Plant Sci. 38(4): 490–494.

HARBERD, D. J. **201**

1957. The within population variance in genecological trials. New Phytol. [London] 56(3): 269–280, illus.

This study was made with *Festuca ovina*, the characters recorded for analysis being date of ear emergence, lengths of stem panicle and leaf, and growth habit.

HASEL, A. A. **202**

1941. Estimation of vegetation-type areas by linear measurement. Jour. Forestry 39(1): 34–40, illus.

The linear-measurement method, by which distances through each type are measured along parallel lines and the data then converted to an area basis by use of a factor, gives results as accurate as those obtained by type mapping. The method is considerably less expensive, tends to eliminate personal bias, and permits periodic comparable remeasurements with a minimum of error. It is applicable to forest-ecol., grazing, and erosion studies.—Biol. Abs.

HEADY, HAROLD F. **203**

1957. The measurement and value of plant height in the study of herbaceous vegetation. Ecology 38(2): [313]–320, illus.

The concept of plant ht., methods of measuring ht., and the usefulness of ht. measurements are reviewed. A method of measuring the ht. of plant materials with the point-plot method, whereby the ht. of hits by the pins are used to measure the ht. of mass for sp. individually and for vegetation, is described. This gives a vertical dimension to foliage cover. The method is objective, easy to operate, and adds another measurement to those normally collected with the point-plot system. Examples are given to illustrate how the method is useful in the comparison of spp. and vegetation between areas, yrs., seasons, and grazing treatments in the Calif. ann. type vegetation. —Auth. abs.

HECHT, H. **204**

1960. Beitrag zur bestimmung von einzelblattflächen. [The estimation of the area of single leaves.] Bayer. Landw. Jahrb. [Munich] 37(4): 479–487.

Red clover leaves were used to test the efficacy of different methods of leaf-area estimation. Direct methods of measurement were much more accurate but more laborious than indirect ones. Of the direct methods considered, the photoelectric ones were rejected because they required the use of complex instruments and a means of calibration; the remainder were in the following order of accuracy, planimetric, paper with mm. squares, and gravimetric.—Herb. Abs.

HECHT, H. **205**
1960. Beitrag zur bestimmung von einzelblattflächen. [The estimation of the area of single leaves.] Bayer. Landw. Jahrb. [Munich] 37(6): 735–744.

Two direct methods of estimation are described: spot-counting and parallel grid. The latter method was more accurate than the former but not so accurate as planimetric, mm.-paper, or gravimetric methods. However, the spot-counting method was the quickest to use. The parallel-grid method seemed the best for combining speed and accuracy.—Herb. Abs.

HOPKINS, J. W. **206**
1939. Estimation of leaf area in wheat from linear dimensions. Canad. Jour. Res. Sect. C, Bot. Sci. 17: 300–304.

JENKINS, H. V. **207**
1959. An airflow planimeter for measuring the area of detached leaves. Plant Physiol. 34(5): [532]–536, illus.

The apparatus consists of 2 identically perforated plates (625 holes, 0.02 in. diam./sq. in.) mounted on an airtight drum connected to a constant speed rotary pump. The rate of air flow is noted with 1 plate covered (the measuring grid) and with the other plate open (the specimen grid); this gives a datum pressure. Leaves are mounted on the specimen grid and held flat by suction. Leaf area is determined by exposing part of the measuring grid to bring the air flow back to that of the datum pressure. The exposed area on the measuring grid is then equal to the area of leaves on the specimen grid. From a vernier scale on the measuring grid area can be read directly.

JONES, R. I. **208**
1961. A simple apparatus for estimation of the area of detached leaves. So. Afr. Jour. Agr. Sci. 4(4): 531–542, illus. [Fr. and Afrikaans sum.]

The leaves are placed, without their touching or overlapping, on a stiff metal screen containing 42 holes of 0.1 in. diam. per sq. in. and are then covered with a wire mesh screen to keep them flat and in a fixed position. The rate of passage (t) of a standard vol. of sand through this system is related to the area (A) of the leaves by the equation $A=S-c/t$ where S is the area of the screen and c is a constant (obtained by calibration with pieces of card of known area). The method is suitable for broad leaves, but it overestimates the area of narrow leaves.—Herb. Abs.

KEMP, C. D. **209**
1959. Estimation of leaf area by regression techniques. Hurley Grassland Res. Inst. Expts. Prog. (1957–58) 11: 90.

For grasses of widely differing leaf shape and size the equation $A=0.905(LB)$ can be used to estimate leaf area (sq. mm.), where A=leaf area, L (mm.)=length, and B (mm.)=breadth of the leaf measured at a point halfway along the length of the leaf. —Herb. Abs.

KEMP, C. D. **210**
1960. Methods of estimating the leaf area of grasses from linear measurements. Ann. Bot. [London] (n.s.) 24(96): 491–499.

MITCHELL, J. W. **211**
1936. Measurement of the area of attached and detached leaves. Science 83: 334–336.

This device measures light that a leaf intercepts and prevents from falling on a Weston Photronic cell. A possible use is in compiling areas of quadrats with great accuracy.

NIQUEUX, M. **212**
1961. Une méthode d'estimation de la surface foliaire pour le sorgho (*Sorghum vulgare* Pers.). [A method for estimating the leaf area of sorghum.] Agron. Trop. [Paris] 16(1): 99–102. [In Fr. with Eng. and Sp. sum.]

A method was studied for measuring the leaf area of sorghum in the field. For vars. of *Sorghum caudatum*, *S. elegans*, and *S. guineense*, a good estimate is obtained with the formula, $S=0.39L(M+m)$, in which S is the leaf area in sq. cm., L the length of the leaf blade in cm., M the maximum width in cm., and m the minimum width of the proximal half of the blade in cm.

SCOTT, D. **213**
1961. Methods of measuring growth in short tussocks. New Zeal. Jour. Agr. Res. 4(3/4): 282–285, illus.

The following methods for measuring the growth rate of short tussock-grasses were compared: (1) rates of elongation of the younger leaves in a tiller; (2) micrometer

measurement of the basal perimeter of the tussock; (3) total yield of the plants; and (4) the yield from clipping. Methods (1) and (2) appeared to have most promise as field techniques.—Herb. Abs.

SPENCER, R. 214
1962. A rapid method for estimating the leaf area of Cassava (*Manihot utilissima* Pohl) using linear measurements. Trop. Agr. [Trinidad] 39(2): 147–152, illus.

The basic requirements for any method of leaf area estimation are discussed. The objective was a routine method that inexperienced staff could use to determine the area of large numbers of deeply lobed cassava leaves quickly and accurately. Several methods were rejected because of practical difficulties or the errors involved. A rapid method that gives accurate results and uses the regression of leaflet rectangular area on leaf area is described.

THIRUMALACHARY, N. C. 215
1940. A rapid method of measurement of leaf areas of plants. Indian Jour. Agr. Sci. 10: 835–841, illus.

WILLIAMS, R. F. 216
1954. Estimation of leaf area for agronomic and plant physiological studies. Austral. Jour. Agr. Res. 5(2): [235]–246, illus.

A method based on leaf photographs is described for the estimation of leaf area. The method of preparing the standards is given, and a set of standards covering the full range of leaf form in young plants of the Pearson variety of tomato is presented. The method is rapid and does not damage the expt. plants. With 5 observers, the method was tested for the presence of bias resulting from fatigue or from variation in leaf size or form. Some of the observers showed personal idiosyncrasies of judgment which did not, however, invalidate the method for comparative studies. Estimates by all observers of leaf area per plant were very highly correlated with estimates based on an independent ref. method.—Auth. sum.

See also **13, 171.**

INDIRECT METHODS

ALEXANDER, C. W., SULLIVAN, J. T., AND MCCLOUD, D. E. 217
1962. A method for estimating forage yields. Agron. Jour. 54(5): 468–469, illus.

The av. ht. above ground level assumed by a light-wt. board dropped onto a sward was found to correlate well with the DM wt. of herbage under the board. By this method the yield of a (uniform) sward may readily be obtained, with minimum disturbance to the sward, after determining a conversion factor.—Herb. Abs.

ARNY, A. C., AND SCHMID, A. R. 218
1942. A study of the inclined point quadrat method of botanical analysis of pasture mixtures. Amer. Soc. Agron. Jour. 34(3): 238–247.

Data have been presented showing that percentages of certain spp. in pasture mixtures determined from readings from the inclined point quadrat apparatus were over- or underemphasized when compared with determinations from dry wts. A method of correcting for the overemphasis of Kentucky bluegrass alone, Kentucky bluegrass and crested wheatgrass together, and for the underemphasis of alfalfa from the readings from the point quadrat apparatus in the mixtures studied in 1941 was derived and used for that purpose. With a few exceptions, the percentages of these spp. as determined from the corrected readings from the point quadrat apparatus approached rather closely the percentages determined for them from dry wts.—Auth. sum.

BAKHUIS, JANNY A. 219
1960. Estimating pasture production by use of grass length and sward density. Netherlands Jour. Agr. Sci. 8(3): 211–224.

The extent that clipping can be replaced by estimates of sward density and herbage length in determining pasture yields was investigated. In view of the results there is no preference for logarithmic or nonlogarithmic processing. Assuming that the variance about the regression line is independent of the estimation values, the results in 1959 at a yield of more than 4,000 kg./ha. were reasonably good. Reliability was less on fields where the sward was more than 10% dicotyls. Compared to clipping only, combining a small number of clips with a larger number of sward density and/or length estimates ("double sampling") improved reliability of the yield determination without increasing the time needed for yield determination.

BALÁZS, F. **220**

1949. A gyepek termésbecslése növény szociológiai felvételék alapján. (The evaluation of the yield of grass fields on basis of phytosociologic surveys.) Agrártudomány [Budapest] 1: 26–35, illus.

A method using 2×2-m. squares in the respective grass field areas was devised. The ratio of surface occupied by the single plant sp. is estimated and the dominance values expressed by numerical rates (D_B nos.). The mean ht. of the single plant sp. must also be determined and mean ht. of grasses calculated from the formula $\frac{10\times\Sigma T}{D_B}$ (where ΣT indicates the total grass yield from summing up the $D_B\times m$ results calculated for each individual plant sp. and m signifies ht. of the individual sp.). The actual hay yield is calculated from the formula $\frac{(M-s)\,Bb}{100E}$ (where M signifies mean ht. of the grass, s the ht. of grass remaining after cutting off the hay, B a constant characteristic for each plant sp. or assoc. that is calculated from their empirical green hay yields, b another constant for degree of cover of grass, and E a drying factor for hay of 2.5 to 3.5). Some examples are given in which the formula gave a good practical evaluation.

CABLE, DWIGHT R. **221**

1958. Estimating surface area of ponderosa pine foliage in central Arizona. Forest Sci. 4(1): [45]–49, illus.

Measurements of tree diam., total foliage wt., and wt., length, and diam. of needle fascicles of ponderosa pine (*Pinus ponderosa*) were made to develop equations by which the foliage area of a tree can be estimated from diam. alone. For 20 trees between 1 and 20 in. d.b.h., wt. of foliage (W) in kg. was found to vary with tree diam. (D) according to the following equation: $\log W=1.8811 \log D-0.8882$. For 11 trees between 1 and 18 in. d.b.h., mean wt. per fascicle (MWF) in g. was found to vary with tree diam. (D) according to the following equation: $MWF=0.00514D+0.1111$. Fascicle area (FA) in sq. cm. was related to oven-dry fascicle wt. (FW) in g. according to the following equation: $FA=5.645+54.502FW$. Surface area of foliage of a tree is estimated from these equations by dividing total wt. of foliage by the mean wt. per fascicle and multiplying by the surface area of the av. fascicle.—Biol. Abs.

CAMPBELL, A. G., PHILLIPS, D. S. M., AND O'REILLY, E. D. **222**

1962. An electronic instrument for pasture yield estimation. Brit. Grassland Soc. Jour. 17(2): 89–100, illus.

This is a prelim. rpt. on an instrument being developed for the measurement of pasture yield *in situ*. In essence the instrument is an elect. capacitance measuring unit in which the introduct. of herbage to a measuring head causes a change in the elect. capacitance of the system. This capacitance change is measured at a radio frequency and used as an indicator of the mass of herbage contained within the measuring head. The devlpmt. and construct. of the instrument is described and data are presented for 15 calibration series in which frequency change has been related to pasture yield. Within series the instrument accts. for approx. 90% of the variation in pasture sample yield measured either as wet, dry, or organic matter. However, significant differences exist between series. These differences would give rise to bias if pasture yield were estimated from a prediction equation derived from the pooled data. Possible sources of the differences between series are discussed and avenues for further devlpmt. indicated—Biol. Abs.

CANFIELD, R. H. **223**

1944. A short-cut method for checking degree of forage utilization. Jour. Forestry 42(4): 294–295, illus.

A chart is presented for determining % ungrazed and % partially grazed forage when the % grazed at a stubble ht. of 2 in. or less is known.

CHARPENTIER, C. A. G., AND SAARELA, O. **224**

1941. Levy'n pisteneliömenetalmä ja sen käyttö laidunnurmien kasvillisuustutkimuksissa. [The point quadrat method of Levy and its use in the investigation of vegetation on pastures.] Valtion Maatalouskoet. Julkaisu. [Helsinki] 108: 1–31. [In Finn. with Eng. sum.]

Since 1936 the State Pasture Expt. Sta. at Mouhijärvi has been trying out the so-called point quadrat method invented by E. B. Levy of New Zeal. for the invest. of vegetation on pastures. As the method showed itself in many respects considerably better suited to this purpose than the systems previously employed, an acct. is given in this pub. of the way in which it has been appl. at Mouhijärvi and of the experiences and observs. so far arrived at concerning its suitability and potentialities in the invests. of the plant growth in grazed sward. A suitable method should be capable of conforming with the

following requirements: (1) It should be possible to undertake invests. as often as one wishes during successive summers as well as during a single summer and at practically the same spots. (2) It should be possible to avoid hay-making on the areas under invest. (3) The method should be relatively simple and quick. (4) The method should be as objective as possible, so that the results are not affected by a change of investigators. (5) The results should agree as closely as possible with the figs. reached by weighing grass specimens. Levy's point quadrat method fulfils the 2 1st conds. and is moreover a quite simple and relatively quick system. Compared with several other quicker methods, it is considerably more objective and more precise scientifically. When using it, it is also comparatively easy to recognise the examined vegetation. A considerable disadvantage, on the other hand, is that its results do not conform sufficiently closely with those arrived at by wt. analysis. In order to remedy this defect attention should be primarily directed to the devlpmt. of the method.

CLARK, IRA. 225
1945. Variability in growth characteristics of forage plants on summer range in central Utah. Jour. Forestry 43(4): 273–283, illus.

Four-yr. records showed that variation in vertical distrib. of forage wt. along the ht. of the stem was the rule rather than the exception in 10 spp. common on high summer ranges. Growth form varied markedly for the same sp. by yr., elevational zone, and site. These studies show that wide variation is to be expected in total forage supply and in the proportion removed when range is grazed to a given stubble ht. Because of the variation in form of plant with season, site, and previous grazing, large errors may result from the use of tables based on av. % of forage vol. above given hts. on the plant (vol.-ht. method).

COLLINS, ROBERT W., AND HURTT, LEON C. 226
1943. A method for measuring utilization of bluestem wheatgrass on experimental range pastures. Ecology 24(1): 122–125, illus.

An objective method for measuring degree of grazing is under devlpmt. as a 1st step in defining the proper degree for utilizing forage plants and for better range mangt. The devlpmt. of a composite curve is briefly described which shows the ht.-wt. relationship of bluestem wheatgrass, *Agropyron smithii*, using both culmed and culmless forms combined in the correct ratio for the site and yr. in question. After the % of plants grazed and their stubble hts. are determined by sampling the pastures along transect lines, the total % util. for grazed plants is read from this curve. The method is objective and reveals slight differences in degree of grazing.—Biol. Abs.

COOK, C. WAYNE. 227
1960. The use of multiple regression and correlation in biological investigations. Ecology 41(3): 556–560, illus.

In many ecol. studies the actual relation of a no. of factors can be evaluated by an analysis of multiple regression and correlation. Prod. volume and herbage wt. in bunchgrasses are not the same but may be closely related. The relation of basal area, ht., and vol. to yield of crested wheatgrass was studied. The method of double sampling was illus. in predicting yield from basal area, ht., and vol. A total of 2,150 plants were measured for basal area, ht., and vol. but actual yield was determined on only 10% (215 plants). The av. yield for the 2,150 plants was predicted by both simple and multiple regression equations. The estimated av. yield from the 3 simple regression equations and the multiple regression equations were, as would be expected, all about the same. But confidence intervals were smaller for the variables or combination of variables accounting for the greater variation in yield. Therefore the multiple regression equations are better than any 1 simple regression equation for predicting av. yield of crested wheatgrass.

CRAFTS, EDWARD C. 228
1938. Height-volume distribution in range grasses. Jour. Forestry 36(12): 1182–1185, illus.

The relation of ht. to herbage vol. (or air-dry wt.) of 11 important southwest. range grasses was studied by clipping at various hts. A similar concentration of herbage vol. was found for all spp. at the lower hts.; degree of util. of the forage cannot be inferred directly from the % of total ht. that is grazed. Line charts relating ht. to vol. for 8 spp. are given.

DAHL, B. E. 229
1963. Soil moisture as a predictive index to forage yield for the sandhills range type. Jour. Range Mangt. 16(3): 128–132, illus.

The principal grasses of the area are *Bouteloua gracilis*, *Calamovilfa longifolia*, and *Stipa comata*, and the av. ann. rainfall is approx. 17 in. (range 10–27 in.). Correlation

data for a 6-yr. period are given for herbage prod. during various pts. of the growing season and various soil moisture and rainfall parameters. Significant positive correlations were obtained between early spring prod., May 1-June 20, and rainfall of previous 2 yrs., and between prod. from May 1-Aug. 7 (96% of the total in 5 of the yrs. studied) and depth of visibly moist soil on Apr. 15. These correlations were increased by combining these 2 parameters.—Herb. Abs.

DASMANN, WILLIAM. **230**
1945. A method for estimating carrying capacity of range lands. Jour. Forestry 43(6): 400–402.

The auth. questions the reliability of estimates of carrying capacity based on methods now used in range surveys, and describes briefly a new method based on (1) the estimated wt. of each sp., (2) a proper-use (or allowable-cropping) factor, and (3) a preference rating which indicates the amount of each sp. that will be consumed when the key sp. receives no more than allowable cropping.—Biol. Abs.

DREW, WILLIAM B. **231**
1944. Studies on the use of the point-quadrat method of botanical analysis of mixed pasture vegetation. Jour. Agr. Res. 69(7): 289–297.

The point-quadrat method was compared to the count-list method of bot. analysis of a lespedeza-grass pasture. Assuming reliability of the wt.-list data in comparison, the point-quadrat method yielded more satisfactory results. No tendency toward underhitting of the legume or overhitting of the grass was noted. The relative efficiency of 4 different appls. of the point-quadrat method was also tested on the same vegetation type. When all hits were counted as the needles of the apparatus were pushed through the plants to the ground, results were more reliable than when the first plant hit by each of the 10 needles was recorded. Vegetation height and spp. morphology affected the results.

EVANS, RAYMOND A., ECKERT, RICHARD E., AND KINSINGER, FLOYD E. **232**
1961. A technique for estimating grass yields in greenhouse experiments. Jour. Range Mangt. 14(1): 41–42, illus.

A linear relation was established between dry wt. and the function LN, where L is the length of the longest green blade and N the no. of blades on the plant. Correlation coefficients ranged from 0.97 to 0.87 for 5 spp. investigated. The appl. of this method is discussed.—Herb. Abs.

EVANS, RAYMOND A., AND JONES, MILTON B. **233**
1958. Plant height times ground cover versus clipped samples for estimating forage production. Agron. Jour. 50(9): 504–506.

The product of plant ht. and ground cover (HG) was compared with clipping as a method for determining forage prod. at different growth stages in 15 fert. trials on range land of varying bot. comp. The effects of the fert. treatments were similar for both methods. On plots with early (2 in. tall), intermed. (>4 in. tall), or mature growth there was a quantitative relationship between the values obtained from both methods, but for early growth the relationship was not the same as for the more mature herbage. In lodged and overmature stands the relationship was erratic. Advantages of the HG method were: (a) a larger area can be sampled, (b) vegetation remains intact during sampling, (c) sampling can be carried out at the same time as step-point vegetational analysis. However, HG values could not be expressed in familiar terms (such as lbs./acre), and where bot. analysis was not necessary, the method took as long as, or longer than, did clipping.—Herb. Abs.

FRAKES, R. V. **234**
1959. Predicting dry matter yield in space planted alfalfa by height, width, and longest stem measurements. Agron. Abs. 1959: 58.

GREENWOOD, E. A. N., AND HALLSWORTH, E. G. **235**
1960. An evaluation of the maximum radius of the rosette as a growth index for subterranean clover. Plant and Soil [Hague] 12(1): 49–56, illus.

The maximum radius of the rosette of *Trifolium subterraneum*, i.e., the distance from the center shoot to the junction between leaflets of the farthest leaf, was found to be positively correlated with DM yields during early growth. The correlation coefficient decreased as the plants (var. Mt. Barker) approached flowering. For comparison of expt. treatments before cutting in nutrient expts., measurements of the maximum radius were a satisfactory and rapid index of DM yields, provided that the correlation coefficient at harvest was greater than 0.85.

GRINGOF, I. G., AND ALIMZHANOV, A. G. 236
1962. [A method for the field determination of the yield of *Carex physodes* in pastures.] Bot. Zhur. [Moscow] 47(8): 1170–1176. [In Russ.]

The devlpmt. of a field method to determine the yield of *Carex physodes*, an important fodder plant in sandy pastures in the U.S.S.R., is described in detail. A nomogram, based on field observs., is derived. This relates the dry wt. of the plant mass (yield in g.) to linear growth and no. of tillers/sq. m. If this nomogram is used there is no need to cut, dry, and weigh the vegetation. In practice, under field conds., 3–5 sq. m. areas are selected to allow for irregular density of the sward. Inside each area, the tillers are counted and the linear growth estimated (av. growth estimated from 40 measurements). The most probable av. dry wt. of the plant mass (g./sq. m.) is then determined from the nomogram. Less than 10 mins. are required to make measurements in 1 area, so that accuracy can readily be improved by increasing the no. of areas. The yield of *C. physodes* can be estimated to within 10 kg./ha. in 1 hr.—Herb. Abs.

HALLS, L. K., HALE, O. M., AND SOUTHWELL, B. L. 237
1956. Grazing capacity of wiregrass-pine ranges of Georgia. Ga. Expt. Stas. Tech. Bul. (n.s.) 2, 38 pp., illus.

In studies carried out during 1950–54 in the Coastal Plain region of Ga., determinations were made of the grazing capacity and optimum rate of stocking of burned-over wiregrass/pine rangelands. The ranges were burned over each Jan., except in 1951, and stocking rates of 4, 6, 7, 9, 14, and 18 acres per steer were used. Grazing lasted from mid-Mar. to mid-Jan. of each yr., except in 1952, when no grazing took place. Forage util. ranged from 30% under light grazing to 65% under the heaviest rate of stocking. On dry land areas, grasses made up 85% of the herbage consumed. Most forage in spring was provided by *Aristida stricta* and *Sporobolus curtisii*. In summer, *Andropogon stolonifer*, *A. virginicus*, and *Axonopus affinis* were the most important spp. Nearly all native spp. in the area studied tolerated burning well and, in many cases, had greater vigor and palatability after winter burning. The ground cover on heavily grazed areas decreased, as did herbage prod., though on localized areas *A. affinis* invaded and completely occupied areas vacated by overgrazed bunch grasses. Herbage prod. on ungrazed open areas averaged about 1,060 lbs. oven-dry forage per acre, compared with 775 lbs./acre on grazed areas. Estimations of herbage prod. could be made by using the following formula: $Y=1{,}060-15X_1-13X_2$, where Y=estimated herbage prod., X_1=% overhead tree canopy, and X_2=% shrub cover. For maximum wt. gains, the equivalent of 9 acres of open range, without trees or shrubs, was needed to feed a 500 lb. steer from Mar. to Jan.—Herb. Abs.

HARRIS, F. B. 238
1941. A short cut method of computing grazing capacity ratings from range survey forage estimates. Nev. Agr. Expt. Sta. Bul. 155, 15 pp., illus.

The proposed method has many advantages over those now in use. It is directly applicable to the point observation plot and ocular reconnaissance methods of range survey, and involves no changes in field procedure. It greatly speeds computing of carrying capacity rating (surface acres per animal unit mo.) from estimates of forage density. This is accomplished by prearrangement on the write-up sheet of the coded products of density times proper use factor (forage factors). The sum of these small whole nos. is converted to surface acres per animal unit mo. by ref. to tables that form pt. of the sheet.

HEADY, HAROLD F. 239
1950. Studies on bluebunch wheatgrass in Montana and height-weight relationships of certain range grasses. Ecol. Monog. 20(1): [55]–81, illus.

During 1946 and 1947, 1,110 plants in 5 spp. of grass from cent. Mont. were processed to determine the nature of variations in ht.-wt. At the same time an attempt was made to determine the causes of the variations in bluebunch wheatgrass. The term ht.-wt. is used to express the proportion of the total air-dry wt. of a grass plant in successive 1-in. segments from the base to the top. When samples of 30 plants from 1 site and 1 yr. were compared with ht. class tables constructed from all plants processed, variations in % of wt. below stubble hts. of 2–6 in. were less than 10%. The variations were not consistent with av. ht. of plants, av. wt., environmental conds. in the habitats, elevation, or comp. of spp. in the stand. However, clipping of bluebunch wheatgrass did result in considerable differences in the ht.-wt. relationships. The ht.-wt. method is used to determine util. of grasses by livestock and under the conds. of the expt. it was shown to be reasonably accurate for that purpose.—Biol. Abs.

HICKEY, WAYNE C., JR. 240

1961. Relation of selected measurements to weight of crested wheatgrass plants. Jour. Range Mangt. 14(3): 143–146, illus.

In a study of 923 plants of *Agropyron desertorum* the following correlations were obtained between dry wt. and certain measurements: basal diameter+compressed crown diameter (measured midway between the highest and lowest leaf collar when the whole plant was grasped in the hand)+compressed leaf length (ht. to the tallest leaf collar when grasped as before), $r=+0.922$; compressed crown diameter+compressed leaf length, $r=+0.918$. The last 2 measurements accounted for 84.3% of the variation in plant wt.—Herb. Abs.

HUGHES, EUGENE E. 241

1962. Estimating herbage production using inclined point frame. Jour. Range Mangt. 15(6): 323–325.

Significant correlations were obtained between herbage yield of *Hilaria mutica* and *Buchloe dactyloides* (determined by clipping) and (a) plant cover (obtained from total nos. of hits using an inclined point-frame), and, to a lesser extent, (b) plant frequency. Results were similar for 3 different types of grassland, although there was evidence that the efficiency of the parameter was affected by the morph. of the sp. —Herb. Abs.

HURD, RICHARD M. 242

1959. Factors influencing herbage weight of Idaho fescue plants. Jour. Range Mangt. 12(2): 61–63.

The relation between herbage wt. and leaf wt., basal area, and no. of flower stalks was determined in 1,150 Idaho fescue plants (*Festuca idahoensis*) growing on 3 soil/plant assocs. in the Big Horn Mountains, Wyo. The correlation between leaf ht. and DM yield was highly significant. Variations in leaf ht., basal area, and no. of flower stalks accounted for 86–94% of the variation in DM yield.

JONES, M. B., AND EVANS, R. A. 243

1959. Modification of the step-point method for evaluating species yield changes in fertilizer trials on annual grasslands. Agron. Jour. 51(8): 467–470.

The quantity of forage produced by individual spp. at various levels of N in ann. grassland in Calif. was measured by means of (a) clipping, sorting, drying, and weighing, (b) by multiplying the av. ht. of each sp. encountered along line transects, using the step-point method, by the % ground cover for each sp. Comparison of the 2 methods gave correlation coefficients significant at the 1% level. Method (b) had lower coefficients of variation, disclosed a greater no. of significant differences between treatments, and was 4 times quicker than method (a).—Herb. Abs.

KELLY, A. F. 244

1958. A comparison between two methods of measuring seasonal growth of two strains of *Dactylis glomerata* when grown as spaced plants and in swards. Brit. Grassland Soc. Jour. 13(2): 99–105, illus.

A trial was made of how well measurements of the leaf-plus-shoot length of spaced plants of strains of *Dactylis glomerata* indicate DM yield, as determined by cutting and weighing the produce of sward plots. Two contrasting strains of *Dactylis glomerata* were used, the British S. 143 and the German von Kamekes. The strains were established during 1955 both as spaced plants (10 plants per plot) and as pure swards, with 6 replications of each. The 2 methods of establishment, the main treatments, occupied whole plots. Each plot was divided into 4 subplots, each carrying 1 of the 2 strains combined with 1 of 2 mangt. treatments. Mangt. treatment 1 was cutting at monthly intervals from 27 Apr. to 23 Aug. Mangt. treatment 2 was cutting on 12 Apr., then cutting of each strain at the mean date of emergence of its inflorescence, and finally cutting at monthly intervals until the end of Aug. Spaced plants were measured before cutting by thrusting a measuring rod into the crown and measuring the leaf-plus-shoot length of one of the longer shoots. Results from cutting produce from sward plots and weighing and sampling for DM content showed that von Kamekes produced more DM in early spring, but that the advantage then passed to S. 143. In early spring significant positive correlations were obtained between sward yields and leaf-plus-shoot measurements from spaced plants. Subsequently the 2 methods did not agree, and some significant negative correlations were obtained. In relation to the physiol. devlpmt. of the strains, the data suggest that: (a) In spring shoot elongation contributes most to yield, with tillers mostly in the reproductive phase. (b) In summer new tiller formation contributes most, with tillers mostly in the vegetative phase. (c) In the early autumn neither factor is dominant and both contribute to yield. Attention is drawn to the

danger of comparing yields from spaced plants with yields from swards where mangt. may influence results, and to the difficulty of assessing hay yields by means of spaced-plant ht. measurements.

KELTING, R. W. 245

1957. Winter burning in central Oklahoma grassland. Ecology 38(3): 520–522.

An area of grassland dominated by *Andropogon scoparius, A. gerardi, Sorghastrum nutans*, and *Panicum virgatum* was burned in early Feb. 1952, after being protected from grazing since mid-1949. Of a no. of climatic and edaphic factors studied after burning, only the maximum soil temp., which was appreciably higher on burned than unburned areas, showed any great response to burning. The area cover of grasses increased more on burned than unburned areas from the 2nd week in Apr., onwards. By mid-June, the area cover of *A. scoparius* had increased from 11.9% on unburned plots to 15.9% on burned plots, while that of *A. gerardi* decreased significantly from 4.3% to 0.6%. The correlation coefficients between area cover and dry wt. for all grasses in burned and unburned plots were +0.91 and +0.81, respectively. It is thought that area cover could be adapted for use in calculating the actual amount of foliage present on a given area, though there is evidence that this may only apply to grasses during the early pt. of the growing season. The need for adding a ht. factor to the area cover is suggested.—Herb. Abs.

KINSINGER, FLOYD E., AND STRICKLER, GERALD S. 246

1961. Correlation of production with growth and ground cover of whitesage. Jour. Range Mangt. 14(5): 274–278, illus.

Measurements for 4 yrs. in 3 locations indicated a significant positive correlation between growth and prod. of whitesage (*Eurotia lanata*). The correlation between growth and prod. for all observs. was 0.39. Ground cover and prod. were better correlated with a coefficient of 0.43. However, ground cover alone apparently was not as reliable as growth in predicting prod., there being 3 instances when ground cover and prod. were not significantly correlated and only 1 nonsignificant growth-prod. correlation. The product of growth×ground cover proved to be a better estimate of prod. with a correlation coefficient of 0.61. The regression lines have practical value to stockmen and land managers in providing a relatively accurate and simple method for determining forage prod. and grazing capacity of whitesage alternes.—Biol. Abs.

KIRA, TATUO, OGAWA, HUSATO, AND SAKAZAKI, NOBUYUKI. 247

1953. Intraspecific competition among higher plants. I. Competition-yield-density interrelationship in regularly dispersed populations. Osaka Univ., Inst. Polytech. Jour. Ser. D 4: 1–16.

The nature and trends of intraspecific competition were investigated, based mainly on the field expt. with soybean for 1952, and in part on the prelim. expts. with sand-cultured vegetables in 1950–52. Soybean plants were regularly distributed over the field in right triangular dispositions, and 5 different grades of planting density were employed. Sampling was made 6 times during the expt. period of 119 days (June 27–Oct. 24, 1952). Fifty plants per each density grade were sampled at a time, and total wt. of each plant was measured. The intensity of competition as indicated by mean plant wt. rose with increasing density. But the relative variation of individual wt. values within a population showed no significant correlation with changes of density. This fact tells that, contrary to the common view, the intensified competition did not accelerate the dominance of the larger individuals over the smaller. Competition in the narrow sense did not occur among individual plants, but the population as a whole reacted to the limited supply of growth factors. The regression of mean plant wt. (w) on density (d) was found to be represented by the following empirical formula, $wd^a=k$, or $w=Ks^a$ where s=mean available space/plant and a, K=constants. The results of the prelim. expts. as well as of previous res. were also successfully fitted to the equation. Its applicability was proved to be wide, so far as individual plants in the population are regularly distributed. Namely, w in the equation may be dry wt., fresh wt., or even the wt. of a certain pt. of plant, such as top, leaf, trunk, root, or seed. The index fig. a, which represents the degree of space util. by plant at certain stages of growth, increased from 0.0 in the seed stage to 1.0 approx., where the equilibrium was reached at which dry wt. was inversely proportional to density. When based on dry wt. of plant, the time trend of the increase of a could be approximated by the following regression, $a=m \log T+n$. The functional relations represented by these equations are named the competition-density effect. It seems to represent 1 of the fundamental quantitative principles underlying the time-space trend of intraspecific competition among higher plants. The index figure a, here called the C–D index, can also be used as a measure of the relative intensity of competition, when the expt. results under different environmental conds. or with different spp. of plants are to be compared. Changes in the index value, when wts. of various pts. of a plant were correlated with density, were also discussed.

The relation between total plant yield/unit area ($Y=dw$) and density is given by the following equation, $Yd^{a-1}=K$ which may be called the yield-density effect. Starting from the equation, some practical considerations were made on the determination of the adequate planting distance for econ. crop cultures.—Biol. Abs.

KITTREDGE, JOSEPH. **248**
1945. Some quantitative relations of foliage in the chaparral. Ecology 26(1): 70–73, illus.

Leaf weight and area are highly correlated, and the wt. per unit of area is nearly constant for a sp. The log of dry leaf wt. is a linear function of the log of crown diameter for *Ceanothus crassifolius* and *Arctostaphylos glandulosa*. For the *Ceanothus*, the total dry leaf wt. per unit of land area is a linear function of the % coverage of the crowns. These relations facilitate estimates of total wts. of foliage of all the plants on areas of land.

KUO, P. C. **249**
1961. The correlation of diameter and length of twig with the weight, length and number of needles of Luchu pine (*Pinus luchuensis*) and Chinese red pine (*Pinus massoniana*). Taipei Natl. Taiwan Univ. Col. Agr. Mem. 6(1): 63–66.

LARIN, I. V. **250**
1957. [Methods of collection and treatment of data on crop and aftermath yields, accumulated in the course of systematic recordings.] Bot. Zhur. [Moscow] 42(6): 903–908. [In Russ.]

In recent yrs. geobotanists have studied the harvest and aftermath yields of plants in different assocs. The auth. has developed an approach for accurately assessing pasture util. when areas are grazed or cut 2 or more times. The calculations take into consideration stage of growth of the sward components, climatic factors in the various zones (forest/steppe, steppe, semidesert), cutting level, and aftermath yield. The method is claimed to indicate the quantity of herbage that stock consumed during a grazing period and during the various growth phases of the plants. This is expressed as a coefficient of consumption.

LEASURE, J. K. **251**
1949. Determining the species composition of swards. Agron. Jour. 41(5): 204-206.

The point quadrat method of sward analysis was compared with other methods. A combination of point quadrat and visual estimation can save much time without impairing accuracy.

LOMMASSON, T., AND JENSEN, CHANDLER. **252**
1938. Grass volume tables for determining range utilization. Science (n.s.) 87(2263): 444.

There is an urgent need for a mechanical means of determining the degree of grazing of forage plants on National Forests and other ranges in the W. In the Mont. region a partial 3-cycle, semicircular logarithmic scale has been developed which converts in. of stubble into % vol. util. A full acct. of this work is to be published.—Herb. Abs.

LOMMASSON, T., AND JENSEN, CHANDLER. **253**
1943. Determining utilization of range grasses by height-weight tables. Jour. Forestry 41(8): 589–593, illus.

LUNDBLAD, K. **254**
1937. Metoder för botanisk analys av vallar. [Methods for botanical analyses of grassland.] Svenska Mosskulturför. Tidskr. [Sweden] 51: 187–235. [Eng. sum.]

A discussion of the advantages and disadvantages of certain lab. and field methods of grassland analysis used in the Scandinavian countries and in Finland is given. An estimation of hay comp. based on degree of covering in the field and on comparisons with tabulations presented proves more satisfactory than a direct estimate of wt. percentages of the field components.—Herb. Abs.

MAKKINK, G. F. **255**
1957. Grass length and yield of dry matter. Wageningen Inst. v. Biol. en Scheik. Onderz. van Landbgewassen. Meded. 1957 (16): 73–77. [In Dutch with Eng. sum.]

MARTEN, G. C., WEDIN, W. F., AND HUEG, W. F. **256**
1963. Density of alfalfa plants as a criterion for estimating productivity of an alfalfa-bromegrass mixture on fertile soil. Agron. Jour. 55(4): 343–344.

During a 2-yr. study, the DM herbage yield of a bromegrass (*Bromus inermis*)/

alfalfa sward was independent of alfalfa plant density in the range 2–12 plants/sq. ft. This relation was not affected by up to 120 lbs. N/acre. It was concluded that alfalfa plant density was a poor criterion of sward yield.

MARTIN, E. P. **257**

1955. Use of regression line to estimate basal cover of sod-forming grasses. Kans. Acad. Sci. Trans. 58(4): 526–527.

In an attempt to eliminate the considerable time and labor entailed in using the pantograph and planimeter technique for estimating basal cover, the possibility of using stem nos. for such estimations was investigated. The correlation coefficient between basal cover and stem nos. for *Agropyron smithii* was 0.88, with a standard error of 0.14, and it was concluded that it was possible to make a satisfactory estimate of basal cover from stem nos. for this sp.—Herb. Abs.

MATTOX, JAMES E. **258**

1955. A study of per cent of plants grazed method of utilization determination and its application. Mont. Agr. Expt. Sta. Mim. Cir. 88, 140 pp., illus.

OSBORN, BEN. **259**

1947. Determining range utilization by frequency tallies. Jour. Soil and Water Conserv. 2(1): 51–55.

The frequency tally which has been used in Soil Conserv. Districts in Tex. is a rapid method of determining comp. and degree of use of range vegetation. It is based on a count of a random sample of individual plants, classified into 3 use classes; namely, fully grazed, partially grazed, and not grazed. Composition is calculated as the % frequency of occurrence of each sp. Percentage of use for each sp. is computed as the total of the % of plants of that sp. fully grazed plus half the % partially grazed. Weighted av. percentages of actual use and proper use can be compared to indicate the existing degree of use of the sample. Both grassland and browse types, or a combination of these, can be evaluated by this method.—Auth. sum.

PASTO, JEROME K., ALLISON, JOHN R., AND WASHKO, JOHN B. **260**

1957. Ground cover and height of sward as a means of estimating pasture production. Agron. Jour. 49(8): 407–409.

Test areas of (a) permanent *Poa pratensis* and (b) sown *Dactylis glomerata/Trifolium repens* var. pastures were enclosed with cages and the ground cover, sward ht., and forage yield measured. There was a correlation between cover and yield figs. for both pasture types; the correlation coefficients were 0.728 for (a) and 0.733 for (b). Yields of forage on (a) were very small when the cover was less than 70% and though the standard error was large, it represented only a very small proportion of the yield. It was concluded that cover could be used to assess forage prod. on low-yielding *P. pratensis* pastures. In the case of (b) the standard error represented a large amount of forage, and yield assessments in terms of ground cover were unreliable. Multiple correlation coefficients for cover and ht. were 0.912 for (a) and 0.875 for (b).—Herb. Abs.

PECHANEC, JOSEPH F. **261**

1936. Comments on the stem-count method of determining the percentage utilization of ranges. Ecology 17(2): 329–331.

Stoddart's method for determining % util. of grazed ranges has been tested under field conds. to verify its accuracy and to compare it with other methods already in use. Because deviations or errors tend to be positive and cumulative, it is contended that the stem count system of obtaining % util. is not accurate enough for unqualified use in pasture or open range studies.

PECHANEC, JOSEPH F., AND PICKFORD, G. D. **262**

1937. A comparison of some methods used in determining percentage utilization of range grasses. Jour. Agr. Res. 54(10): 753–765.

This expt. to test the limits of accuracy, the inherent personal error, and the rapidity of determining % util. of range forage by grazing was carried out on sagebrush-wheatgrass range which was dominated by *Agropyron spicatum* and *Artemisia tripartita*. Clipping to simulate removal by sheep was used as a substitute for grazing which allowed the use of an accurate check in the form of the modified vol.-by-wt. method. Other methods used were (1) ocular-estimate-by-plot, (2) ocular-estimate-by-av.-of-plants, (3) stem count, (4) measurement, and (5) ocular-estimate. From data presented it is recommended that ocular-estimate methods of obtaining % util., supplemented by comparison with determinations made by the modified vol.-by-wt. method, be considered for use in range pasture or open-range studies.—Herb. Abs.

PERGAMENT, E. 263
1959. Components of variation of mature height and yield in *Medicago sativa* L. Agron. Abs. 1959: 64.

PONYATOVSKAYA, V. M., AND SYROKOMSKAYA, I. V. 264
1960. Opyt sravnitel'noi otsenki uchastiya vida v stroenii lugovogo soobshchestva. [A test of the comparative evaluation of the participation of a species in the structure of a meadow association.] Akad. Nauk SSSR Bot. Inst. Trudy 3(12): 171–180. [1960; Referat. Zhur., Biol. [Moscow], 1961, No. 14V203. (Transl.)] [In Russ.]

Some methods for the study of morph. of plant assoc. are compared. The work was carried out on a plot of mixed grass, heavily mossed matgrass, in 1953–56. The floristic list consists of 54 spp. of vascular plants, abundance being given in a table by the Drude method. The table also gives projective cover (in percent) by the Ramenskii and point methods, wt. in g. and in percent, occurrence according to Raunkiaer, and combined indicators (absolute and in percent) for the product of the values of occurrence and wt. and for values of projective cover and wt. For data obtained with different methods, comparison and evaluation are also given.

PRÉCSÉNYI, S. 265
1957. The correlation between ground-cover and vegetation yield. Portug. Acta Biol. Sér. B 6(1): 94–96.

In an invest. to determine mathematically the relationship between ground cover and vegetation yield, using data from 25 plots (1×1 m. each) covered by *Lotus corniculatus* and *Dactylis glomerata*, a good positive correlation was found.—Herb. Abs.

PROUDFOOT, K. G. 266
1957. A comparison of total dry-matter yields obtained in the first harvest year, from five strains of perennial ryegrass under single plant, pure sward, and clover sward conditions. North. Ireland Min. Agr. Res. and Expt. Rec. (1956)6: 19–30.

Irrespective of planting method, DM prod. of all strains of *Lolium perenne* on trial in the first harvest yr. was greater when cutting was less frequent. Sward yields increased with the addition of clover. Strains ranked similarly under both pure and clover-sward conds., but not when assessed as single plants. The discrepancy tended to disappear when single-plant prod. was related to the actual area occupied. It is suggested that the use of the yield/basal-diam. ratio in strain classification will give a more accurate picture of potential yield under sward conds.

PROUDFOOT, K. G., AND WRIGHT, C. E. 267
1958. An assessment of the relative values of three methods of determining the leafiness of perennial ryegrass. North. Ireland Min. Agr. Res. and Expt. Rec. (1957)7: 27–30.

A rapid technique for the estimation of leaf/stem ratio in peren. ryegrass is described and compared with standard methods (determination of no. of heads per unit wt. of plant material, or hand separation of leaves and stems and determination of dry wts. of each). In the rapid method, the bundle of plant material from each spaced plant is weighed with as little disturbance as possible, then grasped by the heads so that the leaf material can be shaken out. The heads are then weighed and a leaf/stem ratio obtained. Significant correlation coefficients were obtained for all comparisons of the 3 methods at 2 aftermath cuts, but the cut at the hay stage (1 mo. after mean ear emergence for each strain) did not give significant correlations between the methods.—Herb. Abs.

REID, ELBERT H., AND PICKFORD, G. D. 268
1941. A comparison of the ocular-estimate-by-plot and the stubble-height methods of determining percentage utilization of range grasses. Jour. Forestry 39(11): 935–941, illus.

Comparison of utility of the ocular-estimate and stubble-ht. methods of estimating % util. of range grasses warrants three conclusions: (1) Both methods give similar estimates of degree of util. when the ht. of stubble after grazing is uniform. When grazing on the individual grass clumps is ragged or uneven the stubble-ht. method tends to give low estimates of use. (2) The number of plots needed to sample util. is about the same for both methods. (3) Because of its simplicity, the ocular-estimate method is more suitable for field use than the stubble-ht. method and is, therefore, recommended to range administrators as best for determining use on large areas.

Reppert, Jack N., Morris, Meredith J., and Graham, Charles A. 269
1962. Estimation of herbage on California annual-type range. Jour. Range Mangt. 15(6): 318–323, illus.

A reliable parameter was sought for estimating herbage yield. Although statistically significant correlations were obtained between yield and (a) plant ht., (b) ocular estimates of cover, and (a)×(b), they were considered too low to use for absolute determinations. While the relation of plant wt.×plant density overestimated herbage yield 6.5–7 times, it gave close relative agreement for a no. of different types of site.

Roach, Mack E. 270
1950. Estimating perennial grass utilization on semidesert cattle ranges by percentage of ungrazed plants. Jour. Range Mangt. 3(3): 182–185, illus.

A util. measurement system based on % ungrazed grass clumps was studied in an effort to lessen disadvantages inherent in present systems. A graph relating % of ungrazed plants and the % of total wt. of herbage removed must be prepared for each local grass type. In making a survey the fieldman need only determine % plants remaining ungrazed in the pasture or range area. This can be done by use of enough paced transects for a representative sample. The mean % ungrazed plants may then be entered on the graph and % use read off directly. The % ungrazed system has been tested for 4 yrs. on the Santa Rita Expt. Range. The av. difference between measured use expressed in % (% ungrazed method) has been 1.6. The greatest difference was 2.4. This accuracy is fully adequate for practical use.

Rodionov, M. S. 271
1959. Ob opredelenii massy listvy zaščitnyh lesopolos. [Determining foliage weight in shelterbelts.] Bot. Zhur. [Moscow] 44(3): 333–337. [In Russ.]

In continued shelterbelt work correlation coefficients between diam. at root collar and fresh wt. of foliage were ≥ 0.90 and ≥ 0.93 for 2- to 4-yr.-old *Quercus robur* and *Fraxinus pennsylvanica*. For older belts, collecting all leaves from enough sample trees becomes laborious. Cummings' method was accordingly used on pure *Populus "canadensis"* with occasional *Salix viminalis* in shelterbelts (5–23 yrs. old), and 65 popular branches (diam. 0.3–12 cm.) and 35 willow branches (0.3–4.6 cm.) were sampled. Correlation coefficients of branch diam. and foliage wt. were 0.89 and 0.86 for popular and willow respectively. This shows it is feasible, both as regards accuracy and labor required, to calculate the total foliage wt. of sample trees or all trees on sample plots from diameters of all 1st-order branches.

Schmutz, Ervin M., Holt, Gary A., and Michaels, Charles C. 272
1963. Grazed-class method of estimating forage utilization. Jour. Range Mangt. 16(2): 54–60, illus.

For each sp. six classes or degrees of defoliation (0, 10%, 30%, 50%, 70%, and 90%) are established and standardized by photographic record onto field cards. Percentage util. is determined from a survey by summing the products: % util. class× % of plants in that class. The method is rapid, simple, statistically sound, and reasonably accurate.

Smoliak, S. 273
1961. Use of regression equations to determine utilization of "shortgrass" prairie. (Unpublished thesis, Montana State Col., Bozeman)

Height/wt. relations were determined for 3 grass spp. in a vegetation complex dominated by *Stipa comata*. For *S. comata* groups, homogeneous correlation coefficients were found for the relations leaf ht./wt., leaf ht./basal area, and wt./wrapped diameter (=compressed basal diameter of plants with roots removed). For *S. comata* plants, homogeneous correlations were found for the relations ht./wt., stubble ht./wt. (50% util.), and stubble ht./% util. From ht.-class tables of *S. comata* plants collected at maturity, the variability of ht./wt. distrib. was found to be low. A ht./wt. regression was used successfully to accurately estimate the % util. (of the whole pasture and under any grazing intensity) from the stubble ht.

Sneva, Forrest A., and Hyder, D. N. 274
1962. Estimating herbage production on semiarid ranges in the Intermountain Region. Jour. Range Mangt. 15(2): 88–93, illus.

Thirteen precipitation-herbage yield series from Oreg., Utah, and Idaho studies were pooled for the calculation of a common herbage response line. Series pooling was done by expressing each yield and precipitation value of each series as a % of its respective longtime median-yr. yield or median crop-yr. precipitation amount. The single regression line of pooled data, which represents a common yield-dependence upon precipitation, was: $Y=1.11X-10.6$, where the X=the precipitation index (crop-yr. precipitation/median precipitation amount) and Y=the yield index. The standard error of the estimate was 18.4% and the correlation coefficient with 92 degrees of freedom was 0.880.

The method was proposed as a basis for estimating the longtime median herbage yield of a range from median precipitation or the herbage yield in any given yr. from an individual crop-yr. precipitation amount.—Biol. Abs.

SPRAGUE, V. G., AND MYERS, W. M. 275
1945. A comparative study of methods for determining yields of Kentucky bluegrass and white clover when grown in association. Amer. Soc. Agron. Jour. 37(5): 370–377.

Percentages of Kentucky bluegrass and white clover were determined by bot. separations and by the inclined point quadrat in trials of 15 strains of Kentucky bluegrass grown in 3×9 ft. plots distributed at random in 4 replications and seeded uniformly with white clover. For the bot. separations, samples were clipped with grass shears before the yield strip was harvested with a lawn mower. At the 1st clipping date the samples averaged 20.7% of the yield of the harvested strip; in the 3 subsequent cuttings, the samples averaged between 12.4% and 16.2%. A sampling study showed that the variance within plots was low compared with the estimated true variance between plots within replications. Evidently the method of sampling provided a reliable measure of the % of white clover in the plots. Since the error in subsampling was low compared to variability within plots, samples 1/4 the size of the usual samples could be used. Using the inclined point quadrat, the estimated % of clover was lower than that found by bot. separations, the general means by the 2 methods being, respectively, 10.2% and 17.1% on June 23 and 49.8% and 68.3% on Oct. 19. Compared on the basis of strains, the greatest difference in % of clover between the 2 methods on June 23 was 13.0 while the least difference was 2.7. On Oct. 19, the differences ranged from 26% to 13.4%. Inaccurate results evidently would be obtained by using a constant to convert the point quadrat data to a % by wt. basis.—Auth. sum.

SREENIVASAN, P. S. 276
1943. Studies on the estimation of growth and yield of jowar by sampling. Indian Jour. Agr. Sci. 13(4): 399–412, illus.

A statis. analysis of the relation of plant characteristics of sorghum to yields, including methods of sampling.

STEINBERG, C., AND DASSOGNO, MIREILLE. 277
1957. Studio comparativo su alcuni metodi di rilevamento botanico per cotiche polifite. [A comparative study on some methods of botanical survey for mixed-species swards.] Ann. della Sper. Agr. [Rome] 11(3): 867–883. [Eng. sum.]

Six bot. survey methods were compared on 10 mixed-spp. swards. Visual estimation of coverage corresponded adequately with survey by wt.; this would justify using the former method when high precision is not required. The greatest number of spp. was found with the coverage method, followed by the wt. method on an av. sample. The frequency methods indicated the most important spp. with enough accuracy.—From auth. sum.

STODDART, L. A. 278
1935. Range capacity determination. Ecology 16: 531–533, illus.

A method is suggested for accurately measuring the stock carrying capacity of a western wheatgrass (*Agropyron smithii*) range in the mixed-grass prairie. It depends on a simple count of grazed and ungrazed wheatgrass stalks in regularly located quadrats.

VANKEUREN, R. W., AND AHLGREN, H. L. 279
1957. A statistical study of several methods used in determining the botanical composition of a sward: I. A study of established pastures. Agron. Jour. 49(10): 532–536.

Several methods for determining the bot. comp. of pasture swards were compared. They included the inclined point quadrat, vertical point quadrat, visual estimates of % comp. of the standing forage and of the green harvested material, and hand-separation. The hand-separation method was the standard. Areas measuring 2×2 ft. were chosen at random at 20 locations in each of 7 pastures of various mixtures of alfalfa, smooth bromegrass, Ladino clover, Kentucky bluegrass, white clover, and medium red clover. The inclined point quadrat method gave reliable and objective estimates of the bot. comp. of pasture swards. The visual estimation methods for deriving % comp. had greater variation than the point quadrat methods. Correction factors were calculated for the inclined point quadrat methods. The % of medium red clover was underestimated and that of Kentucky bluegrass was overestimated in these tests.—From auth. sum.

VOGEL, W. G. **230**

1961. Comparison of three range measurement techniques and response of native vegetation to protection from sheep grazing. (Unpublished thesis, Montana State Col., Bozeman) [Abs. in Jour. Range Mangt. 14(1): 55.]

The 0.75-in. loop method gave values for basal cover and bot. comp. closer to those with the dry-wt. method than the point-quadrat method that tended to underestimate grasses and sedges. The point quadrat method, however, overestimated and the loop method underestimated the forb group. Analysis of variance showed that *Artemisia frigida* was the only sp. showing a statistically significant response to mangt.; it increased under grazing.

WHITTAKER, R. H. **231**

1960. Estimation of net primary production of forest and shrub communities. Ecology 41(1): 177–180.

This estimation method involves: (a) community samples based on counts of trees in 0.1 ha. quadrats, with increment borings and ht. and age determinations, and also clipping of current twigs and leaves of smaller shrubs, (b) computation of estimated stem vol. growth for trees and larger shrubs, (c) analysis of individuals of major spp. to determine distrib. of current growth in different pts. of the plant, and correction factors from clipping wt. and stem vol. growth to total net prod., and (d) multiplication of the community measurements by these correction factors. Analysis of larger individuals of *Rhododendron maximum* gave correction factors of 3.99 for total net prod. (clipping wt. 3.29 g./cu. cm. for total net prod./estimated stem vol. growth).

WILLARD, DONALD R., AND SMITH, JOHN B. **232**

1935. Variability in measurements of height and width of market garden plants. Amer. Soc. Agron. Jour. 27: 798–799.

Products of ht. × width were more variable than either dimension alone, showing a tendency for tall plants to be wide. The 2 dimensions are not compensatory. The limit of nonsignificance is considered 3.3 × probable error.

See also **7, 46, 101, 115, 214.**

FORAGE ANALYSIS

CHEMICAL ANALYSIS AND FORAGE VALUE

BAUMGARDT, B. R. **233**

1959. Comparison and development of laboratory methods for forage evaluation. Diss. Abs. 20(4): 1147.

For determining the *in vitro* cellulose digestibility of forages, a method using rumen inocula is described. Using a regression equation, the digest. energy content of forages (in calories per g.) can be derived from the *in vitro* determinations.

BAUMGARDT, B. R., CASON, J. L., AND MARKLEY, R. A. **234**

1958. Comparison of several laboratory methods as used in estimating the nutritive value of forages. (Abstract.) Jour. Anim. Sci. 17(4): 1205.

The efficacy of several *in vitro* techniques for potential use in estimating nutritive value was studied with 11 forages (3 alfalfa and 8 grasses) of known digestibility as determined in conventional digestibility trials. Included in the studies: (1) Digestible Laboratory Nutrients, DLN (Agron. Jour. 47: 302, 1955) and (2) the prediction of TDN from anthrone carbohydrate digested *in vitro* (Jour. Anim. Sci. 14: 1239, 1955). Also used as lab. measures were cellulose and DM digest. as determined *in vitro* by the artificial rumen technique. Digest. trial values used as ref. guides included (1) TDN, (2) digest. calories per g. as well as digest. coefficients for (3) organic matter, (4) DM, (5) fiber, (6) cellulose, and (7) energy. Of the lab. methods used, cellulose digest. appeared the most closely related to the *in vivo* digestibility data. The correlation coefficients (r) of cellulose digest. *in vitro* versus the several *in vivo* values (as listed above) were: (1) 0.669*, (2) 0.726*, (3) 0.716*, (4) 0.811**, (5) –0.078, (6) 0.499, (7) 0.801**, respectively. Whereas the relation between *in vivo* and *in vitro* cellulose digest. was not significant when all forages were considered, it was highly significant (r=0.901**) for the grass hays. The relation between TDN estimated from anthrone carbohydrate digested *in vitro* and actual TDN was significant ($P < .05$). No significant relation was found between DLN (*in vitro*) and TDN (*in vivo*).

BAUMGARDT, B. R., CASON, J. L., AND TAYLOR, M. W. **235**

1962. Evaluation of forages in the laboratory. 1. Comparative accuracy of several methods. 2. Simplified artificial rumen procedure for obtaining repeatable estimates of forage nutritive value. Jour. Dairy Sci. 45(1): 59–68.

Eleven forages of known digestibility, as determined in conventional digestibility

trials with animals, were used to compare several lab. methods for estimating the nutritive value of forages. The artificial rumen method (*in vitro*) gave values for cellulose digestibility which were significantly correlated with the following components determined *in vivo:* TDN, digest. organic matter, digest. DM, digest. energy. The method described, a modification of the artificial rumen method, determines cellulose digestibility and gives results that are closely correlated with *in vivo* values for TDN, digest. DM, and digest. energy.—Herb. Abs.

BICKEL, H. 286
1960. Die berechnung des futterwertes von dürrfutter aus der chemischen analyse. [The determination of the feeding value of hay by chemical analysis.] Landw. Jahrb. der Schweiz [Bern] 9(7): 635–665. [In Ger. with Eng., Fr., and Ital. sum.]

Regressions are given for calculating the SE of oven- and air-dried hay from crude-fiber content and solubility of the CP fraction and for calculating the digest. CP content from the soluble or total CP content.

BRANCO, M. DE C. 287
1961. Forages: Yield per unit. Agricultura [Lisbon] 10: 7–10. [In Portug.]

The nutrient yield in relation to quantitative yield is discussed.

BREDON, R. M., AND HORRELL, C. R. 288
1962. The chemical composition and nutritive value of some common grasses in Uganda. II. The comparison of chemical composition and nutritive values of grasses throughout the year, with special reference to the later stages of growth. Trop. Agr. [Trinidad] 39(1): 13–17.

COOK, C. WAYNE, HARRIS, LORIN E., AND STODDART, L. A. 289
1948. Measuring the nutritive content of a foraging sheep's diet under range conditions. Jour. Anim. Sci. 7(2): [170]–180, illus.

Despite a great need on the west. range to understand nutrition probs., little is known as to the actual comp. of a grazing animal's diet. The many reasons for this lack include difficulties (a) in collecting representative samples of vegetation because of soil, site, and seasonal variations, (b) in finding what spp. and plant parts are actually consumed, and (c) in interpreting the nutritive content of the ingested forage. For determining the nutritive content of the diet of sheep under range conds. a method is presented which is an entirely new approach and based on chem. analyses of a predetermined no. of plant units collected before grazing and a similar no. collected after. Each plant sp. is sampled and each sample weighed and analyzed chemically. The difference in wt. and chem. comp. between the before-grazing sample and the after-grazing sample serves as a measure of the nutrient content of the ingested forage. Sheep were found to be highly selective in their diet and to consume largely leaves and tender stems, rejecting the more fibrous plant parts. Forage actually making up the diet is consequently much better in quality than chem. analyses of bulk sample would indicate.

DONEFER, E. 290
1962. Evaluating forages by *in vitro* methods. (Includes discussion by Pigden, W. J.) Canad. Soc. Anim. Prod. Proc. 1962: 34–43.

DONEFER, E., CRAMPTON, E. W., AND LLOYD, L. E. 291
1960. Prediction of the nutritive value index of a forage from *in vitro* rumen fermentation data. Jour. Anim. Sci. 19(2): 545–552.

DU TOIT, P. J., LOUW, J. G., AND MALAN, A. I. 292
1940. A study of the mineral content and feeding value of natural pastures in the Union of South Africa (final report). Onderstepoort Jour. Vet. Sci. and Anim. Indus. 14: 123–327.

See Herb. Abs. 7, p. 5, 1937, for earlier rpts. in this series. The work noted in Herb. Rev. 8: 189–194, 1940, is given in detail and includes an app. in which tables are presented giving the origin, date of collection, chem. comp. on a DM basis, and an approx. description of individual pasture samples from 18 areas in the Union.—Herb. Abs.

EDLEFSEN, JAMES L., COOK, C. WAYNE, AND BLAKE, JOSEPH T. 293
1960. Nutrient content of the diet as determined by hand plucked and esophageal fistula samples. Jour. Anim. Sci. 19(2): 560–567, illus.

Sheep with esophageal fistulae were grazed during winter 1956–57 on winter desert range. The vegetational cover consisted principally of *Artemisia nova, Atriplex confertifolia, A. nuttallii,* and *Eurotia lanata.* Also present were *Hilaria jamesii, Sporobolus*

cryptandrus, Oryzopsis hymenoides, Kochia vestita, Stipa comata, Chrysothamnus stenophyllus, Atriplex canescens, and *Salsola kali* var. *tenuifolia.* Chem. comp. differed little between fistula samples and samples obtained by handplucking except for ash and P content. But differences were significant for all forage constituents except either extr., CP, and cellulose. In 5 trials on mixed vegetation, the animals were able to keep the nutritive level of their diet constant by changing the plant spp. grazed. But in 2 trials on vegetation of 1 sp. only, the nutritive level of the diet gradually decreased as grazing progressed.

EL-SHAZLY, K., ABOU AKKADA, A. R., AND NAGA, M. M. A. **294**
1963. The use of the *in vitro* fermentation technique to estimate the digestible energy content of some Egyptian forages. II. The *in vitro* production of total volatile fatty acids and organic acids as criteria of energy content. Jour. Agr. Sci. [England] 61(1): 109–114.

For the nonlegume forages tested, the regression equations from volatile-fatty-acid data gave values for digest. energy per kg. of DM of forages similar to those from organic-acid data and more accurate than those from *in vitro* cellulose digest. (which are considered more accurate than TDN calculations). The digest. energy of legumes could not be estimated accurately by any of these methods.

FRANCOIS, A. **295**
1949. Erreur commise dans le calcul de la valeur fourragère d'un aliment composé en fonction des erreurs de l'analyse chimique. [Error in calculation of the forage value of a feed, as a function of the errors of chemical analysis.] Ann. Agron. [Paris] 19(3): 452–465.

The no. of "forage units" per kg. of product is calculated as follows: (1) $FU=COM\times C_a\times C_t$ where FU=no. of forage units per kg. of product, COM=crude organic matter in kg. per kg. of product, C_a=coefficient of digestibility, and C_t=coefficient of transformation in forage units. Let % organic matter $=COM$; %DM$=DM$; % mineral matter $=MM$; then $COM=DM-MM$, from which the forage value, $y=(d-m)\times c\times t$, and the relative total error will be: (2)

$$\frac{\Delta y}{y}=\frac{\Delta s+\Delta m}{s-m}+\frac{\Delta c}{c}+\frac{\Delta t}{t}.$$

Interpretations and discussion are presented as well as tables showing coefficients of digestibility and "coefficients of transformation in forage units."

GLOVER, J., DUTHIE, D. W., AND DOUGALL, H. W. **296**
1960. The total digestible nutrients and gross digestible energy of ruminant feeds. Jour. Agr. Sci. [England] 55(3): 403–408.

HARDISON, W. A. **297**
1959. Evaluating the nutritive quality of forage on the basis of energy. A review. Jour. Dairy Sci. 42(3): 489–500.

HELLMERS, HENRY. **298**
1940. A study of monthly variations in the nutritive value of several natural winter deer foods. Jour. Wildlife Mangt. 4: 315–325.

Samples of 8 spp. of woody plants browsed by deer were collected at monthly intervals and analyzed to detect variations in their comp. Marked differences were found, especially in protein, NFE, and crude fiber, all of which exhibited trends indicating reduction in nutritive value of the plants through the winter. A representative index to the nutritive value of winter browse may best be obtained by collecting material monthly and analyzing composite samples made by mixing the origin samples of each sp. in equal proportions. The samples should be collected at least in duplicate. This method tends to reduce errors that would be caused by fluctuations and seasonal trends. A few of the spp. analyzed compared favorably in chem. comp. with bluegrass and timothy; most spp. were inferior to these grasses.—Biol. Abs.

HUNDLEY, LOUIS R. **299**
1959. Available nutrients in selected deer-browse species growing on different soils. Jour. Wildlife Mangt. 23(1): 81–90.

In addition to comparison of results of proximate analyses run from Sept. 1954 through Oct. 1955 on 5 browse spp. growing on 4 study areas near Blacksburg, Va., minor elements determination for 1 mo. are reported. Present knowledge is insufficient to allow the use of proximate analyses as a basis for rating different plant spp. with regard to which provides the most nutritious browse for deer. Such analyses may, when accompanied by data regarding deer cond., be helpful in evaluating range conds.—Biol. Abs.

HUTTON, J. B. 300

1961. Studies of the nutritive value of New Zealand dairy pastures. 1. Seasonal changes in some chemical components of pastures. New Zeal. Jour. Agr. Res. 4(5/6): 583–590.

Herbage from a predominantly ryegrass/white clover pasture was sampled when 6–10 in. high through 1 growing season (Oct.-Apr.). The CP content was positively related to the ether extr. and negatively related to the crude-fiber content. The gross energy values for the herbage DM increased by 5–6% and were assoc. with an increase in the proportion of clover and in the CP content of the herbage during autumn. It was found that an accurate estimate of the calorific value of the herbage could be obtained from the CP and crude-fiber contents, especially if values were corrected for % of ash.—Herb. Abs.

IVINS, J. D. 301

1960. Digestibility data and grassland evaluation. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 459–461. [In Eng. with Eng., Fr., and Ger. sum.]

For grassland swards and treatments, comparison of total digest. organic matter (or its constituents) is said to be fundamentally more valid than comparison of animal prod. data.

KIELANOWSKI, J., ZIOLECKA, A., AND OSINSKA, Z. 302

1962. Equations for reciprocal conversions of starch equivalent and total digestible nutrient values. Canad. Jour. Anim. Sci. 42(2): 211–214.

LAMB, K. P. 303

1957. Quantitative microanalysis of leaf tissue for certain organic constituents with special reference to sampling error. New Zeal. Jour. Sci. and Technol. Sect. B 38(9): 1009–1017.

Procedures are given for quantitative estimation of total N, amino N fractions, and soluble carbohydrates in microgram amounts in discs of leaf tissue weighing approximately 5 mg. (fresh) or 1 mg. (dry). Statistical aspects of sampling and analyt. errors are considered.—Herb. Abs.

LEFEVRE, C. F., AND KAMSTRA, L. D. 304

1960. A comparison of cellulose digestion *in vitro* and *in vivo*. Jour. Anim. Sci. 19(3): 867–872.

Cellulose digestibility in 22 samples of alfalfa silage, alfalfa hay+oats, and prairie hay was determined with an artificial rumen technique and compared with that obtained in digest. trials with sheep. Coefficients of cellulose digest. were similar to those obtained using sheep after 48 hrs. digest. *in vitro*, but not after 24 hrs. *in vitro*. The correlation coefficient for the 22 samples was 0.397, and for 16 of the samples it was 0.841. Results were similar for cattle rumen fluid and sheep rumen fluid.

LOFGREEN, G. P. 305

1951. The use of digestible energy in the evaluation of feeds. Jour. Anim. Sci. 10(2): 344–352.

A method is described for calculating the TDN value of feeds from the energy digest. coefficient. The conversion factor is calculated by the formula:

$$F=\frac{OM}{100}\times\frac{100+1.25EE}{100}$$

where *OM* represents the % organic matter in the feed and *EE* represents the % ether extr. in the organic matter. The TDN value is determined by multiplying the energy digest. coefficient by *F* and should more accurately measure energy value of a feed or ration than TDN determined by the conventional method.

MCCULLOUGH, M. E. 306

1954. The use of T.D.N. in forage comparisons. Jour. Range Mangt. 7(3): 129–130, illus.

Calculated or determined TDN values of forages are not always accurate criteria of forage value. Using TDN intake as the dependent variable and animal prod. as the independent variable, multiple regressions were fitted and multiple correlation coefficients determined for forages of different qualities. *R* for forages of less than 65% digestibility was 0.408; for 65–70%, 0.791; above 70%, 0.886.

MILFORD, R. 307

1960. Criteria for expressing nutritional values of subtropical grasses. Austral. Jour. Agr. Res. 11(2): [121]–137, illus.

The results from digestibility expts. made with 17 different subtropical grasses are

discussed. The most suitable criteria for expressing nutritional values are CP content, CP digestibility, N balance, DM intake, and DM digestibility. Feeding standards based on SE and TDN which are used in temperate environments are highly inaccurate when appl. to these subtropical spp. Large seasonal fluctuations occur in the nutritional value of subtropical grasses. At the ht. of the summer growing season values are very high and adequate for all forms of animal prod. In the winter and early spring the grasses are generally of poor quality and are unable to meet the requirements for producing livestock. At this time the CP content and CP digestibility are low. Animals are also unable to obtain sufficient energy because the DM intakes and DM digestibilities of the grasses are low. The very low nutritive values obtained during winter and early spring usually occur after grasses have been killed by frost. Frost resistance is therefore an important criterion in selecting subtropical grasses which will maintain high nutritional values throughout the entire yr.—Auth. sum.

NAGA, M. M. A., AND EL-SHAZLY, K. **308**
1963. The use of the *in vitro* fermentation technique to estimate the digestible energy content of some Egyptian forages. I. The *in vitro* digestion of cellulose as a criterion of energy content. Jour. Agr. Sci. [England] 61(1): 73–79. [*See* **294** for abs.]

NEAL, W. M. **309**
1941. Present knowledge of the nutritional value of grassland herbage. Amer. Soc. Agron. Jour. 33(7): 666–670.

Gives the known nutrients supplied by grassland herbage, and considers methods of evaluation and factors affecting nutrient value.

OHSHIMA, M., AND TASAKI, I. **310**
1962. Studies on the composition and nutritive value of forage grass by means of structural analysis. VI. Jap. Jour. Zootech. Sci. 33(4): 313–319. [In Jap. with Eng. sum.]

QUICKE, GEORGE V., BENTLEY, ORVILLE G., SCOTT, HAROLD W., AND MOXON, A. L. **311**
1959. Cellulose digestion *in vitro* as a measure of the digestibility of forage cellulose in ruminants. Jour. Anim. Sci. 18(1): 275–287.

The digestibility of the cellulose in 7 grass hays and 6 legume hays was determined by an *in vitro* rumen technique using inocula obtained from a steer, and in digest. trials with sheep. No significant difference was observed between results obtained *in vitro* and *in vivo* with grass hays, but in some of the legume hays, cellulose digestibilities, as measured by the 2 methods, were significantly different. Results obtained with the *in vitro* technique showed good reproducibility and, in general, variances were less than those calculated for the corresponding sheep trial data. In an expt. in which different forages were fed to a steer used as a source of inoculum, the digestibility *in vitro* of the cellulose in these forages was not affected by the type of forage fed the steer. Little difference was noted when cellulose digest. was measured using strained rumen juice, a phosphate buffer extr. of pressed rumen contents or resuspended ruminal microorganisms as inoculum. Possible use of the *in vitro* technique as a tool in the evaluation of the nutritive value of forages is indicated.—Auth. sum.

RAYMOND, W. F. **312**
1951. The problem of measuring the nutritive value of herbage. Brit. Grassland Soc. Jour. 6(3): 139–146.

The importance of methods of measuring the feeding value of herbage, without recourse to digestibility expts., is evident. Because the most promising approach seems in the use of relations between the digestibility and chem. comp. of herbage, it is important to know the possible errors in determining either. Differences in the chem. analyis of samples at different centers are likely to be large because of variations in methods of drying, grinding, and chem. analysis. Digestibility may be modified by a number of factors, and should not be looked on as a constant for a given herbage feed. In view of the variability shown, the validity of regressions which do not recognize or correct for it can be questioned. A thorough study of the prob., especially in relation to the grass crop, is recommended. The limitations of present methods of converting digestibility data to net energy units are noted. The complication that may be introduced by selective grazing may be approached via the chem. analysis of the feces. The same factors must be considered as in herbage analyses.

RIGNEY, J. A., AND BLASER, R. E. **313**
1948. Sampling Alyce clover for chemical analyses. Biometrics 4(4): 234–239.

For Alyce clover, *Alysicarpus vaginalis*, duplicate determinations made on each of

2 field samples from 3 replications of 5 fertilizer treatments enabled estimating of variance due to plots, samples, and chem. determination. Estimates were obtained for % of P, K, Ca, and Mg in the clover hay. The accuracy of treatment means involving different nos. of plots, samples, and determinations was examined. Relative costs for the 3 phases of the procedure were estimated, and the cost per unit of inform. was computed for the various schemes under study. The optimum ratio of plots to samples to determination was calculated for a constant variance of the mean. In general, the relatively high cost and low variance of the lab. determination require that this pt. of the technique be reduced to a minimum. The optimum ratio of total samples to total determination per treatment varied from 4 for Mg to 16 for K. Except for the unusually low plot-to-plot variance of Mg, the optimum no. of samples per plot ranged from 2 for P to 4 for Ca.

SAITO, M., OHSHIMA, M., AND KIBE, K. **314**
1959. Studies on the composition and nutritive value of forage grass by means of structural analysis. III–IV. Jap. Jour. Zootech. Sci. 30(2): 84–90; 109–112. [In Jap. with Eng. sum.]

SHELTON, D. C., AND REID, R. L. **315**
1960. Measuring the nutritive value of forages using *in vitro* rumen techniques. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 524–528. [In Eng. with Eng., Fr., and Ger. sum.]

The methods and limitations of different *in vitro* systems of evaluating the nutritive value of forages are considered, and the need for such systems to conform to certain criteria of validity is suggested. High degrees of correlation have been demonstrated between digestibility coefficients determined *in vitro* and corresponding factors from conventional digest. trials with cattle or sheep.

SULLIVAN, J. T. **316**
1962. Evaluation of forage crops by chemical analysis. A critique. Agron. Jour. 54(6): 511–515.

In this rev., the proximate scheme of analysis is considered obsolete and, from the viewpoint of the agronomist, replaceable by estimates of lignin, CP, and moisture content of the standing crop. Although limitations in the lignin method include tediousness and low precision, and the relation between lignin content and DM digestibility varies among spp., particularly between grasses and legumes, there are strong theoretical grounds for using lignin rather than crude fiber as a criterion of forage quality.

SWIFT, R. W. **317**
1957. The caloric value of TDN. Jour. Anim. Sci. 16(4): 753–756.

A study of data on digest. energy and TDN in 312 digest. expts. revealed that 1 lb. of TDN equals 2,000 calories of digest. energy. This value applied to sheep and cattle on roughage alone and to cattle on mixed rations.

TAYLOR, BILLIE G., REPP, W. W., AND WATKINS, W. E. **318**
1960. An artificial rumen technique versus conventional digestion trials for determining digestibility of blue grama, Sudan and alfalfa hays. Abstract.) Jour. Anim. Sci. 19(3): 971.

Cellulose digestibility differed significantly among hays. It also differed significantly between measurements with an artificial-rumen technique and digestibility trials in sheep:

Hay:	*Artificial-rumen technique*	*Trials in sheep*
Blue grama (*Bouteloua gracilis*)	60.7 ± 1.25	66.82 ± 1.9
Alfalfa	60.68 ± 1.22	59.88 ± 4.02
Sudan grass (*Sorghum sudanense*)	57.32 ± 0.97	63.84 ± 5.83

THOMAS, BRYNMORE, AND ARMSTRONG, D. G. **319**
1952. Nutritive value of common heather (*Calluna vulgaris*). I. Preparation of samples of *Calluna vulgaris* for analytical purposes and for digestibility studies. Jour. Agr. Sci. [England] 42(4): 461–464.

An effort was made to devise a sampling procedure to obtain the portion of the heather plant grazed by sheep. Methods discussed include both hand clipping and mechanical means. No evidence of impairment of digestibility by ovendrying for 24 to 48 hrs. at 38° C. was obtained.

TILLEY, J. M. A., DERIAZ, R. E., AND TERRY, R. A. 320
1960. The *in vitro* measurement of herbage digestibility and assessment of nutritive value. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 533–537, illus. [In Eng. with Eng., Fr., and Ger. sum.]

The digestibility of herbage DM was evaluated by an *in vitro* procedure in which anaerobic fermentation with rumen liquor was followed by digest. with acid pepsin. The reproducibility of the method was studied, together with its correlation with the known *in vivo* digestibilities of the herbages studied. Data are given of the proportions of volatile fatty acids in the rumen of sheep fed different herbages, together with their contents of soluble carbohydrates. For estimating relative nutritive values for growth, milk, or meat prod., of herbages differing in their digestive constituents, it is concluded that a study of the volatile fatty acid prod. may be of value.

TILLEY, J. M. A., TERRY, R. A., DERIAZ, R. E., AND OUTEN, G. E. 321
1961. *In vitro* digestion of herbage. Hurley Grassland Res. Inst. Expts. Prog. (1959–60) 13: 75–76.

In vitro determinations of herbage digestibility are shown to be highly reproducible and to compare closely with *in vivo* determinations over the range of 45–85% digestibility. *In vitro* determinations of the digestibility of constituents of Du Puits lucerne herbage on 6 occasions during the growing season showed that the fig. for leaf remained constant at 81–83% while that for stem dropped from 85% in Apr. to 56% in June. Further data reported show that there is a greater reduction in the digestibility of lucerne stem from the top to the bottom of a stem than between similar stem sections of a young and a mature plant.—Herb. Abs.

See also **1, 7, 28, 366, 587, 588, 664, 668.**

DRY WEIGHT AND DRY MATTER DETERMINATION

AGERBERG, L. S. 322
1957. Bestämning av höprocent i vallförsök. [Determination of "hay percentage" in grassland research.] Uppsala Lantbrhögsk. och Statens Lantbrförsök. Statens Jördbrförsök., Meddel. 87, 24 pp., illus.

At this farm in north. Sweden an exploratory study was made into the technique of sampling herbage, with special ref. to rate of drying. This rate varies widely but under favorable circumstances water content can be reduced by up to 6–7% per hr., and the process is especially rapid during the first 30 mins. or so after mowing. Normally, the greatest degree of uniformity is achieved by sampling immediately after mowing. During the ht. of summer, air-drying of hay samples can be done satisfactorily. But with large samples, in poor weather, or for autumn aftermath, air-drying must be supplemented by determination of DM content, which should be obligatory whenever water content appreciably exceeds 15%. A method for sampling immediately after mowing is outlined, small plastic bags being used to prevent evaporation in the samples. After weighing the fresh samples, choice has to be made between determination of DM content or some form of drying. In general a certain amount of predrying is to be recommended. The successful results achieved by artificial drying are noted.—Herb. Abs.

BAILEY, P. H., HUGHES, M., AND MCDONALD, A. N. C. 323
1957. Differential loss of dry matter in the laboratory grinding of dried herbage samples. Brit. Grassland Soc. Jour. 12(3): 157–165.

Compared to hot-air-drying, freeze-drying of herbage samples in tests with commercial green-crop driers resulted in apparent losses of CP and β-carotene. Experiments on lab. technique in drying, milling, and analyzing herbage samples showed a bias in conventional lab. hammer mills towards loss of high-protein particles. While this differential loss was particularly marked for the freeze-dried material, it was also significant for ovendried material. A lab. mill is needed that will disintegrate samples without loss of milled material and without undue temp. rise when used at the same rate as existing lab. hammer mills.

BARTLETT, M. S., AND GREENHILL, A. W. 324
1936. The relative importance of plot variation and of field and laboratory sampling errors in small plot pasture productivity experiments. Jour. Agr. Sci. [England] 26: 258–262.

An invest. was made of the relative importance in small plot pasture productivity expts. of plot variations and of field and lab. errors in sampling and subsampling for % DM and % N. Duplicate sampling and subsampling showed little advantage in reducing the expt. error, which was due mainly to plot variation. Sampling errors were even less important in estimation of actual yields of DM or N.

BLOUARD, R., AND DESCHUYTENER, G. 325
1962. Sampling in grasslands by the "dry weight" method; statistical results and practical importance. Gembloux Inst. Agron. de l'État Bul. 30(1/2): 8–29. [In Fr.]

COOPER, C. S., HYDER, D. N., PETERSEN, R. G., AND SNEVA, F. A. 326
1957. The constituent differential method of estimating species composition in mixed hay. Agron. Jour. 49(4): 190–193.

A method is presented for determining the spp. comp. by wt. of a 2-component forage mixture in which components differ in concentrations of the same constituent. Dry matter, Ca, and CP were used to estimate the bot. comp. of a clover/grass mixture. Measurements were made of the constituent concentrations of a large sample from each plot and of the spp. components from small samples taken at random from plots treated alike. The spp. comp. of the large sample was then calculated using formulae. The method was more efficient than hand separation, at least when DM was measured. —From auth. sum.

GREENHILL, W. L. 327
1960. Determination of the dry weight of herbage by drying methods. Brit. Grassland Soc. Jour. 15(1): 48–54.

The objeet of this invest. was to find a satisfactory method for use in determining the dry wt. of air-dry herbage. In 1 expt., drying was carried out at various temps. over P_2O_5 and also at a sustained high vacuum; in a 2nd expt., ovendrying was carried out at atmospheric pressure at various temps. and for various periods. Decomposition was found at comparatively low temps. while, on the other hand, the intensity with which some of the moisture was held suggested that not all is removed at "safe" temps., even at low vapor pressures. The technique now suggested as best is drying over P_2O_5 at 40° C. For less accurate results, ovendrying at atmospheric pressure at 80° C. for 16 hrs. is proposed.

HUNTER, R. F., AND GRANT, SHEILA A. 328
1961. The estimation of "green dry matter" in a herbage sample by methanol-soluble pigments. Brit. Grassland Soc. Jour. 16(1): 43–45.

To estimate what proportion of total DM of a herbage sample arises either from dead or green herbage, 4 methods have been compared. One of these, the pigmentation method, is described.

ISAACS, G. W., AND WIANT, D. E. 329
1959. An averaging-type meter for measuring the moisture content of hay in the windrow. Mich. Agr. Expt. Sta. Quart. Bul. 41(3): 608–613, illus.

The moisture meter described measures the av. elect. resistance at a large no. of points in the window under test, and gives a quicker and less variable estimate of the av. moisture-content of hay than the orthodox sampling technique.

MCROSTIE, G. P., AND HAMILTON, R. I. 330
1927. The accurate determination of dry matter in forage crops. Amer. Soc. Agron. Jour. 19: 243–251.

Neither green wts. nor the yield of field-cured hay are reliable as a basis of comparison in test plots. While computing yields from loss of moisture in shrinkage samples dried to a constant wt. is reliable for detecting reasonably large differences, it still possesses an appreciable variable factor. Before shrinkage samples held for air drying are finally ovendried, there is an appreciable and variable loss of DM. The immediate drying of shrinkage samples appears to offer the most accurate criterion for comparative tests.

MINSON, D. J., AND LANCASTER, R. J. 331
1963. The effect of oven temperature on the error in estimating the dry matter content of silage. New Zeal. Jour. Agr. Res. 6(1/2): 140–146.

MITCHELL, G. E. 332
1957. Methods of determining dry matter of fresh forages and silages. (Abstract.) Jour. Anim. Sci. 16(4): 1089.

The following methods were used for determining the DM content of 5 lucerne/maize grain (ground, shelled) mixtures both before and after ensiling: toluene distillation, drying under vacuum at 95° C., drying in an oven at 105° C., and drying in an air-blast cabinet at 46° and 54° C. The silage mixtures were made from lucerne +0%, 5%, 10%, 20%, and 40% ground, shelled maize. There were no significant differences between any of the methods of determination, except for the silages con-

taining 10% maize meal, with which vacuum drying resulted in significantly lower DM readings than drying in an air-blast at 46° or 54° C. The toluene method appeared to have no advantages over the other methods used.—Herb. Abs.

RAYMOND, W. F., AND HARRIS, C. E. 333
1954. The laboratory drying of herbage and faeces, and dry matter losses possible during drying. Brit. Grassland Soc. Jour. 9(2): 119–130.

Preliminary studies on drying tray size, cond. of herbage sample, etc., indicated probability of DM losses during some forms of ovendrying. From these results the Unitherm oven was designed. Using the Unitherm oven, 5% of the DM in herbage was lost in warm-air drying, and over 1% in drying in another oven. Using a radio-frequency oven, an av. of 1% of the DM of herbage dried in the Unitherm oven when full was lost. This loss can be minimized by intelligent use of the oven. Similar losses of DM have been shown during ovendrying of wet feces. A loss of 5–10% of the N in feces on ovendrying at 100° C. has been found. The possibility of losses during drying must be considered in relation to overall expt. accuracy, and imprs. made in DM determinations where necessary.

SAVAGE, R. G. 334
1949. Moisture determinations in the comparative testing of forage crops for hay yield. Sci. Agr. [Ottawa] 29(7): 305–329.

From 19 var., strain, or spp. tests in which one 1.5-lb. moisture sample had been taken per plot, yield data were compared on a dry wt. and a green wt. basis for rank of the varieties and statis. significance. Where tests did not include markedly different vars. or spp., ranking and level of significance were essentially the same on a green wt. basis as on a dry wt. basis. To reduce green yields to a dry or hay wt. basis for interyear comparisons, it was concluded that for such tests several random moisture determinations would be sufficient. For tests with more than one spp. or for single sp. tests with markedly different vars., fairly complete moisture sampling was found essential. This was done in 3 tests by taking duplicate 0.75-lb. and 1.5-lb. samples and triplicate 0.5-lb. samples from each plot. The smaller 0.5 and 0.75 lb. samples gave significantly different DM percentages than the 1.5-lb. samples and were more variable. In 1 test one 1.5-lb. sample per plot was as efficient as three 0.5-lb. samples. Use of more than one 1.5-lb. moisture sample per plot was found unjustified. In the 3 tests, sampling every plot in the tests was no more reliable than sampling on the basis of one 1.5-lb. sample per plot in 2 random replicates and averaging the 2 determinations for each var. or treatment.

VRIES, P. DE. 335
1957. Verband tussen het drooggewicht, het versgewicht en de groeistadia van drie grassoorten en variëteiten. [The relationship between dry weight, green weight, and growth stages of three species and varieties of grass.] Wageningen Inst. v. Biol. en Scheik. Onderz. van Landbgewassen. Jaarb. 1957: 155–158, illus. [Eng. sum.]

Three grasses were grown in pots in a glasshouse and harvested at intervals of about 5 days. They were an early *Festuca rubra,* a leafy and late pasture var. of *Lolium perenne,* and a less leafy, early, hay-type var. of *L. perenne.* In the relationships between green- and dry-wt., the data range along straight lines. The 1st line indicates a constant ratio between green- and dry-wt. during the 1st period. The transition to the 2nd line coincides with the time of emerging and occurs when the growing point is in the double-ridge stage. This 2nd line indicates that the water content decreases with increasing dry wt. The time of emerging of *Festuca rubra* fell before the 1st harvesting data. The earlier the grass emerges, the shorter the period of constant water content. The 2nd transition with the hay type *Lolium perenne* occurred when the mass of the ears appeared. The other plants did not reach this stage.—Herb. Abs.

WEIHING, RALPH M. 336
1942. Green and air-dry weights for determining hay yields of varieties of alfalfa. Amer. Soc. Agron. Jour. 34(10): 877–882.

The % DM in a no. of vars. of alfalfa was determined in the green forage and in the forage air-dried under cover. The no. of vars. or strains was 5 in 1 expt. and 55 in the other. There were 25 plots of each var. in the former and 2 in the latter. All vars. were grown in nursery plots. Data are reported on 4 cuttings; 1 in 1938 and 3 in 1939. The data show that some vars. and replications differ in % DM at the time of cutting and that the % DM in samples air-dried under cover for several wks. was nearly equal in all vars. The % DM in green alfalfa evidently varies sufficiently between some vars. at the time of cutting to make forage yields based on green wts. inaccurate. Green wts. should be reduced by plot to ovendryness, to an exact % of DM, or to air-dryness. Forage yields of alfalfa vars. based on samples or plots air-dried under cover are nearly

as accurate as those based on ovendry wts. For comparisons between cuttings or between yrs., air-dry forage yields should be reduced to a definite % of DM.—Biol. Abs.

WILLEY, L. A., AND DENT, J. W. 337
1958. Note on a method for sampling green crops for dry-matter determination. Empire Jour. Expt. Agr. 26(104): 379–381, illus.

Dry-matter determinations for crops such as kale, silage maize, and rape are often made on samples consisting of only 1–2% of the plot yield, thus involving considerable sampling error. A method is described in which all the green material from a given plot is passed through a mechanical chopper before sampling. The method is rapid and gives samples which are highly representative, even for those crops which show wide variations in the comp. of different pts. of the plant. The chopped sample material is also in a form very suitable for ovendrying.—Herb. Abs.

See also **15.**

SITE RELATIONS

EFFECTS OF COMPETITION

ASPINALL, D., AND MILTHORPE, F. L. 338
1959. An analysis of competition between barley and white persicaria. I. The effects on growth. Ann. Appl. Biol. [London] 47(1): 156–172, illus.

Barley and white persicaria (*Polygonum lapathifolium* L.) were grown in pure and mixed populations of varying density in sand culture in a greenhouse. The leaf areas and dry wts. of leaves, stems, and roots were determined at intervals. During the phase of vegetative growth the addition of DM by barley was unaffected, although tillering was reduced, by competition from dense stands of white persicaria, whereas the growth of white persicaria was reduced by low densities of barley. The decline in leaf area and reduction in root growth of barley with the onset of flowering was accompanied by increased growth of white persicaria with the prod. of branches from the upper axillary buds. These flowered and set abundant seed. This behavior probably accounts for the persistence of this weed in arable rotations. The greater competitive ability of barley may be attributed to its larger embryo, giving much larger plants at emergence. The intrinsic relative growth rate of white persicaria is as high as, or higher than, that of barley and falls more slowly with time. This advantage is not sufficient to offset the initial differences in size while barley is vegetative. The larger embryo size of barley also determines the more intense competition that exists between plants of this sp. than between plants of white persicaria at similar densities and times from germination. With equal wts. of prod. per pot (or unit area) the intensity of competition within each sp. appears to be similar. It is emphasized that the course of growth with time, rather than wt.-density relationships at given points of time, must be followed in order to understand the influence of density. Two functions of the relative growth rate with time are examined.—Auth. sum.

DONALD, C. M. 339
1951. Competition among pasture plants. I. Intra-specific competition among annual pasture plants. Austral. Jour. Agr. Res. 2(4): [355]–376, illus.

A series of expts. was conducted to examine the influence of density, stage of growth, and fertility level on intraspecific competition among ann. pasture plants. At sowing there is a linear relationship between density and yield (wt. of embryos or embryo+endosperm per unit area). Competition is evident in dense populations shortly after germination and thereafter becomes operative progressively in populations of lower and lower density. Because of the extreme reduction in growth rate in dense swards later in the season and the high growth rate in sparse swards, the sparse sward tends to approach the more dense sward in its final yield. Final yield of DM is constant from moderate to high densities. There is no reduction in DM per unit area even in extremely dense swards. This maximum yield of DM for the environment is controlled by some factor of the environment. It is considered that N was the factor in 2 of the expts. here reported and light in the 3rd. The significance of light in competition in pastures is discussed. Practical appls. of these findings are discussed.—Auth. sum.

DONALD, C. M. 340
1954. Competition among pasture plants. II. The influence of density on flowering and seed production in annual pasture plants. Austral. Jour. Agr. Res. 5(4): [585]–597, illus.

Inflorescence and seed prod. were studied in swards of varying density of 2 ann. Mediterranean pasture plants, *Trifolium subterraneum* L. and *Lolium rigidum* Gaud., each in pure culture. While the maximum level of DM prod., achieved at moderate

densities, was maintained at all higher densities, seed prod. showed a peak at moderate densities and thereafter a progressive decline. The greatest no. of inflorescences was produced at densities exceeding those of peak seed prod. Although the most widely spaced plants had the greatest nos. of inflorescences and seeds per plant, they had smaller seeds and fewer seeds per inflorescence than did substantially denser swards, apparently owing to intense intraplant (inter-inflorescence) competition at the widest spacings. It is suggested that the results can be explained in terms of the changing competitive relationships between and within the plants of the sward at the times of initiation of flower primordia, of floral devlpmt., and of seed prod. Dense swards give most of the attributes needed in the use of these plants for grazing purposes; for seed multiplication swards of moderate densities give the highest yields of seed per unit area.—Auth. sum.

HOZUMI, KAZUO, ASAHIRA, TADASI, AND KIRA, TATUO. **341**

1956. Intraspecific competition among higher plants. VI. Effect of some growth factors on the process of competition. Osaka Univ., Inst. Polytech. Jour. Ser. D 7: 15–33.

Several garden vars. of vegetable crops were grown in pots or box frames under controlled conds. and the effects of soil moisture, soil depth, and fert. supply upon the process of intraspecific competition were analyzed. The results in terms of av. plant wt. and av. yield/unit area were first examined by the analysis of variance. The conclusions reached were as follows: (a) In all the expts. except 1, the 3 factors exerted promotive effect on av. plant wt. Interactions between them were mostly significantly positive, whereas negative interaction prevailed between the factors and plant density. That is, the promotive effect of the factors on plant growth is reduced towards higher density. (b) The yield/area tended to be more or less constant regardless of the difference in density, although the 3 factors significantly increased the yield. (c) The responses of top-to-root ratio to the factors in root vegetables differed according to the kind of plants and factors. (d) Relative variation of plant wt. was fairly constant on all plots in the turnip and radish expt. Functional analyses of the expt. results proved that the competition-density effect formula, $wp^a=K$ or $w=Ks^a$, was always satisfied by av. plant wt. (w), plant density (p), and mean available space/plant ($s=1/p$). It was noted that the values of C-D index (a) were approx. constant in the same expt. regardless of the difference in treatments. In other words, the $\log w \sim \log p$ regressions were represented by a group of nearly parallel lines, each corresponding to a particular combination of factor supply. This fact indicates that, contrary to the conclusion reached by the analysis of variance, there is no interaction between the effect of density and that of factor supply, when the former is interpreted by the C-D effect law. Further it was found that similar hyperbolic relations as the C-D effect equation always existed between w and the supply of a factor (f), or that $w=Kf^a$. Either accelerative or antagonistic interactions between the 3 factors became apparent when the expt. results were analyzed by this equation. Based on these results, the causes of the C-D effect and the law of constant final yield were discussed.—Auth. sum.

HOZUMI, KAZUO, KIRA, TATUO, AND SHINOZAKI, KICHIRO. **342**

1958. Effect of light intensity and planting density on the growth of *Hibiscus moscheutos* Linn., with special reference to the interaction between two linear factors of growth. Physiol. and Ecol. [Japan] 8(1): 36–49. [In Jap. with Eng. sum.]

The growth of young rose mallow plants was analyzed under 18 different conds. of light intensity and plant density. Seeds were sown on May 28, 1957, in china pots, and after 2 wks. light intensity was regulated with lath frames. Average dry wt. of each plant was recorded 28, 42, 49, 56, and 63 days after planting. Light intensity proved to be a linear factor. Mean available space was also a linear factor, whereas density may be called the reciprocal factor. Formulae for these various relations, related formulae, and implications are discussed.

IWAKI, HIDEO. **343**

1958. The influence of density on the dry matter production of *Fagopyrum esculentum*. Jap. Jour. Bot. 16(2): 210–226.

The influences of planting density on the DM prod. in a plant community were investigated on the basis of field expts. with buckwheat in 1954 and 1955. Buckwheat plants were planted in regular sq. disposition, and 3 different grades of spacing (5 cm., 10 cm., and 20 cm.) were employed. Sampling was made at intervals of 7 days for 2 mos. in each plot. The dry wts. of leaves, stems, roots, and reproductive organs and the total leaf area of the plants were measured. Variations of the net assimilation rate (NAR) with time were determined for each buckwheat stand. From the results, it was indicated that the NAR diminishes with increasing density of stand, at least in the earlier stages of devlpmt. The maximum assimilation of buckwheat leaves in densely

planted stands was found to be lower than that in stands with lower densities. The C/F ratio, the ratio of the nonphotosynthetic systems (stems, roots, and reproductive organs) to the photosynthetic system (leaves) was calculated for each plot. It was shown that the C/F ratio tends to become higher with increasing density in the earlier stages of growth, but in the later stages, no apparent correlation between C/F ratio and density was observed. From the analytical consideration with regard to the DM prod. in buckwheat stands, it was concluded that the higher values of NAR of the widely spaced stands are due mainly to (1) the higher relative light intensity in the plant community, (2) the higher rate of photosynthesis of the leaves, and (3) the lower value of the C/F ratio than that of the closely spaced stand. The DM prod. of buckwheat plants was calculated indirectly from the daily assimilation and respiration, and the growth curve of the standing crop was constructed theoretically for each stand. The results of the calculation agreed well with those of the direct determination. The agreement of these values indicates that the growth curve of a plant community can be composed indirectly by the calculation of DM prod. and reproduction in the community.—Auth. sum.

KIRA, TATUO, OGAWA, HUSATO, HOZUMI, KAZUO, AND OTHERS. 344
1956. Intraspecific competition among higher plants. V. Supplementary notes on the C-D effect. Osaka Univ., Inst. Polytech. Jour. Ser. D 7: 1–14. (Koyama, Hirosi, and Yoda, Kyoji, joint auth.)

Some new knowledge about the C-D effect law was presented which is summarized as follows. Related formulations concerning the density effect in plant populations which appeared prior to our study were discussed. They are essentially the same in their math. representation as our C-D effect law, but more restricted in their scope and applicability. It was proved by several expts. that the C-D effect likewise held true not only in regularly dispersed populations but also in linearly planted and even in irregularly dispersed populations. The influence of the reduction of density during growth due to self-thinning upon the C-D effect was considered. Examples of the C-D effect in natural pure communities were presented with discussions as to the fundamental conds. necessary for the satisfaction of the law. It was found both experimentally and theoretically that the effect of density on the yield of a certain pt. of plant body could also be described by the C-D effect equation, only if the growth of this particular pt. is prescribed by the law of allometry (relative growth). Values of the constant of relative growth calculated from various expt. results were comprised in a table and discussed.—Biol. Abs.

KNIGHT, W. E., AND HOLLOWELL, E. A. 345
1959. The effect of stand density on physiological and morphological characteristics of crimson clover. Agron. Jour. 51(2): 73–76, illus.

In 1953–57, crimson clover (*Trifolium incarnatum*) sown in the 3rd wk. of Sept. in each yr. produced earlier autumn and winter growth and greater forage yields when grown in dense stands than in thin stands. In Nov., 1955, clover plants spaced 0.75 in. apart were about 5 in. high, while those spaced 6 in. apart were about 0.7 in. high. In Dec., 1956, the 0.75 in. spacing produced 10,634 lbs. green matter/acre, with a DM content of 18.3%. The 6 in. spacing did not produce a similar yield until the following Mar. The nos. of seed heads per plant averaged 1.1 and 15.7 for the 0.75- and 6-in. spacings, respectively, and the nos. of stems per plant 1.5 and 18.7. Seasonal variation apparently affected ht. at maturity and no. of florets per head as much as did stand density. Dense clover stands were damaged by *Sclerotinia trifoliorum* when the forage was not clipped. In 1956–57, clipping controlled the disease during the growing season. Clipping reduced total dry-forage yields by an av. of 609 lbs./acre and seed yields by an av. of 89 lbs./acre. Forage from the clipped plots was of much higher quality than that from the unclipped plots.—Herb. Abs.

KOYAMA, HIROSI, AND KIRA, TATUO. 346
1956. Intraspecific competition among higher plants. VIII. Frequency distribution of individual plant weight as affected by the interaction between plants. Osaka Univ., Inst. Polytech. Jour. Ser. D 7: 73–94.

Attempts were made to estimate the nature of interaction between individuals in a population indirectly from the types and time trends of the frequency distribs. of individual plant wt. Experimental evidence has shown that the types of wt. distrib. are approx. normal or Gaussian in the seed and young seedling stage, but that the mode of frequency curve is gradually biased from the central class to the left as plants grow. Sometimes the final distrib. is represented by a kind of L-shaped frequency curve having the mode at the left end class. In many cases, the appearance of the final L-shaped distrib. is promoted by increasing plant density. By assuming a simple math. model, it was shown that these particular types of frequency curve most probably belonged to the lognormal distrib., which is the natural outcome of the exp. nature of

fundamental growth process. The competitive interaction between plants was found to increase the variability of relative growth rate among individual plants and as the result to promote the appearance of L-shaped frequency curve. Close correlation between high density, competitive interaction, L-shape distrib. of plant wt., and high mortality of plants due to self-thinning was discussed based on both theoretical and expt. evidences. These results show that the frequency distrib. of plant wt. can serve as an indirect indicator of the processes of individual level going on within a population. Finally it was emphasized that the processes of populational level, as represented by the density effect laws concerning the av. plant yield/population, are independent to the processes of individual level. This fact may be of great importance in asking for what is meant by the difference of levels in biol. researches.—Auth. sum.

KRAMER, H. H., AND DAVIS, R. L. **347**

1949. The effect of stand and moisture content on computed yields of alfalfa. Agron. Jour. 41(10): 470–473.

Stand and yield relation was determined for 30 vars. and strains of alfalfa in 5-row plots and for 30 vars. and strains in single-row plots. Stand counts were made by dividing rows into 6-in. units and determining the no. of such units where there were no plants. The no. of blank spaces for each plot was determined and expressed as a % of the total. In 1947, the first yr. after seeding, the correlation coefficient (r) of stand and yield was 0.879 and the coefficient of regression (b) of yield on stand was 0.115. In 1948, r=0.801 and b=0.048. The lower b value in 1948 indicates a marked adjustment to thin stands. The apparent linear relation of stand and yield indicates that the method of determining stand measures largely stand differences that contribute to yield differences. Moisture samples were taken for each plot over the 2-yr. period. Under the conds. encountered, sampling each harvested plot for % DM to determine yield at a specified DM content appeared unnecessary.

PIEMEISEL, ROBERT L. **348**

1951. Causes affecting change and rate of change in a vegetation of annuals in Idaho. Ecology 32(1): 53–72.

Communities of Russian thistle, mustards, and downy chess make up most of the ann. vegetation on lands formerly in sagebrush-grass. In appearance time and in space covered, they have an optimum arrangement which is a potential realized on a cleared area where destruction of plants is sufficiently controlled and is open to repeated demonstration and measurement. Under this optimum rate of change Russian thistle dominates the most space the 1st 2 yrs.; mustards, the 3rd and 4th; and downy chess from the 5th yr. on. In each community there is devlpmt. that is best observed in downy chess and in an island somewhat removed from an established stand. The start is a solitaire, a beginning age; then a cluster of a few individuals, the young age; then a dense stand, the mature age; and finally a very dense stand, the degenerate age. Distinguishing these age groups in an island are color, ht., and maturity (head emergence) as well as density. The changes from 1 community to another and the processes that take place within a community are determined by plant characteristics and proceed despite differences in weather between yrs. of above or below av. precipitation. Sparse stands mature and produce seed in yrs. of below av. precipitation, and excessively crowded stands dry prematurely in yrs. of above av. precipitation. Spacing of individuals within groups—the degree of crowding—determines distrib. of the limited soil moisture supply of a unit area. The supply for an individual depends on the amount put into the soil (precipitation) and the no. of individuals (density), precipitation varying far less than density. Repeated observs., measurements, and expts. may be made on these communities because of their short life span and rapid change.

RENSBURG, H. J. VAN. **349**

1942. A comparison of quadrat results and phenological data in a series of highveld grassland grazing experiments subjected to different treatments over a period of six years. So. African Jour. Sci. 38: 186–197.

Fert. treatments of the various plots are described, and the quadrat results on each plot are discussed in detail. In most instances no generalizations could be made and no concl. drawn. But results clearly indicate that the change in certain spp. is most consistent with the treatments given. It is thus clearly shown that the small tufted and runner grasses can seldom compete for light with the tall bunch grasses, so that they are smothered and suffer severely under conds. of protection, while the larger bunch grasses develop to their maximum capacity.

SHINOZAKI, KICHIRO, AND KIRA, TATUO. **350**

1956. Intraspecific competition among higher plants. VII. Logistic theory of the C-D effect. Osaka Univ., Inst. Polytech. Jour. Ser. D 7: 35–72.

In order to give reasonable interpretations to the competition-density effect law empirically suggested in preceding rpts., a theory was proposed based on the following logistic model: (a) The growth of a plant in dry wt. (w) is described by the general logistic curve,

$$\frac{1}{w}\frac{dw}{dt} \quad \lambda\ (t)\left(\ 1\ -\frac{w}{W(t)}\right);$$

(b) The coefficient of growth (λ) in the logistic equation is independent to plant density (p); (c) Final yield/unit area ($Y=Wp$) is constant irrespective of the difference in plant density (the law of constant final yield); and (d) All the plants are seeded simultaneously at $t=0$, when the av. seed wt. is constant and independent to density (the initial cond.). From these basic assumptions it was concluded that the $w\sim p$ relation for any given time could be represented by the equation, $\frac{1}{w}=Ap+B$, in which A and B are the known functions of time (t). This equation was called the reciprocal equation of the C-D effect. The C-D effect equation hitherto used, $wp^{\alpha}=K$ (α and K are both constants determined by t), or the power equation, was considered to be nothing but a crude approx. of the reciprocal equation, but it has certain advantages for practical purposes. The fitness of the reciprocal equation to a no. of expt. results proved satisfactory. It was only when the so-called cooperation occurred that the equation failed to fit the expt. data. The cooperation is to be considered as a kind of abnormal growth from the standpoint of the logistic theory. Probable causes of this phenomenon were discussed. The method for calculating the characteristic quantities of growth such as $W(t)$, $\lambda(t)$, etc. from the observed values of A and B was presented. Quantitative analysis of growth curves of plant upon logistic basis thus became possible. It was proved that the growth curve must be the general logistic curve, provided the reciprocal equation, assoc. with the law of constant final yield, was always recognized as the expt. facts. In other words, the growth process of higher plants has the fundamental property that it can be approximated at any given moment by the simple logistic equation. Necessary modifications to the law of constant final yield at extremely high density ($p\to\infty$) was considered as related to the autoregulation of density of self-thinning. Also a reasonable treatment of the law at another extreme ($p=0$) was presented. Putting $s=1/p$ in the reciprocal equation, the resulting following equation represents the effect of mean available space on plant growth:

$$\frac{1}{w}=\frac{A}{s}+B.$$

This is a new alternative for the well-known Mitscherlich's formula. Although the 2 formulae closely resemble each other, the latter was proved inadequate so far as the space factor is concerned.—Auth. sum.

WIT, C. T. DE, AND ENNIK, G. C. **351**

1958. Over concurrentie. [On competition.] Wageningen Inst. v. Biol. en Scheik. Onderz. van Landbgewassen. Jaarb. 1958: 59–73. [In Dutch with Eng. sum.]

The statis. aspects of expts. on plant competition are described for plants which do, and those which do not, derive benefit from the presence of another sp. It is shown that it is much simpler to carry out 1-yr. expts., using varying proportions of each sp. in the expt. population, than to follow the change in comp. of a mixture over several yrs., as the former are not complicated by changes in growing conds. from yr. to yr. Experiments to determine the effect on yield of the distance between rows of crops can be treated as expts. on competition between rows with plants and rows without plants. A linear relationship can be demonstrated between the row spacing and the reciprocal of the yield.—Herb. Abs.

See also **18.**

OTHER SITE RELATIONS

ALEKSEENKO, L. N. **352**

1958. [Structure of a perennial herbage sward in relation to yield.] Vsesoyuzn. Akad. Sel'sk.-Khoz. Nauk Dok. [Moscow] 23(6): 14–18. [In Russ.]

Sward structure has been studied hitherto chiefly in the period of the sward's maximal devlpmt. This work is concerned with changes in sward structure in pure and mixed sowings during the whole vegetative growth. The sward consisted of *Phleum pratense*,

Festuca pratensis, Dactylis glomerata, Trifolium pratense, and *Medicago sativa,* these being typical spp. for swards in the NW. U.S.S.R. The plants were sown in pure plots and in 6 mixed cultures each comprising 1 legume and 1 grass. Sward structure was determined by cutting herbage samples from the plots on areas 15×15 cm. at 10 cm. horizons from ground level upwards. The samples from each horizon were divided into leaves, stems, and flowers, the vol. and wt. of each group being determined; in addition leaf area was measured. Replication was 4- or 6-fold. Sampling in the 1st yr. was 1st done in mid-Aug. when the grass was 35–45 cm. high, at the tillering stage, and *P. pratense* had some flower initials. The legumes at this date were 50–60 cm. high at the budding stage. The 2nd sampling was done a mo. later. Apart from the general increase in vol., results differed little between the 2 dates of sampling. In pure sowings, the vegetative mass was concentrated nearer to the soil surface in grasses than in legumes, grasses averaging 44.2% of the total mass in the 0–10 cm. horizon, and legumes 23.5%. In mixtures, the above-ground mass was distributed more evenly in the different horizons, and this insures better illumination within the herbage stand and better utilization of CO_2. The sward was analyzed 4 times in the 2nd yr., at tillering/shooting; earing/budding; flowering; and in the aftermath. The data of all the analyses are recorded in charts and tables; it is shown, for example, that in the 2nd yr. leaf area at the flowering stage for red clover in pure sowing was 9.68 sq. m. per sq. m. soil; for red clover+cocksfoot, 23.76; for lucerne in pure sowing, 17.5; for lucerne+cocksfoot, 18.5. Mixtures produced a greater mass of herbage than did pure sowings. In the author's expts. leaf area was closely related to plant spp. and stage of devlpmt. and was greater in mixed swards than in pure sowings. The leaf's assimilating powers determine ultimate yields, and plants in pure sowings show greater photosynthetic activity than plants in mixtures. For example, on 5 July the photosynthetic intensity for clover in pure sowing was 10.5 mg. CO_2 per hr. per sq. dm., but 7.1 mg. in mixed sowing. The total for the mixture, however, was greater because of the greater leaf area in the mixed stand. There is need for a grazing system that will insure an even distrib. of herbage in each horizon of the stand.

ANDERSON, DEREK J. **353**

1961. The structure of some upland plant communities in Caernarvonshire. I. The pattern shown by *Pteridium aquilinum.* Jour. Ecol. [London] 49: 369–376, illus.

A 3-phase pattern in community structure, pioneer, mature, and degenerate, is reported in *P. aquilinum* from N. Wales. The various scales of pattern detected are determined primarily by the morph. of the plant, and the reduction in the scale of pattern detected as the community passes through 3 phases has been attributed to decay of the plant with age. *Pteridium* has been shown able to control the distrib. of oxygen diffusion rates in the soil.

ANDERSON, DEREK J. **354**

1961. The structure of some upland plant communities in Caernarvonshire. II. The pattern shown by *Vaccinium myrtillus* and *Calluna vulgaris.* Jour. Ecol. [London] 49(3): 731–738, illus.

The pattern of these 2 spp. in several communities is described, and evidence of the importance of soil aeration in controlling distrib. and performance of *Vaccinium myrtillus* presented. Further evidence relates the present heterogeneity in soil aeration to agr. mangt. 150 yrs. ago. A field expt. to test the relation of treading and grazing to yield and stem/leaf ratio in *V. myrtillus* is described. The need to know "normal" morph. pattern as a guide to spp. performance under different ecol. conds. is emphasized.

BILLINGS, W. D. **355**

1941. Quantitative correlations between vegetational changes and soil development. Ecology 22(4): 448–456, illus.

Quantitative methods are described for correlating plant succession and soil devlpmt., and the literature is reviewed. Linear and curvilinear regressions are applied to successional and climax soil and vegetation data from the Piedmont and mountain regions of N.C. Using the equation, $E=\bar{y}+(\Sigma xy/\Sigma x^2)(X-\bar{x})$, a highly significant coefficient of 0.0212 is shown for regression of % organic matter in the A_1 horizon on age of shortleaf pine (*P. echinata*) stands. Highly significant coefficients are also presented for the regression of water-holding capacity, vol.-wt., and moisture equivalent of the A_1 horizon on % organic matter in the same soil under shortleaf pine stands. Highly significant regression coefficients for hardwood reproduction under pine and certain soil factors are also presented. Under conds. resulting in high values for % organic matter, its curvilinear relation to vol.-wt. in a virgin hemlock (*Tsuga canadensis*) stand is brought out by use of the 2nd degree polynomial equation $Y=a+bX+cX^2$, yielding in this case $Y = .6969 - .0121X_1 + .00006X_2$ where Y is equal to the vol.-wt.

Boer, T. A. de, and Ferrari, T. J. 356

1957. Bodemvruchtbaarheid, vegetatie-karteringseenheid en opbrengst van grasland in een zandgebied (Gelderse Vallei). [Soil fertility, vegetation-survey units, and production on old permanent pastures in a sandy region (Gelders Valley).] Wageningen Cent. v. Landbpub. and Landbdoc. Verslag. van Landbouwk. Onderzoek. 62.15 [n.d.], 23 pp. [In Dutch with Eng. sum.]

The relation between bot. comp. on the 1 hand and soil fertility, water supply, and yield on the other was studied in 237 plots of 100 sq. m. in a sandy region. The accuracy of estimates was controlled by measuring yield in 5 sq. m. cages on 50 plots. Vegetation survey units (V.S.U.) denote botanical comp. and form a scale indicating the quality of the grassland and its util. For example 0– on the scale indicates a sward having $>75\%$ good grasses of which $>50\%$ is *Lolium perenne*, while at the other end of the scale 8– indicates a sward having $<35\%$ good grasses. Variants of these units indicate moisture conds., so that, e.g., –1 denoted the presence of $>30\%$ of spp. which are indicators of dry conds. Correlations were established between these V.S.U.'s and the grade of quality and grass yield, pH–KCL, K-status, P-status, Mg-status, N-status, ground-water level, and water-holding capacity. The water supply is the main influence on yield and quality of the region's grassland.

Brougham, R. W. 357

1955. A study in rate of pasture growth. Austral. Jour. Agr. Res. 6(6): [804]–812, illus.

The growth curve of a pasture consisting of short-rotation ryegrass, red clover, and white clover was determined by measuring DM yields at intervals over a 9-wk. period in the spring of 1953. To determine the effects of temporary weather variations on growth, the expt. was replicated in time as well as space. The expt. technique is described. The curves of growth for ryegrass and total herbage were sigmoid. In the 2nd phase of growth of approx. 5 wks. when rate of growth was constant, the daily increment in total herbage approached 150 lbs. DM per acre. Total herbage yields were separated into 2 pts. to give a growth effect for a constant (mean) climate and an irregular weather effect. This latter separation showed agreement with fluctuations in temp. and rainfall. The results are discussed in terms of pasture mangt. practices, and the possibilities of growth rate studies for future pasture experimentation are considered.—Auth. sum.

Brougham, R. W. 358

1959. The effects of season and weather on the growth rate of a ryegrass and clover pasture. New Zeal. Jour. Agr. Res. 2(2): 283–296.

An expt. is described in which the effects of seasonal climate and of temporary (weekly) weather variations on the growth rate of a pasture of short-rotation ryegrass and white clover were determined. The technique of measurement included replication in time as well as space. Statistical analyses showed significant positive correlations between seasonal trends in growth rate and light and temp. Positive correlations were also obtained for the weekly fluctuations in growth rate attributable to weather factors. The pasture was irrigated during the summer and early autumn so that water was at all times adequate for growth. The av. daily growth rate of the pasture ranged from 10 lbs. of DM per acre in the winter to 120 lbs. per acre in early summer. The weekly fluctuations in growth rate attributable to weather factors were as large as $\pm 50\%$ of the weekly growth rate. The potential ann. yield of DM obtainable from this pasture type growing in this locality, was estimated as 22,000 lbs. per acre.—Auth. sum.

Cain, Stanley A., and Evans, Francis C. 359

1952. The distribution patterns of three plant species in an old-field community in southeastern Michigan. Mich. Univ. Lab. Vert. Biol. Contrib. 52, 11 pp., illus.

The distrib. patterns of populations of *Lespedeza capitata*, *Liatris aspera*, and *Solidago rigida* were obtained by taking the bearing and distance from a ref. point of all individuals encountered in an area of approx. 2 acres. By means of these data, the location of each individual plant was plotted on a map. An overlay grid representing 1-m.-sq. quadrats was used to prepare frequency charts for the distrib. of each sp. Different relationships between the 3 spp. were indicated by the data for density, mean area, frequency, and abundance. The tendency to clumping appeared to be greatest in *Lespedeza*, least in *Solidago*, and intermed. in *Liatris*. A distinction was made between "major" clumps, which are probably due to clonal devlpmt. resulting from localized seed dispersal or from vegetative reproduction, and "minor" clumps consisting of several individuals only, which may represent either the beginning of such clones or the chance assocs. resulting from random dispersal. The ability of *Solidago* to spread

by rhizomes may account in pt. for the greater devlpmt. of minor clumps in this sp., while the possession of heavier seeds helps to explain the greater degree of major clumping in *Lespedeza*.—Auth. sum.

CALDER, A. B., AND VOSS, R. C. 360
1957. The sampling of hill soils and herbage, with particular reference to the determination of the trace elements. Consult. Comt. Devlpmt. Spectrographic Work [Edinburgh] Bul. 1, 52 pp.

The following factors contributing to variations in the trace-element content of soils and herbage from hill-land were studied: (a) variation in soil type and derivation at different sites and over small areas; (b) seasonal variation at the same site; (c) personal error; (d) variation in bot. comp.; (e) contamination of samples; (f) analytical error. Trace-element contents of soils and herbage from 17 areas on 2 expt. farms are given. Coefficients of variation for Co- and Ni-contents of soil and herbage were relatively high (20–60% for herbage and up to 149% for soil samples). The total analyt. errors were negligible compared with the sampling errors. There was considerable variation within both *Molinia caerulea* and *Nardus stricta*. Variation between spp. was investigated for *Calluna vulgaris, Trichophorum caespitosum, Molinia caerulea, Juncus articulatus, Pteridium aquilinum, Nardus stricta*, and *Festuca ovina*. Co and Fe contents of herbage were positively correlated. The relationship between extractable soil Co and herbage Co is discussed. No suitable indicator sp. was found. Indications were that *Calluna* may accumulate Co and *Trichophorum* and *Molinia* reject it, even if available in the soil. A sampling scheme is outlined for advisory use.—Herb. Abs.

COOK, C. WAYNE, AND HURST, REX.
1962. A quantitative measure of plant association on ranges in good and poor condition. Jour. Range Mangt. 15(5): 266–273, illus.

Thirty-one fence-line contrasts between range in good and poor cond. were surveyed in the Escalante desert in autumn, 1958, for the presence or absence in quadrats mmeasuring 3, 4, or 5×5 ft. of the prominent spp. *Eurotia lanata, Chrysothamnus stenophyllus, Oryzopsis hymenoides*, and *Hilaria jamesii*. *C. stenophyllus* was significantly assoc. with poor cond. and *E. lanata* and *O. hymenoides* with good cond. There was a positive assoc. under both good and poor conds. between *E. lanata* and *H. jamesii*, as well as between *C. stenophyllus* and *O. hymenoides*.

COX, C. P., HOSKING, ZENA D., AND LINE, C.
1958. Within-field changes in herbage composition and soil moisture. Brit. Grassland Soc. Jour. 13(3): 187–195, illus.

In a previously reported uniformity trial on pasture evaluation, there appeared to be systematic areal changes in the herbage crude fiber and CP percentages. Quadratic contours have been calculated to illus. these trends and an investigation made of possible relations of changes to local soil differences, moisture percentages, and copse shelter effects.—From auth. sum.

EMMETT, H. E. G., AND ASHBY, ERIC. 363
1934. Some observations on the relation between the hydrogen-ion concentration of the soil and plant distribution. Ann. Bot. [London] 48(192): 869–876.

Before drawing concl. about pH influence on distrib. of a sp. it is necessary to obtain data regarding the pH distrib. by random sampling independently of sp. presence or absence. Although *Pteridium aquilinum* and *Vaccinium myrtillus*, for example, showed well-defined frequency modes at pH 5.6, random soil samples showed a mode at the same pH. Statistical examination of the data reveals no evidence of correlation between distrib. and pH between 4.7 and 6.2.

EVANKO, ANTHONY B., AND PETERSON, ROALD A. 364
1955. Comparisons of protected and grazed mountain rangelands in southwestern Montana. Ecology 36(1): 71–82.

Vegetation characteristics and water absorption by soils were measured on selected areas in southwest. Mont. to determine effects of grazing and protection. Even though study areas were all within 1-1/2 mile of each other, composition of vegetation varied greatly between them, both within and outside exclosures. On the protected pts. grasses provided more of the total cover than on grazed pts., the only grass sp. persistently most abundant on grazed pts. being *Poa secunda*. On the grazed pts., forbs and shrubs were most common, with small but consistent differences existing, and no sp. appearing to have indicator value. A compositional pattern could not be defined for the type because of variability among areas. On the protected pts. were the greatest leaf hts., basal area per clump, and herbage yield per plant and per sq. cm. for the main forage spp. (*Festuca idahoensis, Agropyron spicatum, A. dasystachum*, and *Calamagrostis*

montanensis). These characteristics were very similar among areas for *F. idahoensis* and *A. spicatum* especially. Calculated herbage yield of most common forage spp., soil surface litter, and rate of water absorption by the soil were usually much less on the grazed pts. of the areas. These items also varied greatly between areas. Light grazing was not reflected in amount and kind of cover or plant frequency when compared with a similar protected area. Differences in height, basal area, yield per clump, and yield per sq.-cm. measurements were greater where more heavily grazed areas were compared to protected areas. Compared to estimates of cover, more usable and reliable criteria for evaluating range cond. of this mountain bunchgrass type are furnished by leaf ht., plant area, and yield per clump and unit of plant area of individuals of important forage spp. Strategically located exclosures may provide a standard for evaluating relatively simply the degree grazing treatment has affected characters, especially those assoc. with plant vigor.

GREIG-SMITH, P. **365**
1961. Data on pattern within plant communities. II. *Ammophila arenaria* (L.) Link. Jour. Ecol. [London] 49(3): 703–708, illus.

Ammophila arenaria shows 2 scales of pattern: (1) at 20–40 cm., resulting from tillering from vertical rhizomes; (2) at 80–160 cm. (tussock pattern), arising either from stimulation of adjacent nodes on horizontal rhizomes at the earliest stage of colonization or from environmental control of seedling estab. Environmentally determined tussock pattern is maintained through later stages by growth of vertical rhizomes. Further seedling estab. on older dunes reinforces the existing pattern. Maximum inflorescence prod. occurs earlier in succession than maximum shoot prod. The probability of a shoot producing an inflorescence is lower in the high density phase of tussock pattern. —Biol. Abs.

GRIZZARD, A. L. **366**
1935. Effects of soil type and soil treatments on the chemical composition of alfalfa plants. Amer. Soc. Agron. Jour. 27: 81–99.

The effect of various fert. treatments on the partial comp. of *Medicago* cut in the bud stage, and the 1st and 2nd cutting for hay at the 1/2-bloom stage, is recorded for different soil types. Correlations are drawn between soil type and nutritional disorders in cattle, the heavy and medium textured soils producing hays with unfavorable nutritive balance. From a comparative study of the random and systematic methods of sampling for chem. analysis, it is concluded that the latter method has no advantage over the former.—Herb. Abs.

HOPKINS, HAROLD H., ALBERTSON, F. W., AND RIEGEL, D. A. **367**
1952. Ecology of grassland utilization in a mixed prairie. Kans. Acad. Sci. Trans. 55(4): 395–418, illus.

Correlations are presented for rainfall, soil moisture, growth, yield, moisture content, protein content, util. of vegetation, and the yield of beef on pasture near Hays, Kans., from 1947 through 1950. Soil moisture is paramount in a successful livestock program in this mixed prairie area.

HOPKINS, J. W. **368**
1935. Weather and wheat yield in western Canada. I. Influence of rainfall and temperature during the growing season on plot yields. Canad. Jour. Res. 12(3): 306–334, illus.

A statis. study of plot yields recorded at several agr. expt. stas. in cent. and south. Saskatchewan and Alberta has demonstrated a significant correlation between yield and amount and distrib. of seasonal rainfall. On the whole, above-av. rainfall is assoc. with higher yield, but the result of a given increment of rain at different times partly depends on soil conds. On fertile soil, rainfall prior to harvesting results in a reduction of yield, probably owing to lodging. The maximum influence of precipitation upon yield appears to be exerted during June. The av. summer rainfall sequence is very similar in each of the above 4 districts. There is a moderate degree of correlation between amounts of rain recorded in different districts during the same season, but simultaneous occurrence of extremely wet or dry seasons over the whole area seems infrequent. Temperature conds. during the growing season seem to be secondary to rainfall in influencing yield. Above-average temp. is beneficial at time of sowing, detrimental during midsummer and again beneficial prior to ripening, but as in the case of rainfall, the effect produced is influenced by soil conds. No consistent relation is evident between either rainfall or temp. and the relative yield of early and late maturing varieties.—Auth. abs.

ISHIMOTO, TOSHIO TOM. 369

1958. Systematic considerations as influenced by certain ecological factors related to plant distribution on serpentine soil in central California. Diss. Abs. 19(4): 650.

ITALLIE, T. B. VAN. 370

1937. De invloed van verschillende factoren (maaitijd, botanische samenstelling, bemesting en grondsoort) op de chemische samenstelling van gras. [The influence of different factors (time of mowing, botanical composition, manurial treatment, and soil type) on the chemical composition of grass.] Landbouwk. Tijdschr. [Wageningen] 49: 155–170. [Eng. sum.]

In the Netherlands the chem. comp. of grass is as a rule much more affected by the stage of growth and by bot. comp. than by manurial treatment and soil type. This is illus. by sampling of herbage at different dates from pure cultures and normal grassland respectively. The relation of lime content to % of clovers and weeds after 3 or 4 yrs. of different manurial treatment is shown. In discussing the influence of manurial treatment, a distinction is made between direct effect (increasing uptake of N, P, and K, etc.) and indirect effect (changes in bot. comp.). The use of K and P usually causes changes in grass comp., but, at least in the case of P, changes in subsequent yrs. due to cutting at different stages of growth may be much greater than those caused by manuring. The influences of Ca, Mg, and Na are briefly mentioned. The impr. of natural grassland on peat soil with farmyard manure followed by artificial ferts. produces great changes in chem. comp., due to changes in bot. comp.—From auth. sum.

JOWETT, G. H., AND SCURFIELD, G. 371

1949. A statistical investigation into the distribution of *Holcus mollis* L. and *Deschampsia flexuosa* (L.) Trin. Jour. Ecol. [London] 37(1): 68–81, illus.

The succession within woodlands from *Deschampsia*-dominated soils with pH less than 3.25 to *Holcus*-dominated soils with pH above 3.25 involves changes from a mor type toward the mull type, and a change in moisture from more xeric to mesic.

JOWETT, G. H., AND SCURFIELD, G. 372

1952. Statistical investigations into the success of *Holcus mollis* L. and *Deschampsia flexuosa* (L.) Trin. Jour. Ecol. [London] 40(2): 393–404.

Estimates of the success (determined as yields fresh and dry wt. and no. of shoots per quadrat) of the 2 spp. in different woodlands and under different types of tree cover within a woodland are correlated with the edaphic variables pH, % moisture, and % organic content of the soils at the sampled points. Increase in pH is assoc. with an increase in yield of fresh wt. of *Holcus mollis* and a decrease in that of *Deschampsia flexuosa*. Two sampling designs are employed, the relative merits of which are critically examined; a transect design with the sampling points at the equally-spaced intersection of a carefully mapped grid is recommended.

KAYAMA, R. 373

1961. Studies on estimation of grazing capacity and utility of mountainous grassland. V. Relation of slope elevation to yield and nutritive composition of pasture grass in tame grassland. Jap. Jour. Zootech. Sci. 32: 25–30. [In Jap. with Eng. sum.]

Three plots 100 m. long on a slope of about 15° were sown with Italian ryegrass, peren. ryegrass, Ladino clover, and cocksfoot (orchardgrass). Grass yields in early May, mid-June, and early Aug., and chem. comp. in early May were studied in 5 areas of 1 sq. m. When season was taken into acct., yields from the 2 lowest samples were significantly greater than from the 2 highest. Crude fiber and Mg were positively correlated with altitude, but CP, NFE, ash, Ca, and P were not. Equations are given relating productivity to yield and constituents. It was concluded that productivity was greatest at the low levels.

KAYAMA, R., AND MIZUNO, T. 374

1959. Studies on estimation of grazing capacity and utility of mountainous grassland. I. Effect of slope elevation on the chemical composition of topsoil and the yield of native plants. II. Relation of slope elevation to the physical character of topsoil and estimation of the yield of native plants. Jap. Jour. Zootech. Sci. 30(4): 231–241, illus. [In Jap.]

KERSHAW, KENNETH ANDREW. 375

1958. An investigation of the structure of a grassland community. I. The pattern of *Agrostis tenuis*. Jour. Ecol. [London] 46(3): 571–592.

This is the 1st of a series of papers in which the patterns of 4 spp. in a grassland community are discussed in relation to their environment and to each other. The area

studied was an upland *Festuca/Agrostis* grassland that had been reseeded over a no. of yrs. and was reverting to its original state. There is support for the view that the nutritional level in the soil is a limiting factor in the distrib. and relative abundance of *A. tenuis* and *F. ovina*.—Herb. Abs.

KERSHAW, KENNETH A. **376**

1959. An investigation of the structure of a grassland community. II. The pattern of *Dactylis glomerata, Lolium perenne* and *Trifolium repens*. III. Discussion and conclusions. Jour. Ecol. [London] 47(1): 31–53, illus.

The importance of replicated samples is discussed in relation to the interpretation of pattern analyses. A pattern of low intensity, but repeated occurrence in a comparable series of analyses, can thus be established as a characteristic of the vegetation under invest., and not a chance heterogeneity. The causal factors of pattern in vegetation can be grouped under 3 headings: (a) morph. pattern; (b) pattern resulting from competition between 2 or more individuals (sociol. pattern) and (c) pattern resulting from variation in topog., soil depth, water availability, etc. (physiographic pattern). It is suggested that cyclic phases in vegetation are a widespread phenomenon, especially in rhizomatous spp. The structure of "climax" vegetation is discussed in relation to the "amount," type, and intensity of pattern present. It is concluded that stable vegetation will have a minimum no. of scales of pattern present, and in a climax community, with absolute homogeneity of the environment, the pattern present would be solely (a). The existence of such an idealized vegetation is doubtful and it is likely that, to some extent, (c) will be present; (b) will be absent, such pattern being characteristic of seral phases leading to a stable vegetation type.—Herb. Abs.

KERSHAW, K. A., AND TALLIS, J. H. **377**

1958. Pattern in a high-level *Juncus squarrosus* community. Jour. Ecol. [London] 46(3): 739–748.

The structure of a *Festuca ovina-Juncus squarrosus* assoc. is examined and a series of mosaic patches is described. The mosaic patches are visually indistinguishable, consisting of areas where the density, vigor, and pattern of *J. squarrosus* varies, expressing the different times of colonization. The mosaic patches are probably maintained by varying depths and water-holding capacities of the soil and show a general trend of reduction of pattern with their increasing devlpmt.—Biol. Abs.

LISTER, PAUL B., AND SCHUMACHER, FRANCIS X. **378**

1937. The influence of rainfall upon tuft area and height growth of three semi-desert range grasses in southern Arizona. Jour. Agr. Res. 54(2): 109–121, illus.

The effect of variation in precipitation distrib. during a 15-mo. period on the ann. density change and ht. growth of the 3 forage grasses [three-awn grass (*Aristida* spp.), black grama (*Bouteloua eriopoda*), and *Rothrock grama* (*B. rothrockii*)], within the growing season of the current yr., was determined by statis. analysis. The method used consisted in describing the observed monthly precipitation during each 15-mo. period ending with Aug. for each sta. and yr., by orthogonal polynomials of degree 8; the coefficients of these were then used as independent variables in 6 multiple-correlation analyses, the dependent variables of which were (1) the ann. density change, and (2) the ht. growth of flower stalks of each of the 3 grasses according to sta. and yr. All the correlations are highly significant. Graphic expressions of the av. effect of an added in. of precipitation per mo. indicate, in the case of the 2 grama grasses, that the most beneficial precipitation distrib. from normal for both density change and ht. growth consists of relatively dry winters sandwiched between relatively wet autumns and springs. Three-awn grass seems admirably adapted to the variation in precipitation distrib. characteristic of the area studied in that either positive or negative departure from normal seasonal precipitation benefits, in general, either density change or ht. growth, although not both at once.—Auth. sum.

LUSH, R. H. **379**

1935. Five years results on monthly clipping of pastures. Jour. Dairy Sci. 18: 295–299.

The expts. were carried out in the 5 growing seasons, 1930–34. The prevailing, early vegetation consisted of *Trifolium repens* and/or *T. procumbens, Lolium* spp., *Phalaris* spp., and *Avena*. This was replaced later in the seasons by *Paspalum dilatatum, Cynodon dactylon*, and a small amount of *Axonopus compressus*. The areas were cut each yr. during the 1st wk. of Mar. and at 30-day intervals throughout the growing season. A tabulation is given of rainfall, yield, chem. analyses, and nutritive values for the different cuttings. The following points are emphasized: (a) Yields were at a maximum in Apr. and Aug., (b) Early spring grass contains nearly twice as much CP as that cut in

Sept.; in view of chem. changes during the advancing season, the computed TDN per 100 lbs. of grass tends to rise to 15 in midsummer and then gradually declines, (c) There is considerable uniformity in analyses of grass clipped on the same date irrespective of bot. comp. Rainfall and maximum and minimum temps. are discussed in relation to growth rate, comp., and yield of herbage.

METZGER, W. H. 380
1935. The relation of varying rainfall to soil heterogeneity as measured by crop production. Amer. Soc. Agron. Jour. 27: 274–278.

The crops grown on 1/20-acre plots during 9 yrs. were corn, oats, wheat, *Medicago*, and Atlas sorgho. An inverse relation between rainfall and soil heterogeneity is reflected in the extent of variability of the crop yields from uniformly cropped field plots receiving no fert. treatments. This indicates smaller plots and more replications are needed in many field expts. and the value of a uniform cropping period is limited for establishing definite variability in the crop-producing ability of a group of expt. plots.

MOTT, N. 381
1957. Die anwendung von futterwertzahlen bei der beurteilung von grünlandbeständen. [The application of the fodder-value marking system for the estimation of grassland output.] Grünland [Hannover] 6(7): 53–56.

In applying the fodder-value marking system of Klapp (Herb. Abs. 24: 557) to manurial expts. on grassland, Jende (1955) coined the term "quality-fodder yield" to express the effects of manuring on hay output. He obtained the "quality-fodder yield" by multiplying the hay-yield by the fodder-value (Klapp system) of the hay. The auth. of the present paper suggests that "yield-fodder-value-unit" (Ertrags-Futterwert-Einheit or EFE) is more accurate than Jende's term. The results of 2 manurial trials on grassland are used to compare hay yields, the Klapp marking system, and EFE (all in both absolute and relative values). The auth. concludes that EFE is more accurate than the Klapp system which, in turn, is more accurate than hay-yield figs., for the true interpretation of the effect of manuring on the hay output of grassland.—Herb. Abs.

PASE, CHARLES P. 382
1958. Herbage production and composition under immature ponderosa pine stands in the Black Hills. Jour. Range Mangt. 11(5): 238–243, illus.

In 1956 a logarithmic relation was found between herbage prod. and % pine crown cover, basal area, and pine litter. Total herbage ranged from 40 lbs./acre air-dry under a 70% crown canopy to 2,160 lbs. on clearcut areas. Grasses and sedges produced 66% of the herbage under relatively open stands (0–19% crown cover). Grasses and sedges increased the most in lbs./acre as crown cover decreased. Kentucky bluegrass (*Poa pratensis*), the heaviest producer under open stands and in clearcut areas, decreased sharply as crown canopy increased, as did little bluestem (*Andropogon scoparius*), prairie dropseed (*Sporobolus heterolepis*), and fuzzyspike wildrye (*Elymus innovatus*). Roughleaf ricegrass (*Oryzopsis asperifolia*) and sedges (*Carex* spp., largely *C. pennsylvanica*) increased in relative importance but decreased in lbs./acre. Bearberry (*Arctostaphylos uva-ursi*), common juniper (*Juniperus communis*), and snowberry (*Symphoricarpos occidentalis*) were the most plentiful shrubs. Bearberry produced the most herbage under moderately open stands. Snowberry, while not a heavy producer, was persistent under dense pine canopies.

PASE, CHARLES P., AND HURD, RICHARD M. 383
1957. Understory vegetation as related to basal area, crown cover and litter produced by immature ponderosa pine stands in the Black Hills. Soc. Amer. Foresters Proc. 1957: [156]–158, illus.

Production of grasses, broad-leaved herbs, and shrubs all increased as the basal area and crown density of the pine stand and lbs. litter/acre decreased. As the basal area of the pine stand decreased from 200 sq. ft./acre to 0, grass prod. increased from 13 to 1,330 lbs./acre, prod. of broad-leaved herbs increased from 2 to 210 lbs./acre, and shrub prod. increased from 7 to 120 lbs./acre.

RATLIFF, RAYMOND D., AND HEADY, HAROLD F. 384
1962. Seasonal changes in herbage weight in an annual grass community. Jour. Range Mangt. 15(3): 146–149, illus.

The seasonal progression of herbage wt. in a wild oat, *Avena fatua*, community was studied Mar. 13–Aug. 20, 1960. Problems investigated were how long herbage wts. of spp. and of the plant community remained at or near maximum and the magnitude and rate of loss in herbage wt. in the dry season. Conclusions were: (1) Some spp. start their most rapid growth earlier, and some lose wt. earlier than others; (2) once wt. reaches a peak, it remains reasonably constant for a period whose length varies among

spp.; (3) initial losses in herbage wts. are usually the most rapid, later losses more gradual; (4) the period of constant wt. for a community will vary in length and starting date depending upon spp. comp.; (5) the total loss in wt. for a community will depend mainly on its spp. comp. Data suggest that sampling for herbage wt. must be carefully coordinated with spp. comp. and with stage of growth and so designed that normal seasonal wt. losses are not confounded with forage eaten by livestock.

RAYSON, PATRICIA. **385**

1957. Dark Island Heath (Ninety-mile Plain, South Australia). II. The effects of microtopography on climate, soils, and vegetation. Austral. Jour. Bot. 5(1): 86–102, illus.

By the method of positive interspecific correlation, 4 plant communities were distinguishable in the heath vegetation. Three were delimited by differences in microhabitat dependent on the essentially unidirectional rain-bearing winds and on dune topog., and were located on east. dune slopes, west. dune slopes, and sandplain. The 4th was found in scattered sites. The habitats and communities were not sharply delimited, and the concept of a varying continuum was found applicable to the vegetation.

ROGLER, GEORGE A., AND HAAS, HOWARD J. **386**

1947. Range production as related to soil moisture and precipitation on the northern Great Plains. Amer. Soc. Agron. Jour. 39(5): 378–389, illus.

Whether fall soil moisture in rangeland could be used to predict the following season's forage yields and cattle gains was studied from 18 yrs.' forage yields and 19 yrs.' cattle gains. The relations to yields and gains of Apr.–July precipitation alone and together with the preceding fall soil moisture were also studied. Highly significant coefficients were obtained for the correlation of forage yields and available fall soil moisture in the surface 3 ft. (0.72) and 6 ft. (0.74). For cattle gains, the coefficient of correlation with fall soil moisture was significant (0.52 in the surface 3 ft.) or highly significant (0.64 in the surface 6 ft.). April–July precipitation showed approx. the same correlation to yields and gains as fall soil moisture in the surface 6 ft. When Apr.–July precipitation and soil moisture were added together, the correlation with yields and gains was higher. The data indicate that below av. yields and gains can be predicted fairly accurately when the soil is dry the preceding fall. With increasing quantities of moist soil, higher yields and gains can be expected on the av., but prediction is less accurate.

SEARS, P. D. **387**

1956. The effect of the grazing animal on pasture. Seventh Internatl. Grassland Cong., Palmerston North, Proc. 1956: 92–101.

Aspects discussed include animal treading, defoliation by grazing stock, and manuring. "A natural corollary to the appreciation of grazing animal effects is the necessity to incorporate such effects into pasture trials, or to allow for the absence of such effects, in the interpretation of the experimental results." Of possible methods for pasture mangt. trials, limitations are found in all but use of self-contained blocks for each replicate, in which the true ecosystem of soil, plant, and animal is complete for that replicate. With this system treatment differences are valid for direct appl. to practice.

SHEPHERD, W. O., DILLARD, E. U., AND LUCAS, H. L. **388**

1951. Grazing and fire influences in pond pine forests. N. C. Agr. Expt. Sta. Tech. Bul. 97, 56 pp., illus.

Response of pine reproduction and other understory vegetation to grazing and wildfire, and cattle performance under 2 intensities of grazing, were studied in logged and unlogged pond pine (*Pinus rigida* var. *serotina*) forest in east. N. C. Pine reproduction and other vegetation were inventoried initially and annually for 5 yrs. on 128 plots, half of which were protected from grazing, and the wildfire effects evaluated. Grazing influences were mostly favorable to the forest. The better forage spp. such as cane (*Arundinaria*) and palatable browse were reduced 50–60%, and the total understory vegetation about 25%, by 4 yrs. of heavy grazing. Light fuels were reduced correspondingly. Reduction of competing vegetation increased the growth rate of small pine seedlings 23–67%, but had no effect on seedlings taller than the cane and brush (about 3 ft.). Seeding estab. increased more than 50% on grazed plots, but mortality of seedlings less than 1-ft. tall was 6–13% greater than on ungrazed plots. Aside from skid trails and roads, logging had little influence on pine seedlings or other understory vegetation. Fire was found essential for regenerating pond pine stands, not only to provide a favorable seedbed but also to release seed accumulating for several yrs. in closed cones on trees. On grazed unburned areas about 50 seedlings per acre were established each yr., and without grazing fewer than 10 per acre. After an intense fire, 2,250 seedlings appeared the 1st yr. and 1,700 more the next year. The 2nd yr. influence indicated either an

incomplete seedcast or much seed dormancy. About 1/6 as many seedlings followed a light fire. Grazing before burning decreased the fire intensity and consequently its effect on seedling estab. Although all understory spp. sprouted after a burn, cane was favored because it regained its former ht. in a few mos. and overtopped competing shrubs for several yrs. Burning, however, increased cane susceptibility to grazing damage. Cows gained best on the less heavily stocked ranges, but calf gains were not affected significantly by the stocking rate. Heavy stocking produced considerably more beef per acre the 1st 2 yrs., but not in later yrs. when the range deteriorated. Burning tended to increase cattle gains during the yr. of the fire, but not after.

SLATYER, R. O. 389
1957. The significance of the permanent wilting percentage in studies of plant and soil water relations. Bot. Rev. 23(10): 585–636.

STEEN, E. 390
1958. Betesinflytelser i Svensk vegetation. [Effects of grazing on Swedish vegetation.] Uppsala Lantbrhögsk. och Statens Lantbrförsök. Statens Jördbrförsök., Meddel. 89, 82 pp. [Eng. sum.]

On the basis of published results and of his own invests., the auth. discusses the effects of grazing in Sweden, principally in relation to forest which, for the most pt., forms the climax in sociol. devlpmt. The changes produced by grazing in the vegetation of hitherto ungrazed areas is outlined, as are the individual effects of the 3 factors, grazing *per se*, droppings, and treading. Finally the effects produced by different animals and the ecol. effects of using different grazing techniques are discussed.—Herb. Abs.

STEWART, GEORGE, AND KELLER, WESLEY. 391
1936. A correlation method for ecology as exemplified by studies of native desert vegetation. Ecology 17(3): 500–514.

Simple, partial, and multiple correlations show that *Chrysothamnus stenophyllus* and *Oryzopsis hymenoides* compete strongly with each other in the north. desert shrub assocs. of Millard Co., Utah. This is likewise true of *Hilaria jamesii* and *Sporobolus asperfolius*, whereas *Artemisia nova* and *O. hymenoides* are apparently commensals. *C. stenophyllus* was found on heavily grazed areas to compete excessively with *Eurotia lanata* but not actively on moderately grazed areas. Soil heterogeneity of the desert soils was extremely high, and accounted for a large pt. of the difference in density of *E. lanata* on plots that were nearby but not immediately adjacent. The method of study exemplified, though both useful and definite, has been little used by ecol.—Biol. Abs.

THOMAS, A. S. 392
1959. Sheep paths. Observations on the variability of chalk pastures. Brit. Grassland Soc. Jour. 14(3): 157–164.

The variability of some chalk pastures above the Pewsey Vale in Wiltshire was studied by recording point-quadrats 2 in. apart on strips across sheep paths; the results are shown diagrammatically. Lines of tall grasses were usually at the edges of the paths, and belts of shorter grass, richer in forbs, between the paths. Some spp. of grasses and forbs were most common on or near the paths; others were more common in the short turf. The theoretical and practical implications of this variability are briefly discussed.

VRIES, D. M. DE. 393
1953. Objective combinations of species. Acta Bot. Néerlandica 1(4): 497–499.

Distributional features of grassland spp. are arranged in a diagram that indicates frequency of assoc. between spp. and type of soil (acid, lime, moist, dry, fertile, poor).

VRIES, D. M. DE, AND ENNIK, G. C. 394
1953. Dominancy and dominance communities. Acta Bot. Néerlandica 1(4): 500–505.

A study of 855 Dutch grasslands showed that the more frequently a sp. occurs the more it is correlated with specific environmental factors. Thus *Anthoxanthum odoratum* occurs most frequently when the pH of the soil water is 5.7 ± 0.5, while *Dactylis glomerata* is most frequent at 6.7 ± 0.5.

WARD, GEORGE M. 395
1959. Effect of soil fertility upon the yield and nutritive value of forages. A review. Jour. Dairy Sci. 42(2): 277–297, illus.

The effects of fertil. of forage crops vary with soil types, relative levels of fertility within soil type, ratios of available nutrient crops, and climatic conds. The chem. comp. of forages may be altered by fertil. Application of a nutrient in quantities greater than

those required for maximum yield response usually results in luxury consumption of the nutrient. The nutrients whose level in plants may be increased by large appls. include N, P, K, Ca, S, and Co. The N and P levels in leguminous forage usually were not influenced by heavy appls. of these nutrients. Biological assays of forages produced with different fert. treatments have yielded varying results. Several studies with sheep and rabbits have indicated that appls. of P fert. increase the biol. value of forages when these forages are fed alone or in highly simplified rations. Application of limestone to the soil has been shown to exert a favorable effect on the biol. value of forage. Forages grown on light soils have lower biol. value for guinea pigs than do forages grown on heavy soils. Other rpts. indicate no difference in biol. value of forage due to level of soil fertility.—Biol. Abs.

WEAVER, J. E. **396**

1924. Plant production as a measure of environment. A study in crop ecology. Jour. Ecol. [London] 12: 205–237, illus.

These studies were made in true prairie (*Stipa-Koelaria*) at Lincoln, Nebr., in mixed prairie (*Stipa-Bouteloua*) in N. cent. Kans., and in short grass plains, (*Bulbilis-Bouteloua*) at Burlington in east. Colo. During 3 growing seasons at each sta., measurements and comparisons were made of all important aerial and edaphic ecol. factors such as rainfall, water and nutrient content of soil, humidity, evaporating power of the air, soil and air temp., and wind movement. Plant prod. of native grasses and the smaller cereal crops was determined from many clipped quadrats. The relative prod. of certain legumes and of maize was also determined. The water relations of soil and air were early found to be controlling, other factors being merely contributory. The yields of pure stands of short grass (*Bulbilis dactyloides* and *Bouteloua gracilis*), wheatgrass (*Agropyron intermedium*), mixed short and tall grasses, and mixed tall grasses were found to decrease from the true prairie through mixed prairie to short-grass plains. This decrease was directly proportional to available water of soil and inversely proportional to the evaporating power of the air. This was found not only for the smaller cereals but also for alfalfa, sweet clover, and maize. The plant yield at each sta. during different seasons also correlated well with the variations in the water relations. Since water was most deficient in late summer, the differences in plant prod. were often greatest in late maturing tall grasses at the east. stas. Thus, native and crop plants are shown to integrate environmental conds. and to express them quantitatively in yield.

WHEELER, J. L. **397**

1958. The effect of sheep excreta and nitrogenous fertilizer on the botanical composition and production of a ley. Brit. Grassland Soc. Jour. 13(3): 196–202.

Results in a previously described expt. are presented for its last 2 yrs. The return of dung and urine by sheep to a ryegrass/white-clover ley was controlled by suitable harnesses to give 4 treatments (no dung or urine, dung, urine, dung and urine), and the treatments were combined with 4 levels of nitrogenous fert. (0, 52, 182, 312 lb. N per acre) in a replicated factorial design. Applied N and urine were the dominant influences on bot. comp. With progressive increases in N, % ryegrass increased and clover decreased. Volunteer spp. (mainly *Poa* spp.) contributed up to 20% by the final yr., the most under medium-high N. Urine restricted incursion of weed grasses. Combined with urine or the full return of excreta, high N increased herbage prod. by up to 120%. There was little response to dung except at the highest N. The yield response to N was almost linear. In the absence of animal returns, response was poor, partly due to shortage of potash. When both excreta were withheld, the light N dressing depressed the ann. prod. compared with the control; where both excreta were returned together with this dressing no reduction occurred in ann. yield, and the spring yield improved ($P<0.05$).

WICHT, C. L. **398**

1948. A statistically designed experiment to test the effects of burning on a sclerophyll scrub community. I. Preliminary account. Roy. Soc. So. Africa, Cape Town, Trans. 31(5): 479–501, illus.

Five blocks of 6-yr.-old scrub regrowth were laid out, and in each of these the 8 burns on the 15th day of the mos. Jan to Apr. and Sept. to Dec. were made in random quadrants. Each quadrant included 4 sq. m. A careful analysis was made of the quadrants before treatment. This gave some idea of the magnitude of the differences that would have to develop in the different burns before they could be accepted as statistically significant. The results of the Jan. to Apr. burns, as observed in the succeeding winter and spring, are described. Burning had no immediate adverse effect on moisture or organic material in the surface soil layers. The expt. provided no evidence that germination of the seeds and devlpmt. of geophytes were either promoted

or retarded by fire. Burning in summer and autumn will generally promote the flowering towards the end of winter and spring of *Oxalis* spp., other geophytes, and probably some therophytes. But such burning will prevent the flowering, for 1 season at least, of many peren. shrubby spp., especially those that redevelop from seed. It also appeared probable that late burning in autumn was more unfavorable for flowering in spring than burning in midsummer.—Biol. Abs.

See also **18, 46.**

QUANTITATIVE PLANT DISTRIBUTION

SPATIAL DISTRIBUTION, HOMOGENEITY, PATTERN, AND FREQUENCY-DENSITY RELATIONS

ABERDEEN, J. E. C. **399**

1958. The effect of quadrat size, plant size, and plant distribution on frequency estimates in plant ecology. Austral. Jour. Bot. 6(1): [47]–58, illus.

The theoretical foundation for frequency estimates, as used in plant ecol., is discussed. An equation is derived in which the absence value is linked with the quadrat size, the plant unit size, the plant density, and the aggregation of the plant units. Graphical methods are used to estimate the density and the av. size of the individuals of a sp. for a random distrib. Departure from a random distrib. can also be detected by these methods. It is shown that if an estimate of the av. plant unit size is combined with the frequency estimates, then the reliability of the results is increased considerably. The value of frequency estimates made with 1, 2, or more sizes of quadrats is discussed.—Auth. sum.

ARCHIBALD, E. E. A. **400**

1952. A possible method for estimating the area covered by the basal parts of plants. So. African Jour. Sci. 48(9): 286–292, illus.

When % frequency is plotted against the log of the area of the quadrat, a series of S-shaped curves for different fractions of cover is obtained. The point of inflection of these curves is variable. In using % frequency to estimate basal cover, it is found that the av. size of the cluster of individuals of a sp. (or of the individual itself if distrib. is random) must be considered 1 of the variables. Size of the quadrat from which an estimate of the basal area covered by the sp. can be made is determined by the point of inflection of the curve. By the multiple quadrat method inform. concerning all spp. in the community can be obtained in a single survey. The method is considered practicable provided an equation can be found to express the increase in % frequency with increase in sample area.—Biol. Abs.

ARRHENIUS, O. **401**

1922. A new method for the analysis of plant communities. Jour. Ecol. [London] 10: 185–199, illus.

ASHBY, ERIC. **402**

1935. The quantitative analysis of vegetation. (With an appendix by Stevens, W. L.) Ann. Bot. [London] 49(196): [779]–802, illus.

Statistical examination of data from 4,000 quadrats, of 2 sizes, taken at random in a population of *Salicornia europea*, showed that the individuals were distributed almost at random in the uniform environment, but there was a small but significant aggregation of the individuals. The relation between % frequency and density is given approximately by $p=1-e^{-kx}$ where p is the probability of finding a sp. of density x in a quadrat of area k. Percentage frequency (defined by Raunkiaer as the % occurrence of spp. in a no. of quadrats taken at random) is therefore not a satisfactory index to the density of a sp. Support is given to Kylin's suggestion that J-shaped skew distrib. of spp. in % frequency classes depends on the fact that frequency classes of equal width do not correspond to equal density classes, and is no indication of homogeneity of a community.—Biol. Abs.

ASHBY, ERIC. **403**

1948. Statistical ecology. II.—A reassessment. Bot. Rev. 14(4): 222–234, illus.

The appl. of statis. methods to the analysis of vegetation is critically examined in the light of pubs. since 1936. The following conclusions are reached: (a) statis. methods are of no value in the classification of plant communities; (b) statis. methods are valuable in the analysis of the distrib. of individual sp. There is abundant evidence that most spp. are overdispersed, and an important prob. in statis. ecol. is to work out quantitative methods of studying overdispersion.—Biol. Abs.

BARTLETT, M. S. **404**

1960. Stochastic population models in ecology and epidemiology. 90 pp. New York: John Wiley and Sons, Inc.

BLACKMAN, G. E. **405**

1935. A study by statistical methods of the distribution of species in grassland associations. (With an appendix by Bartlett, M. S.) Ann. Bot. [London] 49(196): [749]–777, illus.

The nature of spp. statis. distrib. over small areas in a no. of grassland assocs. was critically analyzed. Some 12,000 quadrats were observed. Some spp., of which the individual plants could be distinguished, showed a random distrib. (Poisson type). Others such as *Plantago media* and *Primula auricula* were not distributed at random. In stoloniferous and other spp. the density was estimated by area covered or no. of tillers; the distrib. curves were markedly asymmetrical, the "skewness" being greatest for occasional and least for dominant spp. The relation found between quadrat size and av. no. of spp. did not agree closely with the theoretical relation calculated on the assumption of random distrib. of all the spp. But exclusion of the rarer spp. improved the agreement. If a sp. is distributed at random, the log of the % absence is directly proportional to density. Estimation of % absence in the quadrat is liable to little personal error, is rapid, and has much to recommend it for an ecol. study of bot. changes. On theoretical grounds, the most accurate measure of density is to be obtained by using a quadrat of such a size that the % absence is 20–30%.

BLACKMAN, G. E. **406**

1942. Statistical and ecological studies in the distribution of species in plant communities. I. Dispersion as a factor in the study of changes in plant populations. Ann. Bot. [London] (n.s.) 6(22): [351]–370, illus.

This further study of plant populations was of the distrib. of 10 spp. in grassland communities. In each sample area (100 sq. m. or less) the no. of individuals in 100–200 random quadrats was counted, 18,000 observs. in all being made. Data for *Arnica montana, Campanula barbata,* and *Gentiana acaulis* were collected in the Austrian Tyrol. The sample areas were confined to alpine meadows in which *Nardus stricta* was dominant. For the remaining 7 spp.—*Cirsium arvense, Erythraea centaurium, Gentiana amarella, Ohyrys apifera, Poterium sanguisorba, Senecio campestris,* and *Ranunculus bulbosus*—the observs. were on chalk downland in south. England. For most spp., variations in distrib. within a single community were studied in a block of plots. Departures from a random distrib. could be tested for by calculating the coefficient of dispersion, i.e., the variance divided by the mean. Plants were significantly overdispersed or underdispersed if the coefficient was greater or less than unity by $2\sqrt{\frac{2n}{(n-1)^2}}$ where n equals number of quadrats. If the coefficient did not differ significantly from unity, then the χ^2 test for the fitted Poisson distrib. had to be appl. This was because the coefficient of dispersion is not a sensitive test for certain skew distribs. The results showed that nature of the distrib. depended on the sp. and locality. Only *P. sanguisorba* could be considered distributed at random. Since the coefficient of dispersion of the remaining 9 spp. tended to exceed unity, individual plants were overdispersed. Dispersion was least for *S. campestris, G. acaulis, C. barbata,* and *C. arvense.* These 4 spp. might have been randomly distrib. in some areas and overdispersed in others. The other 5 spp. were rarely or never randomly distrib., and the degree of overdispersion was greatest for 3 of them, *A. montana, R. bulbosus,* and *E. centaurium* (mean coefficient of dispersion 2.31, 2.63, and 8.44, respectively). In only 1 site was there underdispersion; here markedly underdispersed *P. sanguisorba* plants had a coefficient of dispersion of 0.62. Despite the general tendency to overdispersion, it has been found that the relation between the log of % absence (% number of quadrats containing no individuals) and mean plant density of each sp. is approximately linear. Density changes can therefore be estimated from changes in % absence even when the distrib. is not random. Under these conds. it is necessary to apply a correction factor to determine the absolute changes in density from % absence figs. on a log scale. For the 10 spp. this has been found to vary from 0.96 for *P. sanguisorba* to 2.28 for *E. centaurium.*

BÖCHER, TYGE W. **407**

1935. Om en metode til undersøgelse af konstans, skudtaethed og homogenitet. [On a method for investigating constancy, shoots density, and homogeneity.] Bot. Tidsskr. [Copenhagen] 43(4): 278–304, illus. [Eng. sum.]

This is a modification of Raunkiaer's method for determining frequency. The auth.

was able, however, by dividing the radius of the circle into 4 equal pts., to investigate the occurrence of the spp. within 4 circular areas, 1 outside the other, the innermost being 0.01 sq. m., the outermost 0.9 sq. m. Examples of analyses by the new method are given, and comparative invests. of some types of vegetation are recorded.

BÖCHER, TYGE W., AND BENTZON, MICHAEL WEIS. 408
1958. Density determination in plant communities. Oikos [Copenhagen] 9(1): [35]–56, illus.

Böcher's (1935) modification of Raunkiaer's method of frequency analysis is further modified. Instead of using circles of 4 different sizes and of awkward areas, concentric circles of 3 sizes are utilized, covering areas of 0.1, 0.01, and 0.001 sq. m. The apparatus used is simply an alpenstock with an attached crosspiece that indicates the radii of the 3 circles. In practice, all spp. occurring within the innermost (smallest) circle are listed, then all additional spp. in the middle-sized circle, and finally all additional spp. in the largest circle. This procedure is repeated 10 times at random locations. The results are treated statistically. The method is elucidated by the analysis of communities of lichens at Korshage, north. Seeland, Denmark. It is concluded that by use of this method it is possible to detect and analyze rather small differences in the comp. of the vegetation in such communities of small plants. In a 2nd pt. of the paper the math. basis of the density determinations is examined. It is found that the method gives a broader range of discrimination than the older method, but that the accuracy within the range is somewhat smaller.—Biol. Abs.

BRAY, J. ROGER. 409
1962. Use of non-area analytic data to determine species dispersion. Ecology 43(2): 328–333.

A proposed method of estimating spatial dispersion does not require a separate sampling procedure but utilizes nonarea analyt. sampling techniques such as the quarter and order methods. It is based on the observ. that in a nonarea analyt. sample with a constant no. of individuals per point, the distrib. of nos. of individuals per point should follow a binomial distrib. for a randomly dispersed sp. Models for extreme regular, random, and extreme contagious dispersions are presented, and the use of χ^2 as a significance test is discussed. Four trees per point were tallied in sampling of two map populations and 20 natural forest stands by the quarter or order methods. Relative dispersion agreed with actual spatial dispersion measured by the Hopkins and Clark-Evans methods. Of 53 tree dispersions in the field survey, 16 were contagious and 2 regular; of 7 understory spp., 5 were contagious. Some mechanisms discussed that may underlie these dispersions include manner of dissemination and regeneration, stage in forest devlpmt., recovery from disturbance, and microsite differences.

CLAPHAM, A. R. 410
1936. Over-dispersion in grassland communities and the use of statistical methods in plant ecology. Jour. Ecol. [London] 24(1): 232–251.

Data of T. L. Steiger [Ecology 11: 170–217, 1930] are studied statistically to determine mode of spp. distrib. Of 44 spp. tabulated, the relative variance in 42 exceeds 1 and is less in but 2. Because the relative variance in randomly distributed spp. equals 1, the frequent exceeding of 1 indicates that most spp. were less uniformly dispersed than random and tend to be patchy. The relative variance tends to increase with increase of sp. mean density. When the quadrats were divided into classes of 0, 1, 2, 3, etc., individuals of a sp. per quadrat, the size of the classes deviated from what would be expected from random dispersion. And the deviations increased with mean density. The auth. concludes that in the prairies of east. Nebr. the individuals of most of the spp. show strong overdispersion. He suggests this may be due to the methods of reproduction of the spp., vegetative propagation tending to result in formation of patches with greater than mean density around the older plants. He also suggests that overdispersion may greatly increase the difficulty of determining the mean density of the different spp. from a set of random quadrats.

CLARK, PHILIP J. 411
1956. Grouping in spatial distributions. Science 123(3192): 373–374.

CLARK, PHILIP J., AND EVANS, FRANCIS C. 412
1955. On some aspects of spatial pattern in biological populations. Science 121(3142): 397–398.

COTTAM, GRANT. 413
1951. Phytosociological measurements of non-random plant distributions. Ecol. Soc. Amer. Bul. 32: 58.

CURTIS, JOHN T. 414

1955. A note on recent work dealing with the spatial distribution of plants. Jour. Ecol. [London] 43(1): 309.

A set of field data used in several theoretical invests. is shown to be invalid because of subjective choice of the location of samples.

DĄBROWSKI, M. J. 415

1956. [Numerical distribution and occurrence of the species comprising the ground vegetation.] Ekologia Polska, Ser. A, 4(12): 349–376. [In Polish with Eng. and Russ. sum.]

DICE, LEE R. 416

1948. Relationship between frequency index and population density. Ecology 29(3): 389–391.

Counts of 3 plant spp. in a series of random yd.-sq. plots in south. Mich. showed none is distributed at random over the field. The frequency index of each sp., consequently, gives an erroneous estimate of its population density. These densities range from about 2/3 to less than 1/10 of actual densities from counts of individuals.

EVANS, FRANCIS C. 417

1952. The influence of size of quadrat on the distributional patterns of plant populations. Mich. Univ. Lab. Vert. Biol. Contrib. 54, 15 pp., illus.

The distributional patterns of populations of *Lespedeza capitata*, *Liatris aspera*, and *Solidago rigida* occurring in an old-field grassland community in southeast. Mich. have been subjected to analysis by quadrats of several different sizes. The size of quadrat was found to affect the resulting values of frequency and abundance, as well as the frequency distribs. of the no. of individuals per quadrat. It was also shown to have a marked effect upon various measures of dispersion. This demonstration suggests the desirability of utilizing several sizes of quadrat in securing samples for the study of distrib. patterns and other phytosociol. characteristics. If data for several quadrat sizes are available, a frequency-density curve may be derived that will enable one to determine qualitatively the degree to which the observed distribs. depart from randomness and to compare material obtained with quadrats of different size.—Auth. sum.

GOODALL, D. W. 418

1961. Objective methods for the classification of vegetation. IV. Pattern and minimal area. (Includes Appendix I, by Binet, F. E.) Austral. Jour. Bot. 9(2): [162]–196, illus.

The structures of Victoria salt marshes and mallee scrub and Uganda rain forest were studied. The quadrats used formed a continuous grid or transect or were distributed by restricted randomization; the measures used were cover or basal area. Increase in variance as the mean spacing between the sample areas increased was mostly continuous, a linear regression between the logs of the variables often fitting the data. A quadratic or higher-order regression was indicated at other times, and some approximated to a "stepwise" curve of the type suggested by Greig-Smith and others. This, however, appeared to be the exception. The theoretical implications of a continuous increase of variance with spacing are briefly discussed.

GRANT, J. A. C. 419

1951. The relationship between stocking and size of quadrat. 35 pp. Ontario: Univ. of Toronto Press.

The stocked quadrat system, attributed to Lowdermilk, is a method for rapid survey of vegetation. It attempts to eliminate the shortcomings of stocking figs. based on no. of seedlings per acre. An area is broken up into squares and quadrats of perhaps 1/500 to 1/1000 acre, and a randomly selected number of such quadrats are merely classified as stocked or unstocked. A quadrat will be classified as stocked if it contains at least 1 seedling. In a quadrat of ideal size 1 seedling would ultimately lead to a fully stocked stand of several hundred trees per acre. Obviously no acct. is taken of mortality and no allowance made for mature trees possibly growing in clumps, or for ideal stocking at maturity not necessarily being ideal at the regenerative stage of a plant community. Despite these and other shortcomings, results from surveys with the stocked quadrat system have been useful. The auth. discusses influence of quadrat size and shows that it makes a significant difference in the stocking figs. obtained. This poses the prob. of how to convert stocking figs. from 1 size of quadrat to those for a different size. If x (expressed as a decimal fraction of unity) represents the stocking observed with a quadrat of, say, p milacres, then the corresponding stocking for a quadrat of $q=rp$ milacres, is $y=1-(1-x)^r$. The

quantity, $1-x$, is the probability that a randomly selected quadrat is not stocked. Assuming that the probabilities of stocking on neighboring quadrats are independent, then the probability that a contiguous quadrat of size rp would not be stocked is $(1-x)^r$, and conversely, the probability that a contiguous quadrat of size $q=rp$ is stocked is $1-(1-x)^r$. This formula therefore permits conversion from 1 size quadrat to another. The proposed conversion formula represents an approx. only as the probability of stocking on 1 quadrat is not unrelated to the probability of stocking on a neighboring quadrat. Bias inherent to the formula can be reduced by subdividing an area on which a stocking survey is made into more homogeneous blocks or strata. It is explained, and documented with numerical data, that the actual stocking fig. for a new size of quadrat lies between the original figure x, and the value y given by the conversion formula.

GREIG-SMITH, P. 420
1952. The use of random and contiguous quadrats in the study of the structure of plant communities. Ann. Bot. [London] (n.s.) 16(62): [293]–316, illus.

Individuals of many spp. are nonrandomly distributed. The nature of such nonrandomness is discussed and a mosaic pattern of phases suggested as 1 cause, the phases having the same spp. at different densities. Artificial "communities" of discs have been sampled by random quadrats of various sizes and by a grid of contiguous quadrats. The variance shown by grid data has been analyzed into components contributed by blocks of grid units of increasing size. These expts. have shown that (1) use of a single quadrat size is not sufficient to detect nonrandomness; (2) in grid sampling of a clumped distrib. where the clumps are underdispersed, variance is at a peak at the block size corresponding to the mean area of clump; where clumped distrib. is in a mosaic of phases of different densities, variance is at a peak at the mean size of mosaic unit; (3) if clumps are random or overdispersed no significance can be attached to any peak in the variance graph. Such distribs. are, however, likely to be detectable by observ. in the field. Compared to random quadrats a grid gives more inform. on the nature of a nonrandom distrib. and can detect mosaic patterns not revealed by subjective methods. It can also be used where random quadrats are impractical, e.g., in forest.

GREIG-SMITH, P. 421
1961. The use of pattern analysis in ecological investigations. Internatl. Bot. Cong. Recent Advn. Bot. 9(2): 1354–1358.

GREIG-SMITH, P. 422
1961. Data on pattern within plant communities. I. The analysis of pattern. Jour. Ecol. [London] 49(3): 695–702, illus.

Pattern within superficially homogeneous vegetation is more revealing of relation of spp. performances to controlling factors than if obviously different communities are compared. Both vegetation and environmental factors are recorded in grids or transects of contiguous samples, and the variance analyzed into pts. appropriate to different block sizes. Peaks in the mean sq./block size graph indicate scales of pattern present. Length of transect is determined by maximum scale of pattern to be detected, size of basic unit by the smallest scale, and no. of units by intensity of pattern and abundance of spp. involved. Significance of peaks is assessed by (a) consistency between observs., (b) use of calculated significance bands. Terms for covariance with position may be deducted to allow for trends along the transects. The relation between patterns for different spp. may be examined by the use of correlation coefficients for different block sizes.

GREIG-SMITH, P., AND KERSHAW, K. A. 423
1958. The significance of pattern in vegetation. Vegetatio [Hague] 8(3): [189]–192.

GREIG-SMITH, P., KERSHAW, K. A., AND ANDERSON, D. J. 424
1963. The analysis of pattern in vegetation: A comment on a paper by D. W. Goodall. Jour. Ecol. [London] 51(1): 223–229, illus.

In a recent paper, Goodall criticized the interpretation put forward by Greig-Smith and others for variance in block size graphs, and claimed that peaks in such graphs represent random fluctuations only. He offered an alternative interpretation in terms of regression of variance on spacing. Greig-Smith et al. reply that the apparent fit by linear regressions sometimes obtained by Goodall results from (a) failure to allow for overall trends in representation of spp. along transects, (b) the rising curve to be expected for random distrib., (c) the appl. of log transformation to the variance data. Tests more appropriate than that proposed by Goodall show lack of correspondence with expectations in observed no. of graphs with 1, 2, 3, and 4 peaks and in observed no. of peaks at different block sizes. Goodall's criticisms are

thus invalid, his alternative interpretation making at least as many assumptions as the original and raising the difficulty of the biol. meaning of the calculated constants.

HOPKINS, BRIAN. **425**

1957. Pattern in the plant community. Jour. Ecol. [London] 45(2): 451–462.

A method is described for obtaining groups of positively assoc. spp. (called basic units) within a plant community. Data from numerous small quadrats are analyzed with a 2×2 contingency table and a χ^2 significance test. The quadrats used for this analysis are allotted to basic units, and the proportion of the community area occupied by each basic unit is estimated. Using data from quadrats of different areas, mean size of these basic units can be estimated. Three different types of Brit. vegetation were studied. They were found to consist of a matrix of 1 basic unit occupying over 60% of the community area and at least 2 other basic units. It is suggested that the concept of minimal area should be replaced by that of basic unit.

HUTCHINGS, SELAR S., AND HOLMGREN, RALPH C. **426**

1959. Interpretation of loop-frequency data as a measure of plant cover. Ecology 40(4): 668–677, illus.

The inherent positive bias of the loop-frequency index as an index of % plant area depends on plot (loop) size, and no. and size of plants. Algebraic equations by which loop indices may be converted to % plant area are given. The influence of plant distrib. pattern on the bias is shown, and a way to eliminate this effect, which cannot be corrected for by math. manipulation, is suggested. Although deviation of individual plant shape from circularity increased the bias, no formula is available for correcting for this. Some of the theoretical relations were tested on synthetic and natural plant populations. Results conformed closely to theory. Possible modifications for reducing the inherent bias of the loop-frequency method are discussed.—From auth. sum.

KAYAMA, RYOSEI. **427**

1961. New methods of quantitative representations on the structure of plant communities. I. Application of discriminating equation on Pólya-Eggenberger distribution. Jap. Jour. Ecol. 11(1): 4–10, illus. [In Jap. with Eng. sum.]

New methods of representing dominance in a plant community are introduced. To discriminate coarsely the distrib. type of Pólya-Eggenberger on a plant community,

$$\lambda=\frac{h+xd}{1+d}$$

diagram is usually used, where h is $\bar{x}$ and d is $1-v/x$ for the maximum likelihood estimate. In the new method of representing the dominance with this diagram, the points obtained from the equation draw a straight line in the 1st plane constructed from 2 axes. The auth. found that dominance is closely related to the angle formed by the straight line and x-axis. The relation between the distrib. type and the angle shows an ascending line for the Pólya-Eggenberger type, a line nearly parallel to x-axis for the Poisson type, and a descending line for binominal type. The angle constructed from the ascending line and x-axis does not exceed about 40°. The distrib. type varies with time in such a process as Poisson type→Pólya-Eggenberger type→Poisson type→binominal type.—From auth. sum.

KAYAMA, RYOSEI. **428**

1961. New methods of quantitative representation of the structure of plant communities. II. Representation of the dominance in a plant community by the degree of competition. Jap. Jour. Ecol. 11(2): 62–66, illus. [In Jap. with Eng. sum.]

A method is described for representing dominance in a plant community by the area of a triangle constructed from $\lambda=\frac{h+xd}{1+d}$ diagram, the area being computed by the intersected length of the straight line and 2 axes. Two lines of different spp. are drawn separately on the same system of coordinate axes at 1 point in the 1st plane. The angle formed by these intersected straight lines is regarded as the degree of competition of 2 spp. The dominance subordination relation of 2 spp. is indicated by the degree of competition.—From auth. sum.

KAYAMA, RYOSEI. 429
1961. New methods of quantitative representation of the structure of plant communities. III. Representation of the dispersive structure by the difference of variation ratio. Jap. Jour. Ecol. 11(3): 93–97, illus. [In Jap. with Eng. sum.]

KERSHAW, K. A. 430
1957. The use of cover and frequency in the detection of pattern in plant communities. Ecology 38(2): 291–299, illus.

A method using frequency and cover data to determine the dimensions of heterogeneity in plant communities is outlined. Adjacent transect readings are grouped together into different block sizes, the variance of any block size rising to a peak at the mean dimension of an area of heterogeneity. The difficulty of testing the significance level of such a peak, once nonrandomness has been established, is discussed, and from the analyses of a series of expts. with artificial communities, a subjective approach to this prob. is proposed. Field work has established cover as the more suitable measure of plant abundance, especially for work on grassland communities.—Auth. abs.

KERSHAW, KENNETH A. 431
1960. The detection of pattern and association. Jour. Ecol. [London] 48(1): [233]–242, illus.

A method of analysis has been designed to detect both pattern and the level of assoc. between individuals in a community. If 2 spp., A and B, are assoc., then comparing variance of the grouped data AB to expected variance (assuming independent variables, i.e. Variance (A+B)=Variance A+Variance B) will show the trend of correlation at all block sizes: (a) Positive assoc., the amplitude of a peak is increased; (b) Negative assoc., the amplitude of a peak is decreased; (c) Nil assoc., a slight variation of amplitude at a nonsignificant level (t or r being calculated directly from the variance of A, B, and AB at any block size). The effectiveness of the method is demonstrated with artificial layout and field data. Although the method was originally developed for use with a computer, it is less laborious than calculating correlation coefficients at all block sizes.

KERSHAW, KENNETH A. 432
1960. Cyclic and pattern phenomena as exhibited by *Alchemilla alpina*. Jour. Ecol. [London] 48(2): [443]–453, illus.

The varying levels of performance of *Alchemilla* throughout its life cycle, expressed as leaf diam. and leaf no., have been investigated. Counts of growth rings give the age of each plant, and the performance values for each age class fit a 2nd order polynomial. The results are related to cyclic phases in vegetation and the occurrence of nonrandomness.

KERSHAW, KENNETH A. 433
1963. Pattern in vegetation and its causality. Ecology 44(2): 377–388, illus.

A general classification of pattern in vegetation based on causality is suggested, 3 groups being established: morph. pattern, environmental pattern, and sociol. pattern. The relation between quantity and intensity of pattern in relation to the degree of maturity and stability of vegetation is discussed, and further data are described which support the hypothesis of a minimum pattern and assoc. between spp. in climax vegetation. The possibility of an increase in the level of assoc. between 2 spp. (*Festuca rubra* and *Agrostis tenuis*) in the intermed. zone between 2 communities merging along an environmental gradient is discussed with ref. to pattern data from chalk grassland.—Herb. Abs.

LYNCH, D. W., AND SCHUMACHER, F. X. 434
1941. Concerning the dispersion of natural regeneration. Jour. Forestry 39(1): 49–51, illus.

Although reproduction is not distributed at random on cutover areas, analysis of recently published data from the west. pine type shows that a range in size of quadrats from 1 to 4 milacres leads to strictly consistent estimates.

MCGINNIES, W. G. 435
1934. The relation between frequency index and abundance as applied to plant populations in a semiarid region. Ecology 15(3): 263–282, illus.

Under ideal conds., there is a high degree of correlation between frequency index and abundance. Under field conds., although the relationship between frequency index and abundance is somewhat altered, there is still a high degree of correlation. Under both conds., abundance can be calculated for a given frequency index by means of

the proper curve or equation. There is a high degree of correlation between the frequency indices obtained simultaneously for 1 sq. m. and 0.1 sq. m. quadrats. Furthermore, the frequency index for 0.1 sq. m. quadrats multiplied by 10 approximates the abundance on the 1 sq. m. quadrats. The 1 sq. m. quadrat gives the lowest n/FI ratio for the less abundant spp., and 0.1 sq. m. quadrat gives the lowest for the more abundant spp. The size of the quadrat used should be determined by the character of the vegetation and the purposes of the study.—Auth. sum.

MACHIN, E. J. **436**

1948. Determination of plant densities. Nature [London] 162: 257.

In surveying plant assocs., it is usual to determine the valence by noting the presence or absence of each sp. in sample areas, and the density by counting the no. of individuals of each sp. in the same, or other, sample areas. Two difficulties are frequently encountered in determining densities by this method, the length of time needed in the field and the intermingling of root systems of individual plants of the same sp. with consequent indecision as to the exact no. present in the sample. The following method has the advantages of requiring 1 set of observs. only, from which valence and density may be determined, and of avoiding counts within the sample areas. Suppose the sp. has a density N/A plants per unit area and that a sampling area a is taken t times at random. Then the expected no. of plants per trial will be aN/A, and the no. y_0 of trials containing no individuals of the sp. would be expected to be given by the expression

$$y_0 = t \exp(-aN/A).$$

$$\text{Whence } N/A = 1/a \cdot \log_e \cdot t/y_0.$$

If the no. of trials is 50 and the sampling area 0.1 sq. m., a graph relating density and y_0 can be drawn and shows a remarkable sensitivity for densities 33 per sq. m. to 3 per sq. m. By increasing the sampling area to 1 sq. m., the density values on the graph are reduced 10 times, and we have a sensitive range from 3.3 per sq. m. to 0.3 per sq. m. Much time has been saved in the field, and results are reasonably in accord with densities found by the more laborious method. [Entire article.]

MARGALEF, RAMÓN. **437**

1956. Información y diversidad específica en las communidades de organismos. [Information and specific diversity in communities of organisms.] Invest. Pesquera [Barcelona] 3: 99–106, illus. [In Sp.]

Expressions from inform. theory that may be substituted for the well-known "diversity indices" are free of the postulate of a certain regularity in the distrib. of individuals into spp. The "mean entropy" per individual, as computed by the expression of Brillouin, $D = \frac{1}{N} \log \frac{N!}{N_1!\, N_2! \ldots N_s!}$, where N is the total no. of individuals and N_1, N_2 . . . N_s, the no. of individuals of each sp. 1, 2, . . . s, gives results in agreement with those supplemented by other diversity indices, but of wider appl. When confounding samples separated in space or time, degree of increase in "diversity" provides a useful tool for the study of spatial heterogeneity and for the analysis of population sequence.

MARGALEF, RAMÓN. **438**

1957. La teoría de la información en ecología. [Information theory in ecology.] Barcelona R. Acad. de Cièn. y Artes, Mem. Ser. 3, 32(13): 373–449, illus. [In Sp.]

This paper begins with math. now generally used in biol., and its inadequacy. Then there is a long treatment of inform. theory in mixed population description with many equations and charts, and illus. taken from analysis of plankton in Vigo estuary. Topics include spp. diversity or richness in mixed populations, study of spatial structure of communities, dynamics of mixed populations, and appl. to other organic structures.

MITSUDERA, MITSUO. **439**

1954. Studies on phytometer, II.—Phytometer method in communities. Jap. Jour. Ecol. 4(3): 113–120. [In Jap. with Eng. sum.]

This paper considers the mode of response of a plant community, the assumption being that the mode of distrib. of a component sp. probably approaches randomness. As a measure, the deviation of a component sp. from the mode of distrib. of the dominant seems to be the most useful expression of the effective environment of a plant community.

MOUNTFORD, M. D. 440
1961. On E. C. Pielou's index of non-randomness. Jour. Ecol. [London] 49(2): 271–275.

The index is calculated from the distances of random points to the nearest plants. The sampling properties of the index are determined. A test of the randomness of a plant distrib. is given.

PIDGEON, ILMA M., AND ASHBY, ERIC. 441
1940. Studies in applied ecology. I. A statistical analysis of regeneration following protection from grazing. Linn. Soc. N. S. Wales, Proc. 65: 123–143, illus.

Vegetation was studied in reserves protected from grazing and in adjacent unfenced grazed commons. The quantitative analysis included observs. on (1) the relation between spp. and area and (2) the density and distrib. of individual sp. in fenced and unfenced areas. Spp.-area curves from sample strips of different sizes showed the communities studied were homogeneous, and spp. as a whole randomly distributed. Since most spp. recorded in these samples had a frequency of 20% or less, the density and distrib. of individual sp. was determined from sample strips 10 m.×0.15 m. In 24 cases out of 75, there was no significant difference between observed density and that calculated from the appropriate Poisson series. In nonrandom distrib. where the χ^2 test indicated significant departure from Poisson distrib. (random distrib.), differences were significant between observed and calculated densities. It was found that the same sp. may be randomly distributed in 1 area and aggregated in another; normality of distrib. disappears with increasing density. The data indicate that protection from grazing for less than 2 yrs. has (1) markedly increased the growth of the individuals present before fencing, increase in the ht. of *Stipa* being mainly responsible for the visible differences between fenced and unfenced sects. in lightly grazed areas; (2) increased the density of peren. individuals in heavily grazed areas; (3) decreased the density of the 3 most undesirable species, *Malva*, *Lotus*, and *Argemone*, which apparently cannot withstand competition; (4) reduced in good seasons the mean density of anns. by competition with robust perens.; (5) increased the var. of peren. and ann. spp.

PIDGEON, ILMA M., AND ASHBY, ERIC. 442
1942. A new quantitative method of analysis of plant communities. Austral. Jour. Sci. 5: 19–21, illus.

A simple quadrat sampling method for determining the structure or pattern of a plant community is described and involves the construction of lines of equal % frequency (isonomes). The method need not be confined to a physiognomically homogeneous community.

PIELOU, E. C. 443
1960. A single mechanism to account for regular, random and aggregated populations. Jour. Ecol. [London] 48(3): [575]–584, illus.

A single mechanism of population growth can account for regular, random, and aggregated populations. In a uniform habitat, it is assumed that (a) The spatial pattern of germinating seeds is random; (b) the plants thrive only if their root systems occupy ground not already occupied by earlier colonizers; and (c) the size plants grow to depends on the space available. Appl. of the tests commonly used to detect randomness or departures from it may then give any of the 3 possible results, an aggregated population being indicated when the size range of the plants and the density are great enough. Where this mechanism of population growth is operating one finds the distance from a plant to its nearest neighbor positively correlated with the sum for the 2 plants of some measure of the sizes of the root systems (e.g. sum of the trunk circumferences). This mechanism also explains the rarity of regular populations in nature. The study of model populations shows that with circular "plants" pattern is regular only when the range of possible circle diameters is small, or, if this range is large, when the density is low. But in a natural population of low density, intraspecific competition, the only conceivable cause of regular spacing, would be comparatively unimportant.

PRÉCSÉNYI, S. 444
1959. The estimation of density of *Convolvulus arvensis* in a grass-legume mixture. Ecology 40(4): 732.

SHIUE, CHERNG-JIANN, AND BEAZLEY, RONALD. 445
1957. Classification of the spatial distribution of trees using the area sampling method. Forest Sci. 3(1): 22–31, illus.

A means of consistently classifying spatial tree assocs. by areal plots is by relative terms of probable departure of skewness and cent. tendency from a rectangular distrib. Two tests are involved, 1 for cent. tendency and 1 for skewness. The departures can be

used to express the clumpness and evenness of tree distrib. on the ground and are shown in a table and fig. at probability levels 0.25 and 0.05. Differences between 2 spp. or 2 plant communities in spatial distrib. can also be tested in terms of skewness and cent. tendency in ref. to a rectangular distrib.

SKELLAM, J. G. **446**
1952. Studies in statistical ecology. I. Spatial pattern. Biometrika [London] 39: [346]–362, illus.

In considering a number of quadrat sampling distribs. in relation to the underlying pattern of organisms, it is most noticeable that the same distrib. may arise from several distinct models. Satisfactory graduations of frequency data are usually possible on a wide var. of alternative hypotheses. Whether a given model is appropriate must be determined in the light of additional evidence of a different kind. A few ways are briefly suggested as to how this prob. might be approached.

SUDIA, THEODORE W. **447**
1960. Frequency calculations from several different forest ecological sampling methods. Ohio Jour. Sci. 60(2): 100–105, illus.

Three sampling methods are the quadrat, the point-centered-quarter, and the plotless variable radius. It is demonstrated that spp. frequencies estimated by all 3 methods can be compared, so long as the following are reduced to common terms: Sp. frequency (the probability of finding the sp. of interest in a given subsample), sp. density (number of stems of the sp. of interest per unit area), and relative sp. density (the probability of encountering the sp. of interest when sampling the stems 1 at a time). Analysis of variance showed no significant differences between methods.

SUZUKI, K. **448**
1960. The average variation rate line as a method of statistical analysis for the mode of distribution of plants in plant communities. Jap. Jour. Ecol. 10(4): 168–171. [In Jap. with Eng. sum.]

THOMPSON, H. R. **449**
1955. Spatial point processes, with applications to ecology. Biometrika [London] 42(1/2): [102]–115.

THOMPSON, H. R. **450**
1956. Distribution of distance to *n*th neighbour in a population of randomly distributed individuals. Ecology 37(2): 391–394.

THOMPSON, H. R. **451**
1958. The statistical study of plant distribution patterns using a grid of quadrats. Austral. Jour. Bot. 6(4): [322]–342, illus.

The statis. theory of the method of analysis of variance on a grid of contiguous quadrats is examined and the results from theoretical models for plant communities giving rise to nonrandomness in the field discussed. Some field data are analyzed and the theoretical and practical results correlated to determine the efficiency of the method as a practical technique. The large element that chance variation plays in practice makes it essential for several samples of the same community to be taken so that real and chance effects can be distinguished. A knowledge of the morph. of the sp. under consideration is desirable, for then some idea of the expected analysis of variance is available and there should be no confusion between different models.—Auth. sum.

TURNER, FREDERICK B. **452**
1962. Some sampling characteristics of plants and arthropods of the Arizona desert. Ecology 43(3): 567–571.

Neither *Larrea* nor *Franseria* shows contagious dispersion, and density of both plants could be estimated effectively by quadrat counts. For estimating total nos. of arthropods, tests of geog. homogeneity indicate that spp. vary in minimal area to be surveyed. Tests could be adapted to estimate area size. A count of individuals in such an area may be more reliable than in a no. of small quadrats of the same total extent. Nonrandom arthropod spatial dispersions are not related to dispersions of the 2 most abundant perens. or to burrow location. Five of the 6 arthropod spp. studied were, on 1 night or another, captured in nos., indicating nonrandom behavior. This implies unequal probability of capture during sampling and invalidates the removal method of estimating nos. Run tests did not indicate nonrandomness in sequences of captures.

VRIES, D. M. DE, AND HOOGERS, B. J. **453**
1959. Distribution of tillers of plant species in old permanent grassland with different types of use. Netherlands Jour. Agr. Sci. 7(3): 232–236.

WAGNER, R. O. 454
1960. Distribution patterns of some prairie plants and their relationships to methods of reproduction. Diss. Abs. 21(6): 1348–1349.

WHITFORD, PHILIP B. 455
1949. Distribution of woodland plants in relation to succession and clonal growth. Ecology 30(2): 199–208.

A random quadrat study was made of 26 forest stands representing various successional stages in the prairie-forest border region of Wis. Three arbitrary tolerance classes were established, and the stands were classified as oak-hickory, intermed., and maple-basswood by % basal area. While the typical woodland spp. commonly show up as contagiously distributed in the earlier stages of succession in quadrat data, they tend to become better dispersed, or more random, as succession advances. Species more typical of prairie and early forest stages sometimes tend to poorer dispersion again in their relict stages as the climax is approached. As a relative measure of dispersion, use was made of the ratio of abundance (no. of stems per occupied quadrat) to frequency, termed the A/F ratio. Hypothetical curves were constructed for abundance, frequency, and density of any sp. in advancing succession, and showed that while there is a distinct peak in abundance for most spp. in the early stages of invasion, density and frequency reach their maxima in that order within the optimum ecol. range of a sp. All stands studied had some spp. of distinctly contagious distrib., indicating that validity of statis. studies on an assumption of random distrib. is doubtful.

See also **7, 8, 20, 22, 23, 28, 88, 96, 151, 156, 159–161, 163–167, 169, 170, 353, 354, 359, 365, 375–377, 398, 460, 461, 467, 472, 479, 482, 490, 496, 508, 509, 511, 520, 525, 540, 551, 789–793, 795, 798, 800, 801, 804, 807, 810–813, 815, 820, 825, 826, 845, 848, 939, 1040, 1063, 1069, 1100, 1106, 1117.**

SPECIES-AREA RELATIONS AND SPECIFIC DIVERSITY

ARCHIBALD, E. E. A. 456
1949. The specific character of plant communities. I. Herbaceous communities. Jour. Ecol. [London] 37(2): [260]–273, illus.

Data for the frequency of occurrence of the spp. in quadrats of different sizes for 10 herbaceous communities are presented as a prelim. to a statis. analysis which will be directed towards defining the specific character of these communities in quantitative terms. It is assumed that the plant community occupies a finite area and consists of a finite no. of spp., both of which are determined by the dominant spp. in conjunction with the climatic, topog., and edaphic factors. A new form of folding frame for a multiple quadrat which facilitates sampling is described. A method is suggested for estimating the commonness and rarity of spp., and it is noted that for the plant populations under consideration the common and rare spp. are less numerous than the spp. which are represented by individuals of intermed. density.—Auth. sum.

ARCHIBALD, E. E. A. 457
1949. The specific character of plant communities. II. A quantitative approach. Jour. Ecol. [London] 37(2): [274]–288, illus.

Plant communities with a large pattern unit (greater than 1 sq. m.) can be divided from those with a small pattern unit. The "pattern" is defined by (a) the 50% area (x_{50}) on which an av. of half the total no. of spp. in the community occurs, and by (b) the specific density (y_0) in av. no. of spp. per sq. cm. If the av. no. of spp. per unit area is plotted against the log of the area, an S-shaped curve is obtained. This curve can be approximated by the equation

$$\log_{10}\frac{y}{S-y}=k(\log_{10}x-\log_{10}x_{50}),$$

where y is the av. no. of spp. on area x, S is the total no. of spp. in the community, and k is a constant. A scale for the pattern of plant communities is developed from a consideration of the greatest no. of spp. that can populate 1 sq. cm., the largest area over which ecol. conds. are likely to remain constant, and from the total no. of spp. in the community. As an example, it is shown how the probable limits for herbaceous angiosperm communities in the Brit. Isles may be defined.—From auth. sum.

ARRHENIUS, O. 458
1920. Distribution of the species over the area. K. Vetensk. Akad. Nobelinst. Meddel. [Uppsala] 4(7): 1–6.

The increase of spp. with area can be expressed by a math. approx. for spaces as far

apart as Switzerland, central Sweden, and Åland. This also holds for areas of unequal size. The mean deviation between the lines used by the transect-examination also seems calculable by the law of probability.

ARRHENIUS, O. 459
1921. Species and area. Jour. Ecol. [London] 9: 95–99.

ARRHENIUS, O. 460
1923. Statistical investigations in the constitution of plant associations. Ecology 4(1): 68–73, illus.

ARRHENIUS, O. 461
1923. On the relation between species and area.—A reply. Ecology 4(1): 90–91.

CAIN, STANLEY A. 462
1935. Ecological studies of the vegetation of the Great Smoky Mountains. II. The quadrat method applied to the sampling of spruce and fir forest types. Amer. Midland Nat. 16(4): 566–584, illus.

Briefly described are examples of 2 forest types in the Great Smoky Mountains National Park, the red spruce type (*Piceetum rubentis*) and the south. balsam fir type (*Abietum fraseri*). A method of sampling the arborescent strata (similar to that widely used for nonarborescent communities) is described, based on a random sample by minimum area quadrats. The minimum area quadrat is determined for each community type by the form of spp.-area curves. Surveys with different nos. of minimum area quadrats are compared statistically from basal area data to determine the necessary no. of quadrats to be studied. Although the present paper does not contain definite studies, forest types, subtypes, and site classes will probably be found to be characterized by certain spp. inferior to the tree layer. *Abies fraseri* is thought to form, in the Great Smoky Mountains at least, a forest type in which it is the sole dominant.—From auth. sum.

CAIN, STANLEY A. 463
1936. The composition and structure of an oak wood, Cold Spring Harbor, Long Island, with special attention to sampling methods. Amer. Midland Nat. 17(4): 725–740, illus.

The tree-layer of a small woods dominated by *Quercus montana* was sampled by 3 methods: a single [illegible] plot (50×50 m.); a strip (10×250 m.); 25 scattered quadrats (10×10 m.). The [illegible]a for each method were secured on a basis of basal area by 100 sq. m. units, and spp.-area curves were drawn. For statist. analysis of the woods as a whole the method of scattered quadrats was best. If, however, the forest-type is to be considered on a basis of subtypes, resulting from small changes in topog., the single plot method, 1 plot per subtype, is a more efficient and yet an adequate method. Data are also given for the complete flora by life-form groups, the biol. spectrum, basal area, density, coverage, frequency.—Biol. Abs.

CAIN, STANLEY A. 464
1938. The species-area curve. Amer. Midland Nat. 19(3): 573–581, illus.

A spp.-area curve relates areas of different sizes and the no. of spp. found on them. Curves have been constructed using as areas entire stands of an assoc., single plots of standard area 1 in each stand, plots of increasing area, and scattered plots of constant area within single stands. The curves rise rapidly at 1st and with increased area tend to become asymptotic with the x axis. According to the purpose or manner of construction of a curve, the point where it flattens strongly is taken to indicate minimal area for the assoc., minimum quadrat size (for constancy or frequency data), or minimum quadrat no. It is shown that its shape depends on the ratio between the 2 axes. Hence it is necessary to standardize the y/x ratio or to determine mathematically the region of the curve where 10% increase of area gives 10% increase of spp. (or a 5% relation, if greater accuracy is desired).

CAIN, STANLEY A. 465
1943. Sample-plot technique applied to alpine vegetation in Wyoming. Amer. Jour. Bot. 30(3): 240–247.

Minimal area for alpine fell-field vegetation of the Snowy Range was determined to be 32 sq. m. For scattered plots in this vegetation, 1/10 sq. mile (1×10 dm.) is large enough if 20 plots per stand are studied. Statistical data are presented for 5 typical stands. The spp. of greatest statis. importance in this area in frequency, coverage, constancy, and presence are *Arenaria sajanensis*, *Selaginella densa*, and *Sieversia turbinata*. When compared with other regions, the south. Wyo. alpine fell-field community appears typical of comparable situations in the south. Rocky Mountains.

CURTIS, JOHN T., AND GREENE, H. C. 466
1949. A study of relic Wisconsin prairies by the species-presence method. Ecology 30(1): 83–92.

All higher plants were listed in each of 65 relic stands of relatively undisturbed prairie in Wis. The stands were grouped physiographically into high prairie, low prairie, dry limestone prairie, and sand prairie. In stand-frequency, the 237 spp. found included 2 (*Andropogon furcatus* and *Euphorbia corollata*) present in 80% or more of the stands, 19 present in 50% or more, and 88 present in less than 10%. Only the high prairie and the dry limestone prairie had an index of homogeneity [(number of spp. with 50+% presence/total number of spp.) ×100] greater than 25%.

CURTIS, J. T., AND MCINTOSH, R. P. 467
1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology 31(3): 434–455, illus.

An artificial population with numbers of spp. and individuals arranged on a log-normal curve was used to study the effect of quadrat size on math. relations of frequency, density, mean area, abundance, constancy, and presence. Although theoretical expectations were realized for spp. with a random areal dispersion, spp. with contagious dispersions showed lower frequency and constancy values than expected. The size of quadrat used in sampling markedly affected various well-known measures of nonrandomness. Examples from Amer. field studies indicated that the apparent randomness of tree spp. increased with increasing diameters.

DAHL, EILIF. 468
1960. Some measures of uniformity in vegetation analysis. Ecology 41(4): 805–808.

It is pointed out that most measures of uniformity or homogeneity can be predicted if the mean number of spp. per sample and Fisher's index of diversity for the vegetation under analysis are known. A new index of uniformity is proposed, the ratio of mean number of spp. per sample to index of diversity, and its relations to other measures of uniformity are discussed.

DUREITZ, G. EINAR. 469
1922. Über das wachsen der anzahl der konstanten arten und der totalen artenzahl mit steigendem areal, in natürlichen pflanzenassoziationen. [The increase in number of constant species and the total number of species with increasing area, in natural plant associations.] Bot. Notiser [Sweden] 1922: 17–36, illus.

DUREITZ, G. E. 470
1957. Vegetation analysis in relation to homogeneousness and size of sample areas. Cong. Internatl. de Bot., Paris, Raps. et Commun., Deuxiéme Sér. 8 (1954) (Sect. 7/8): 24–35.

DUREITZ, G. E., FRIES, TH. C. E., OSVALD, H., AND TENGWALL, T. A. 471
1920. Gesetze der konstitution natürlicher pflanzengesellschaften. [The constitution of plant associations.] Vetensk. och Prakt. Undersökn. i Lappland [Stockholm] 7: 1–47.

This is a theoretical discussion of the idea and law of constants, their ratio to area, results of appl. of the law of constants to the assoc. complex and to larger vegetation regions, etc.

EVANS, FRANCIS C., AND CAIN, STANLEY A. 472
1952. Preliminary studies on the vegetation of an old-field community in southeastern Michigan. Mich. Univ. Lab. Vert. Biol. Contrib. 51, 17 pp., illus.

An abandoned field on the Edwin S. George Reserve, of the Univ. of Mich. in southeast. Mich., is being investigated to study the organ. and operation of a natural community. Two principal community types are recognized within the field: a dense growth of *Poa pratensis*, which characterizes the hollow depressions or swales, and the vegetation of the upland areas, which is dominated by *Poa compressa* and *Aristida purpurascens*. Studies of frequency, biomass, density, and spacing indicate that the prevailing vegetation of the field is a secondary grassland, with which are assoc. various spp. common in this region to such comparatively sterile, exposed habitats. Most of the plants of the *Poa-Aristida* community of the upland areas in the field show some tendency towards clumping, and the mosaic or patchwork character of the vegetation is clearly evident. There is a slow successional trend towards deciduous forest, which formerly covered the field and which now adjoins it along much of its periphery. Within the framework of succession there appear to be more rapid microsuccessional changes,

which repeat themselves over and over in the form of a cycle, marked by pioneer, building, mature, and degenerating stages, with the established grasses representing the mature stage.—Auth. sum.

EVANS, F. C., CLARK, P. J., AND BRAND, R. H. **473**
1955. Estimation of the number of species present on a given area. Ecology 36(2): 342–343.

FLORA, C. J. **474**
1961. The species commonality index: A method for comparing habitats. Pacific Sci. [Honolulu] 15(2): 307–308.

Habitats are compared on the basis of the ratio of the no. of plants they have in common to the total no. of spp. listed from a concurrent survey of both areas. A high index indicates similarity and a low index diversity of habitat. Certain limitations are discussed.—Herb. Abs.

GILOMEN, H. **475**
1926. Neuere methoden zur untersuchung der pflanzengesellschaften. [Newer methods of investigating plant communities.] (Abstract.) Naturf. Gesell. in Bern, Mitt. 1925: 19–21.

The relationship between area and no. of spp. seems better expressed by Kylin's than by Arrhenius' formula. Homogeneity may be expressed by a curve based on no. of spp. —Bot. Abs.

GLEASON, HENRY ALLAN. **476**
1922. On the relation between species and area. Ecology 3(2): 158–162, illus.

Discusses fallacy in Arrhenius' reasoning regarding the math. relation between no. of spp. and area.

GLEASON, H. A. **477**
1925. Species and area. Ecology 6(1): 66–74.

GLEASON, H. A. **478**
1929. The significance of Raunkiaer's Law of Frequency. Ecology 10(4): 406–408.

GOODALL, D. W. **479**
1954. Minimal area: A new approach. Cong. Internatl. de Bot., Paris, Raps. et Commun. (1954), Sect. 7: 19–21.

HANSON, HERBERT C. **480**
1950. Ecology of the grassland. II. Bot. Rev. 16(6): 283–360.

This rev. supplements that in Bot. Rev. 4: 51–82, 1938. Restricted largely to plant community comp. (floristics and structure) and methods of measurement, it has a bibliog. of 304 citations.

HANSON, HERBERT C., AND BALL, WALTER S. **481**
1928. An application of Raunkiaer's Law of Frequence to grazing studies. Ecology 9: 467–473, illus.

Raunkiaer's Law of Frequency is shown to be useful in grazing studies in bringing out and summarizing differences in 2 adjacent range pastures. In 1 pasture grazed by the deferred and rotation system the frequency ratio was 62, 14, 7, 7, and 10; in another grazed by the continuous system it was 59, 13, 13, 11, and 4. The ratio under the deferred and rotation system is nearer to the normal ratio of distrib. as developed by Raunkiaer. The ratios differ because palatable plants not resistant to continuous grazing decrease under it and unpalatable invaders or palatable spp. highly resistant to grazing increase.

HOPKINS, BRIAN. **482**
1955. The species-area relations of plant communities. Jour. Ecol. [London] 43(2): 409–426.

Spp.-area curves in twelve natural Brit. plant communities all show a rapid initial rise in number of spp. with increase in area, the rate of this rise gradually decreasing. Spp.-log area curves all show a very gradual rise in number of spp. with increase in area, the rate increasing until, on fairly large areas, the curve becomes very steep and approx. linear. Curves of a log nature have been fitted to the observed data and a reasonably good fit obtained. The ecol. meaning of the parameters used in the equation is discussed.

HOPKINS, BRIAN. 483
1957. The concept of minimal area. Jour. Ecol. [London] 45(2): 441–449.

The views on minimal area of the Zürich-Montpellier and Uppsala schools of plant sociol. are discussed. The Zürich-Montpellier school defines plant community minimal area as the point ("break") where the spp. area curve becomes approx. horizontal. The Uppsala school defines minimal area as the point ("step") where the constancy-area curve becomes approx. horizontal. Later work has thrown doubt on existence of the "break" and "step" in these curves. Twelve natural Brit. plant communities are analyzed by means of spp.-area, spp.-log area, constancy-area, and constancy-log area curves. Analysis of results gives no evidence for either the "break" or "step." It is concluded that minimal area cannot be determined from either the spp.-area curve or from the constancy-area curve, and it is doubted that minimal area exists.

KENOYER, LESLIE A. 484
1927. A study of Raunkiaer's Law of Frequence. Ecology 8(3): 341–349.

KOCH, L. F. 485
1957. Index of biotal dispersity. Ecology 38(1): 145–148.

"Geobiology" is the name proposed for the science of all spatial transactions of living organisms. Its 2 principal fields are biogeography and ecol. Whereas biogeography studies and interprets geog. distribution patterns, ecol. studies and interprets environmental physio-morph. influences on living organisms. Attention is drawn to P. Jaccard's contribs. to biogeographical theory, and to the virtual disregard of his work in American ecol. and biogeographical literature. One primary objection to Jaccard's Coefficient of Community is that it cannot be applied to more than 2 biotas. This difficulty is eliminated by the proposed Index of Biotal Dispersity (IBD) that is suggested as a measure of biotal homogeneity of biogeographical areas. Its use is shown for data from known distrib. of mosses in Calif.

KURLJUŠKIN, M. I., AND PETROV, M. P. 486
1938. [Determination of a minimum area for description of the vegetation on the *Arthrophytetum caricosum* pastures in the desert of Kara-kum.] Sovet. Bot. [Moskva] 1938(3): 84–95. [In Russ.]

Statistical elaboration of data from tests showed that, owing to the scattered vegetation, larger areas must be used. To attain an accuracy of 5% occurrence on the *Arthrophytetum caricosum* pastures, a transect of 3.1 ha. (10 × 1,550 m.) was adequate; for a precision of 10% occurrence (sufficient for grazing purposes) the transect may be reduced to 0.45 ha. On the mixed *Arthrophyteto-Haloxylonetum caricosum* pastures (with a better vegetation than the previous type) the transect may be reduced to 0.4 and 0.25 ha. respectively for 5% and 10% accuracies.—Herb. Abs.

LABOURIAU, LUIZ GOUVÊA. 487
1948. Nota sôbre o baricentro dos diagramas de frequência das associações vegetais. [Note on the mean of frequency diagrams of plant associations.] Rio de Janeiro, Jard. Bot. Arq. 8: 221–225. [In Portug. with Fr. sum.]

This note proposes the abscissa of the mean of the frequency diagram of plant assocs. as a new index of homogeneity. Several concrete examples serve to compare this index with the degree of homogeneity defined in the author's note in Soc. Brasil. de Agron. Biol. [Rio de Janeiro] 10(1): 49–55, 1947.—Auth. sum.

MCINTOSH, R. P. 488
1962. Raunkiaer's "Law of Frequency." Ecology 43(3): 533–535.

PEARSALL, W. H. 489
1924. The statistical analysis of vegetation: A criticism of the concepts and methods of the Uppsala school. Jour. Ecol. [London] 12: 135–139, illus.

PENFOUND, WILLIAM T. 490
1945. A study of phytosociological relationships by means of aggregations of colored cards. Ecology 26(1): 38–57.

Using aggregations of colored cards, effects of quadrat size, no. of spp., and total cover were investigated. Analysis of their effects on the sampled frequency, density, and cover of spp. showed all affect frequency (frequency percentages, the frequency relation among spp., and the no. of spp. in the frequency classes of Raunkiaer). On density (no. per unit area) and on actual cover (areal spread) per sp., though both no. of supp. and total plant cover have an effect, changes in quadrat size have none; the cover relation among species is also unaffected by any of the changes. Among frequency, density, and cover, the most artificial and least important concept seems to be frequency and the most valuable cover; if the three are to be studied, quadrat size cannot be predetermined.

As to number of quadrats in a sample, this depends on quadrat size, the data suggesting that the number for a proper quantitative sample in community analysis is large, at least 10 times the "break in spp.-area curve."

PENFOUND, WILLIAM T., AND WATKINS, ALLAN G. **491**
1937. Phytosociological studies in the pinelands of southeastern Louisiana. Amer. Midland Nat. 18(4): 661–682, illus.

The longleaf pine and slash pine-pond cypress communities of SE. La. are characterized by parklike stands of tall, slender trees with no shrub stratum but with a well-developed prairielike herbaceous layer. *Andropogon virginicus* was the most important sp. in the longleaf pine habitat, in virgin, 2nd-growth, and cutover longleaf pine units. Other important spp. were *A. scoparius*, *Aristida virgata*, and *Elephantopus nudatus*. In the slash pine-pond cypress swamp the spp. of highest frequency and cover grade included *Arundinaria tecta*, *Erigeron vernus*, *Eriocaulon decangulare*, *Rynchospora gracilenta*, and *Sphagnum* spp. Grasses and sedges contributed 37% of the 166 spp. listed in all communities and are to be considered as the controlling spp. Since the spp.-area curves break most strongly before the 15th quadrat is reached and since the spp. encountered after the 15th quadrat are very low both in frequency and in cover grade, 15 quadrats of 1 sq. m. each seem sufficient for a phytosociol. analysis of herbaceous vegetation.—Biol. Abs.

PICHI-SERMOLLI, RODOLPHO E. **492**
1948. An index for establishing the degree of maturity in plant communities. Jour. Ecol. [London] 36(1): 85–90.

The maturity index is the total frequency percentages of all spp. in the community divided by the no. of spp. found on the sta. The more highly developed the community the nearer to 100 is its maturity index.

POORE, M. E. D. **493**
1955. The use of phytosociological methods in ecological investigations. II. Practical issues involved in an attempt to apply the Braun-Blanquet system. Jour. Ecol. [London] 43(1): 245–269.

RICE, ELROY L. **494**
1952. Phytosociological analysis of a tall-grass prairie in Marshall County, Oklahoma. Ecology 33(1): 112–116, illus.

Of a total of 39 spp. found in a prairie community, the dominants were considered to be *Sorghastrum nutans*, *Panicum virgatum*, and *Andropogon gerardi*. Although it is usually considered the most important dominant in the tall-grass prairie of Okla., *Andropogon scoparius* was less important here than the above spp. Characteristic spp. were delineated fairly well with 20 or 40 0.1-sq. m. quadrats. But the actual cover and frequency data differed somewhat for most spp. if based upon 20 versus 40 quadrats. The present data suggest that several times the number of quadrats required for the break in the spp.-area curve would be required for exactly reproducible cover and frequency data.

RICE, ELROY L., AND KELTING, RALPH W. **495**
1955. The species-area curve. Ecology 36(1): 7–11, illus.

Chief use of spp.-area curve in U.S.A. has been in indicating minimal quadrat size and minimal nos. of quadrats required for adequate sampling. These appls. of curve necessitate location of so-called break in curve. Cain suggested that sampling is adequate when a 10% increase in sample area results in a 10% increase in no. of spp. Such a point on spp.-area curve can be easily located mechanically. In 1943, Cain pointed out that location of such a point as that suggested above on spp.-area curve depends on total area sampled. Despite this warning and those of Ashby, Vestal, and Goodall later, many persons have continued to use the 10% point on the spp.-area curve especially for determining adequacy of sampling. It was decided that a careful restatement of defects of such a procedure documented with results of field expts. might be of value. Species-area curves were drawn from data obtained from many sources. Several 10% points were usually located mechanically on each curve, each point being determined on basis of a different no. of quadrats. In all cases it was found that the 10% point of Cain moved upward along curve with each addition in no. of quadrats. Since 10% point shifts with a change in no. of quadrats used in locating it, it would seem that such a point has little value as an indicator of adequacy of sampling.—Auth. abs.

ROMELL, L. G. **496**
1930. Comments on Raunkiaer's and similar methods of vegetation analysis and the "Law of Frequency." Ecology 11(3): 589–596.

As a complement to Kenoyer's (1927) and Gleason's (1929) articles, an acct. is given

of the efforts of some Scandinavian auth. to analyze or explain the *F%*-curve (distrib. of spp. in classes of frequency of representation on a no. of sample areas). The peculiar mosaic-structure of numerous plant assocs. is not accounted for by the ordinary statis. and probability formulae based on normal dispersion. Frequency nos. computed from empirical *F%*-nos. by current formulae are therefore liable in many cases to give erroneous results. For the same reason, statis. analyses of vegetation by means of methods of the Raunkiaer type (presence-absence sample-plot methods) cannot be compared, if made with different sizes of sample areas, since there is no way of correcting the values for another size of area. The desirability is stressed of a common agreement on a standard size of sample area for such analyses and on the definition of the statis. units. Attention is drawn to the valuable Lagerberg-Raunkiaer method of estimating cover, which has received inadequate attention and has recently been grossly misinterpreted. —Auth. sum.

Vestal, Arthur G. 497

1949. Minimum areas for different vegetations: Their determination from species-area curves. Ill. Biol. Monog. 20(3): 1–129, illus.

Species-nos. are plotted using log scale for areas. Curves are S-form and convex in the upper section. On a given curve, 2 reference areas are found by locating 2 points which satisfy empirical ratios (adopted after many trials). *Af* or "fair-sized stand" is 50×*Ar* or "smallest representative area," and has twice the no. of spp. *Am* or "minimum area" is then found: it is 5*Ar*, with about 1.44–1.5 the no. of spp. in *Ar*. It is assumed that a ref. area in 1 vegetation is equivalent, at least in some respects, to the same ref. area in any other vegetation. For many purposes, *Ar* is a sufficient 1-piece sample; *Am* is a fairly conservative standard. "Minimal areas" found by auth. using other methods are usually between these 2 ref. areas, and their spp.-nos. were found for about 240 examples of vegetation (and a few animal assemblages) from many regions. Examples are mostly from published descriptions (briefly summarized). Necessary conversions of data are described. Minimum areas found range widely, from 0.025 milacre (0.1 sq. m.) with 12 spp. (small lichens on rock) to 21 acres with 100 spp. (mora forest in Brit. Guiana), and are summarized in a detailed table, graph, and "procession of curves." Many phenomena of vegetation, e.g., richness of comp. and peculiarities of heterogeneous communities, are incidentally explored. Sects. include geometry of S-curves, departures of curves from the form determined by Fisher's log series, hypotheses to explain spp.-area relations, and implications for sampling, modified field methods, conserving natural areas, and classifying vegetation.

Williams, C. B. 498

1943. Area and number of species. Nature [London] 152: 264, illus.

See also **8, 20, 23, 50, 142, 398, 403, 415, 435, 437, 438, 441, 512, 520, 524, 534, 820, 822, 827, 830–832, 929, 1073, 1084, 1090.**

INTERSPECIFIC CORRELATION AND ASSOCIATION

Cole, LaMont C. 499

1957. The measurement of partial interspecific association. Ecology 38(2): 220–233.

Each sample or collection in a series can be classified in 1 of 4 categories by whether 2 spp., A and B, are both present, both absent, or 1 present and the other absent. It is then possible to determine if 2 spp. occur together more often than would be expected from chance (positive assoc.), less often (negative assoc.), or simply as from chance. A coefficient has been defined to measure the strength of assoc. Statistical reliability can be determined. Association might result from actual attraction between spp. or from attraction of both to some 3rd sp. or some other environmental feature characterizing a portion of samples. Coefficients of partial assoc. are derived to make actual attraction distinguishable from mutual assoc. with 3rd sp. Coefficients measure such partial assoc. and permit tests of statis. significance so that one can reach conclusions: spp. A and B are significantly more closely assoc. when C is absent than when C is present.

Dagnelie, P. 500

1960. Contribution à l'étude des communautés végétales par l'analyse factorielle. [A contribution to the study of plant communities by factor analysis.] France Serv. de la Carte Phytogéog. Bul., Sér. B 5(1): 7–71; 5(2): 93–195.

The numerous coefficients of interspecific assoc. and of similarity between stands are presented with a coherent system of symbols. Phytosociological tables, especially ones

obtained through Braun-Blanquet's method, and ecol. data are analyzed. Advantages of the various coefficients depend on the pursued aim and the structure of the vegetation studied. Few auth. have attempted the analysis of the numerical values of the coefficients they had calculated. Factor analysis has only once been appl. in plant sociol. It includes several statis. methods principally used in expt. psychol. They tend to explain observed connections within a set of interdependent variables, called tests, by a few fundamental variables, called factors. Therefore, a linear math. model is used which binds the observed variables to the fundamental variables. For observed values of several variables and several individuals 1 scatter diagram can be formed that 2 variables showing almost the same fundamental aptitude occupy neighboring points, and another that 2 individuals having almost the same fundamental aptitude lie side by side. Extensions of the method, e.g., to the analysis of discrete and qualitative data, are presented, and possible uses of factor analysis in plant sociol. are shown through a comparison with expt. psychol. This poses the probs. of choice of a method for computing the loadings, choice of a correlation parameter, choice of a test of significance, and choice of a method of estimation of factors. Examples based on data gathered by the auth. indicate: Centroid and principal factor methods are practically equivalent. Product-moment and point-correlation coefficient are the best coefficients of interspecific assoc. for factor analysis. Best tests of significance are those presented by Burt, especially the χ^2 test based on the residual correlations. A new method of estimation of factors gives equivalent results with the least squares method and is faster to use. If one wants to apply factor analysis its specific use should be considered before the vegetation is sampled. Analysis of interspecific assocs. in a given forest vegetation shows estimation of the indicator value of a sp., delimitation of groups of strongly connected spp., forming and checking of classifications of stands, study of the structure of vegetation, and relations between spp. distrib. and "ecol. factors." Some of these probs. can be studied more directly by the analysis of similarities between stands. Associations between groups of spp. and similarities between groups of stands are analyzed too. Factor analysis of ecol. data permits study of the same probs. on an ecol. and no more on a floristic basis. Both approaches can be combined through the method.—Biol. Abs.

DAWSON, G. W. P. **501**

1951. A method for investigating the relationship between the distribution of individuals of different species in a plant community. Ecology 32(2): 332–334.

From published data of Steiger on the no. of individuals of *Andropogon furcatus, A. scoparius, Bouteloua curtipendula,* and *Poa pratensis* in each of 40 quadrats of high prairie grassland in Amer., the partial correlation coefficients were calculated for these spp. by pairs. Significant positive correlations were found between *A. furcatus* and *P. pratensis* and between *A. scoparius* and *B. curtipendula.* In similar data from low prairie grassland the same significant correlations were found. When quadrat data of this type are available, it is suggested the calculation of such partial correlation coefficients (to be preferred to ordinary correlation coefficients) will provide useful clues to the spatial arrangement of plants of different spp. in a community, thus crystallizing probs. for invest.

DICE, LEE R. **502**

1945. Measures of the amount of ecologic association between species. Ecology 26(3): 297–302.

The coefficient of assoc. of Forbes indicates the amount of assoc. between 2 given spp. compared to the amount of assoc. between them expected by chance. To provide a simple direct measure of the amount of assoc. of 1 sp. with another, the assoc. index is proposed. If a is the no. of random samples of a given series in which sp. A occurs and h is the no. of samples in which another sp. B occurs together with A, then the assoc. index $B/A=h/a$. Similarly, if b is the no. of samples in which sp. B occurs, then the assoc. index $A/B=h/b$. There is also proposed a coincidence index, $2h/(a+b)$, whose value is intermed. between the 2 reciprocal assoc. indices. As a measure of the statis. reliability of the deviation shown by the samples of a given series from the amount of assoc. expected by chance, the χ^2 test may be used.—Auth. sum.

FAGER, E. W. **503**

1957. Determination and analysis of recurrent groups. Ecology 38(4): 586–595, illus.

A new index of affinity between spp., based on presence and absence, is proposed, and a table is provided from which the significance of an observed no. of joint occurrences can be estimated. Using this index, together with a 4-pt. definition of a recurrent group, a procedure is described which indicates the largest, most frequent, separate

groups within which all spp. formed a nearly constant pt. of each other's biol. environment. Ranking methods are suggested for examining interspecific concepts, such as numerical dominance, relative abundance, concordance, and correlations within these groups.—Herb. Abs.

FORBES, S. A. 504
1925. Method of determining and measuring the associative relations of species. (Abstract.) Science (n.s.) 61: 524.

Formulae which show the ecol. affiliation of pairs and groups of spp. are discussed.

GOODALL, D. W. 505
1953. Objective methods for the classification of vegetation. I. The use of positive interspecific correlation. Austral. Jour. Bot. 1(1): [39]–63, illus.

It is argued that correlations between the presence or quantity of different spp. recorded in quadrats imply heterogeneity in the vegetation in which the quadrats were placed. If the quadrat data can be so divided that within each subdivision no interspecific correlations occur, these subdivisions represent elementary classification units of the vegetation, and an objective classification may be arrived at if methods can be found of satisfying this requirement. Four procedures are described for dividing a set of quadrat data into groups satisfying the above criterion of homogeneity. The simplest and apparently the most satisfactory consists in finding the most frequent sp. showing significant correlations with others, and separating in the 1st instance all quadrats containing this sp. Within this group correlations are again tested, and the process is repeated until a group with no significant correlations has been extracted. All other quadrats are then lumped together and the process is begun again from the beginning. When the whole collection of quadrat data has been divided in this way into homogeneous groups, these groups are recombined where this can be done without the resulting larger group showing interspecific correlations. The 4 procedures suggested are illus. on data from a small area of the Victorian Mallee. Some of the results suggest that classification is an inappropriate method of dealing with variation in this type of vegetation, and that a coordinate treatment might be more suitable.—Auth. sum.

HARBERD, D. J. 506
1960. Association-analysis in plant communities. Nature [London] 185(4705): 53–54.

KAYAMA, R. 507
1959. Studies on estimation of grazing capacity and utility of mountainous grass lands. III. Relation of slope elevation to vegetation and estimation of yield of native plants. Jap. Jour. Zootech. Sci. 30(5): 278–282. [In Jap. with Eng. sum.]

KERSHAW, KENNETH A. 508
1961. Association and co-variance analysis of plant communities. Jour. Ecol. [London] 49(3): 643–654, illus.

A comparison is made of 2 methods of community analysis using the same chalk grassland data. The profound effect of quadrat size on the trend of assoc. detected is demonstrated, and the effect on the assoc. analysis based on summed χ^2 values discussed with ref. to a joint analysis of the same data using 2 quadrat sizes. The limitations and advantages of the methods are indicated and it is concluded the covariance analysis is of more value for detailed invest. of small areas whereas the assoc. analysis is of use in the primary survey of an area despite the dependence of the results on the size of sampling quadrat used.—Biol. Abs.

KOLBE, W. 509
1956. Korrelationsstatistische probleme der grünland-soziologie. [Statistical correlation problems in grassland sociology.] (Unpublished dissertation, Univ. of Bonn, 92 pp.)

LAMBERT, J. M., AND WILLIAMS, W. T. 510
1962. Multivariate methods in plant ecology. IV. Nodal analysis. Jour. Ecol. [London] 50(3): 775–802, illus.

Nodal analysis is a method of extracting concentrates of vegetational inform. from a matrix of spp./site records by examining coincidence in normal and inverse assoc. analysis. The "vegetation-units" extracted can be defined and characterized by ref. to both plants and habitat, and ranked in importance according to the precision of the statis. definition. The method was demonstrated on data from 2 natural populations, "stand" data from heathland, and transect data from fenland. The results of both analyses have been assessed as ecologically meaningful. The nature of the vegetation units extracted by nodal analysis is related to certain current vegetational concepts, and statis. analysis in vegetational studies is briefly discussed.

PIELOU, E. C. 511
1961. Segregation and symmetry in two-species populations as studied by nearest-neighbour relationships. Jour. Ecol. [London] 49(2): 255–269, illus.

If the assoc. between 2 spp. of plant is assessed by quadrat sampling, the result is strongly influenced by the size of quadrat used. However, the degree to which the individuals of 2 spp. are mingled together is an intrinsic property of a 2-spp. population. A method of measuring it is described that is independent of any arbitrary characteristic (such as quadrat size) of the sampling method. Two spp. are said to be segregated if the individuals of each tend to have a member of their own sp. as nearest neighbor, rather than a member of the other sp. The test for segregation described is unaffected by the finite sizes of plant individuals. Allowance is also automatically made for the possibility that the population may be unsymmetrical; i.e., that the individuals of one of the sp. may tend to be more isolated than those of the other, possibly but not necessarily because of their greater size. Field results from a mixed stand of *Pseudotsuga menziesii* and *Pinus ponderosa* are used to illustrate the concepts developed. —Biol. Abs.

VESTAL, ARTHUR G., AND HEERMANS, MARY FRANCES. 512
1945. Size requirements for reference areas in mixed forest. Ecology 26(2): 122–134.

This study determines how large of an areal unit is needed for specific inform. in 2 old-growth mixed forests. Such ref. areas may be useful in comparing different communities. The plot size found effective for the no. of tree spp. (av. 13 of the 25 spp. in a fair-sized stand) appears to be the same as the "smallest representative area," 0.8 acre, that adequately represents leading spp. (12 spp. in this type). By testing different combinations of these 12 spp. in plots of 0.1 to 6.4 acres, it was found that 0.8 acre includes, in 7 or 8 of 10 plots, at least 10 of these spp., and most combinations. A 4-acre unit further tells approx. order of abundance among spp. and identifies the type. This "minimum area for assignment to type" proves the same as the "minimal area" of plant sociologists (if trees only are considered). When 7/10 of all the spp. are represented, the trees are numerous enough (504 in 4 acres) to indicate proportions among spp. A brief name for this ref. size is "minimum area." Close agreement of 2 tracts in these forests may not be expected with much less than 20 acres. This size gives a dependable statement of comp. and is called "definitive area." A dependable array of diam.-distribs., showing form of stand, requires about 80 acres. This unit embodies most characteristics of a stand, and is termed "complete stand." Ref. areas in some other forest types are estimated; with fewer spp., or if large old trees are lacking, areas 2/9 to 5/9 as large are equivalent to the sizes here found. The smallest unit that can be called a stand is considered to be minimum area.

VRIES, D. M. DE. 513
1954. Constellation of frequent herbage plants, based on their correlation in occurrence. Vegetatio [Hague] 5–6: 105–111, illus.

This paper supposedly gives math. evidence for discontinuity in grasslands, as opposed to the continuum.

VRIES, D. M. DE. 514
1956. Ecological results obtained by the use of interspecific correlation. European Grassland Conf., Paris, Sum. (1954): 32–36.

WILLIAMS, W. T., AND LAMBERT, J. M. 515
1959. Multivariate methods in plant ecology. I. Association-analysis in plant communities. Jour. Ecol. [London] 47(1): 83–101.

The method of Goodall (Austral. Jour. Bot. 1: 39–63, 1953) of subdividing a set of sample quadrats into homogeneous groups, in which all spp.-assocs. were made nonsignificant or indeterminate, is analyzed theoretically. A new sorting method is proposed, consisting of hierarchical division of the spp. with the highest aggregated value of the chosen assoc.-index in the class under study. The properties of suitable indices are briefly considered; and in this hand-computed exploratory study, $\Sigma\chi^2$ (constructed from corrected χ^2 values) is used, nonsignificant and indeterminate values being taken as 0 and equal wt. being given to positive and negative assocs. The statis. efficiency of the method is confirmed by its appl. to 2 heathland communities, and the nature of the ecol. inform. obtained is assessed.—Biol. Abs.

WILLIAMS, W. T., AND LAMBERT, J. M. 516
1960. Multivariate methods in plant ecology. II. The use of an electronic digital computer for association-analysis. Jour. Ecol. [London] 48(3): 689–710, illus.

WILLIAMS, W. T., AND LAMBERT, J. M. 517
1961. Multivariate methods in plant ecology. III. Inverse association-analysis. Jour. Ecol. [London] 49(3): 717–729, illus.

"Normal" assoc.-analysis of qualitative ecol. data, described previously in this series, identifies major discontinuities between groups of quadrats by ref. to the spp. whose presence-or-absence records are correlated in all possible pairs. "Inverse" analysis similarly detects discontinuities between groups of spp. by ref. to the correlations between quadrats. The method is exemplified by analysis of 2 different communities, results of normal and inverse analyses in each being compared. Certain differences between the 2 forms of analyses are briefly discussed.

WILLIAMS, W. T., AND LANCE, G. N. 518
1958. Automatic subdivision of associated populations. Nature [London] 182 (4651): 1755.

See also **20, 23, 161, 265, 371, 372, 376, 385, 391, 393, 422, 425, 431, 520, 528, 535, 540, 542, 543, 545, 546, 548–550, 554, 1084.**

FLORISTIC SIMILARITY (STANDS AND COMMUNITIES)

ASHBY, E. 519
1933. Quantitative methods in the analysis of vegetation. Linn. Soc. London, Proc. 146: 30–31.

ASHBY, ERIC. 520
1936. Statistical ecology. Bot. Rev. 2(5): 221–235.

BRAY, J. ROGER. 521
1961. A test for estimating the relative informativeness of vegetation gradients. Jour. Ecol. [London] 49(3): 631-642.

A proposed estimate of informativeness measures the degree a sp. predominates in a limited portion of an ordination and consistency of decrease from the area of predominance. The estimate comprises order (the difference between maximum quantitative value and the minimum value or values to either side), disorder (the amount the gradient must change to show a consistent trend), and inform. (order minus disorder). This test was appl. to transect survey results for an open savanna in southeast. Wis. Eight gradients were constructed: 2 vegetational, 2 locational, 3 environmental, and 1 random. The test showed the locational and environmental gradients to be less informative than the vegetational, and the random gradient to be less informative than any of these. The 2 locational gradients had a higher mean informativeness than the 3 environmental factors. As a technique of quantitative classification, the vegetational ordinations gave the most complex vegetation pattern. A correlation study indicated the possible existence of 2 factorial regimes, each including 3 intercorrelated gradients. The 1st included the 2 vegetational gradients and an elevation regime and reflected soil moisture and drainage. The 2nd included gradients of distance from tree, light intensity, and soil water retaining capacity and reflected shading effects.

BRAY, J. ROGER, AND CURTIS, J. T. 522
1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monog. 27(4): [325]–349, illus.

Fifty-nine stands of upland hardwood forest in south. Wis. were studied by means of a new ordination technique, which considered the degree of similarity of 2 stands as shown by their coefficient of community value could be transl. into a spatial pattern in which the inverse of the coefficient was equated with linear distance. By means of a geometric method of arc projection and intersection, 3 vegetational gradients were constructed. These gradients were used as independent axes to give a 3-dimensional orientation of the 59 stands. It was found that spp. in 3 dimensions formed atmospheric distribs. with high values in a restricted portion of the array, surrounded by decreasing values in all directions. Each distrib. was interspersed to varying degree with that of other spp., in a continuously changing pattern. Correlation of environmental factors was made with the 3 gradients, and some interaction patterns between vegetation and environment were initially described.—Biol. Abs.

CLAUSEN, J. JOHANNA. 523
1957. A comparison of some methods of establishing plant community patterns. Bot. Tidsskr. [Copenhagen] 53(3): 253–278, illus.

A study was carried out to determine what differences in pattern occur when 3 sets

of correlation coefficient values for the same group of communities are derived independently from the 3 measures of frequency, presence, and relative frequency. Sampling of the 47 communities studied was by means of 10–20 quadrats, 0.01 sq. m. in size, per community. The methods of arrangement tested were: 1 dimensional inspection by the methods of Bray [see Herb. Abs. 26: 1308 and 1314] and Sorenson (1955); 2 dimensional inspection. The results are discussed.—Herb. Abs.

EVANS, FRANCIS C., AND DAHL, EILIF. **524**

1955. The vegetational structure of an abandoned field in southeastern Michigan and its relation to environmental factors. Ecology 36(4): 685–706, illus.

The vegetation of a 50-yr.-old abandoned field in southeast. Mich. was analyzed from 65 selected sample plots, in each of which were recorded the floristic comp., plant cover estimates, and surface soil characteristics. Two major divisions recognized were: (a) vegetation of the shallow, basinlike depressions dominated by a dense growth of *Poa pratensis*, and (b) that of the upland area dominated by *P. compressa* and *Aristida purpurascens*. Eleven lesser vegetation types with dominant, constant, and differential spp. were also identified. Phytosociological analyses of each type were used for diagnostic descriptions. Study of spp.-area relations in the *Poa-Aristida* vegetation type, used as a test, suggested that plot size (4–15 sq.m.) satisfied the requirements of minimal area. Nine of the types were classified in 1 depression and 3 upland groups. Floristic similarity indices were used to compare groups, and the floristic distinctness of the depression (*P. pratensis*) group was substantiated. Topographic variability was held primarily responsible for major vegetational divisions. The vegetation of the depressions occurred on silt loams, that of upland on sandy loams and sands. Soil texture and depth to the plowline between the types also differed significantly. Comparison with undisturbed soils from the adjacent woods supported the hypothesis that field soil differences were due to the effects of clearing and plowing, followed by differential erosion. The overall plant cover pattern was seen as the result of interspersion of minor habitats, each with its own constellation of selective forces. There was little evidence of current change in pattern, and it was concluded that the field vegetation has attained considerable equilibrium with the environment.

GLEASON, HENRY ALLAN. **525**

1920. Some applications of the quadrat method. Torrey Bot. Club Bul. 47: 21–33.

GUYOT, H. **526**

1923. Association standard et coefficient de communauté. [A standard association and a coefficient of community.] Soc. Bot. de Genève Bul., Ser. 2, 15: 265–272.

An ideal standard assoc. is advocated. A comparison of the no. and frequency of the spp. in any given assoc. and the standard assoc. may be expressed in a ratio termed "coefficient of community."

HARBERD, D. J. **527**

1962. Application of a multivariate technique to ecological survey. Jour. Ecol. [London] 50(1): 1–17, illus.

Making certain necessary assumptions, it is shown that Mahalanobis's D^2 between a pair of spp. lists scored for presence or absence reduces to the no. of spp. present once only in the 2 spp. lists. This is adopted as the definition of d^2, and its properties and value explored. So long as the spp.-log-area curve is linear, the quadrat size employed does not affect the mean value of d^2 between stands of the same community. Between different communities d^2 increases rapidly with quadrat size, the increase being most marked with the most distinct communities. By expressing d^2 as a % of the sum of the nos. of spp. in the 2 lists, relative d^2 is obtained. With increasing quadrat size in the same community, relative d^2 decreases, the decrease being less marked between distinct communities. In grouping a complete table of d^2 for the several sites in a particular study, only a difference of more than 1.6 between group mean d^2 minus within group mean d^2 is likely to be of ecol. interest. Application of these principles to the data from 80 local *Agrostis-Festuca* communities produced a meaningful classification. The sites were arranged in a series of groups from the most flushed to the most leached, and the spp. were distributed between the groups in an intelligible manner. Certain inform. not used in the analysis, such as topog. and soil pH, tallied reasonably well with the classification.

HUGHES, R. ELFYN, AND LINDLEY, D. V. **528**

1955. Application of biometric methods to problems of classification in ecology. Nature [London] 175 (4462): 806–807.

These methods are illus. by comparison of 2 plant communities, and by study of classification of 6 soil series. Statistics and equations are given, and further appls. are suggested.

JACCARD, PAUL. 529
1929. Considération sur le coefficient générique et sa signification floristique et phytosociologique. Soc. Bot. de France Bul. 76(1/2): 47–66.

The auth. gives further emphasis to his former thesis that the generic coefficient, (no. of genera×100)/no. of spp., varies inversely with ecol. diversity of the area under consideration. He illustrates this by comparing the flora of the richly diversified district of Herault (generic coefficient 31%) with the more uniform district of Auvergne (generic coefficient 35%). It is now announced that when the flora of a country is in a cond. of relative stability and acct. is taken of Linnean spp. only, the generic coefficient of the entire flora, of the Dialypetalae, of the Gamopetalae, the Compositae, and of the Monocotyledonae agree very closely. For the flora of France the coefficients of these groups are respectively 20.3%, 19.7%, 20.1%, 20.7%, and 20.0%. If subspecies, vars., and ecotypes are included, the agreement is not so close. When the generic coefficients of various plant families depart materially from those of the great groups mentioned above, it may be assumed that the ecol. conds. in the region are particularly favorable or decidedly detrimental to particular plant families.—Biol. Abs.

JACCARD, PAUL. 530
1939. Cas particulier concernant le coefficient générique. Soc. Vaud. des Sci. Nat. Bul. [Switz.] 60(248): 249–253.

JACCARD, PAUL. 531
1941. Sur le coefficient générique. Chron. Bot. 6(16): 361–364.

In comparing the generic coefficient (ratio of the no. of genera corresponding to 100 spp. in a given community) for various territories, the auth. finds a distinct correlation with ecol. variations shown.

JACCARD, PAUL. 532
1941. Sur le coefficient générique, II. Chron. Bot. 6(17/18): 389–391. [Concluded from Chron. Bot. 6: 361–364.]

The relation between generic coefficient and frequency of assoc. spp. furnishes the plant sociologist a valuable tool for comparing floras of limited territories.

KAYAMA, R. 533
1961. New methods of quantitative representation of the structure of plant communities. IV. On the summed dominance ratio weighted by plant weight. Jap. Jour. Ecol. 11(4): 135–139. [In Jap. with Eng. sum.]

LOOMAN, J., AND CAMPBELL, J. B. 534
1960. Adaptation of Sorensen's K (1948) for estimating unit affinities in prairie vegetation. Ecology 41(3): [409]–416, illus.

In phytosociol. studies of indigenous vegetation in southwest. Saskatchewan, Sorensen's Quotient of Similarity, K, was adapted to estimate site affinity by spp. presence. As used by Sorensen, K proved unsatisfactory because the probability of a quotient could not be estimated. This weakness was corrected through a technique that combined K and Kendall's Rank Correlation Coefficient, T. It was concluded that the technique (1) could be employed to estimate similarity of sites—both within and between phytosociol. units, (2) could be employed to group sites by ecol. characteristics with a preciseness not obtainable when only standard phytosociol. procedures were employed, and (3) required a little extra time to calculate T_e and Ke, this being more compensated for by the additional inform. obtained.—From auth. sum.

MCINTOSH, ROBERT P. 535
1962. Pattern in a forest community. Ecology 43(1): 25–33, illus.

Forest pattern is examined using χ^2 as a measure of interspecific correlation. To determine utility in studies of relational patterns, three means of applying it are tried. The results suggest that while distinct or basic units of mutually assoc. spp. do not characterize community organ., useful patterns in spp. relations are discernible and suggest ecol. probs. not otherwise apparent.

POORE, M. E. D. 536
1955. The use of phytosociological methods in ecological investigations. III. Practical application. Jour. Ecol. [London] 43: 606–651.

RAABE, E. W. 537
1957. Zur systematik in der pflanzensoziologie. Vegetatio [Hague] 7(4): 271–277.

WILLIAMS, C. B. 538
1949. Jaccard's generic coefficient and coefficient of floral community, in relation to the logarithmic series and the index of diversity. Ann. Bot. [London] (n.s.) 13(49): 53–58.

Evidence accumulates that a log series can closely represent the frequency distrib. in plant communities of relative abundance of individuals in spp. and spp. in genera (*see* Williams, Jour. Ecol. 34: 253). If true it is possible to calculate an "Index of Generic Diversity" and an "Index of Specific Diversity" for any population being sampled. Jaccard's Coefficients are then each a double function depending partly on the Index of Diversity and partly on the size of the sample. Thus in a population structure based on the log series, the "Index of Diversity" is a better ecol. measure than Jaccard's Coefficients.

See also **20, 23, 133, 468, 485, 506, 507, 517, 540, 543, 549, 550, 554.**

VEGETATIONAL CLASSIFICATION AND CONTINUA

ANDERSON, D. J. 539
1963. The structure of some upland plant communities in Caernarvonshire. III. The continuum analysis. Jour. Ecol. [London] 51(2): 403–414, illus.

An ordination technique has been used to analyze some plant communities of the upland grassland of Ffridd Ddu, Caernarvonshire, and the individual sp. performance has been related to a single axis of floristic variation, which correlates well with a similar single-axis variation in some edaphic factors. The particular technique of ordination used is described in detail, and the potential value of this approach in ecol. analysis emphasized.

BOURDEAU, P. 540
1961. L'outil statistique en écologie et sociologie végétales. [The statistical tool in ecology and plant sociology.] Biométrie-Praximétrie [Brussels] 2(3/4): 193–216. [In Fr. with Eng. sum.]

CURTIS, J. T. 541
1955. A prairie continuum in Wisconsin. Ecology 36(4): 558–566, illus.

The prairies of Wis. were studied from presence lists in 157 remnant stands on varied topog. sites in 34 counties covering about 22,000 sq. miles. In 57 of the stands, quadrat frequencies based on 20 quadrats each 1 m. sq. were also determined. Soils were analyzed for vol.-wt., moisture-holding capacity, pH, and available nutrients. Several groups of indicator spp. were chosen for high % of occurrence in a topog. type. An index for each stand was calculated from the relative occurrence of each indicator group and a weighted summation of values. When the stands were arranged by the index, all spp., both indicators and nonindicators, formed smooth curves of occurrence, with a peak in some restricted pt. of the stands. Some spp. had broad amplitudes of occurrence while others were narrowly limited. No groups of spp. of similar behavior were found. The entire spp. complement formed a continuous series, from spp. growing best in the wettest sites to those growing best in the driest sites. As a result of this spread in spp. behavior, the stands themselves formed a continuous series, or vegetational continuum, with no discrete community entities present. When the stands were grouped into classes based on water-retaining capacity, and the % presence calculated for each sp. for each class, the resulting curves showed the same relations as before. No significant correlation between spp. comp. and any soil nutrient could be demonstrated in the range studied.

DAGNELIE, P. 542
1960. Quelques problèmes statistiques posés par l'utilisation de l'analyse factorielle en phytosociologie. [Some statistical problems set by the use of factor analysis in phytosociology.] Gembloux Inst. Agron. de l'Etat Bul., Sér. Extraordinaire 1: 430–437. [Eng. sum.]

DAGNELIE, P. 543
1962. L'application de l'analyse multi-variable à l'étude des communautés végétales. [The application of multivariate analysis to the study of plant communities.] Inst. Internatl. de Statis. Bul. [Hague] 39(2): 265–275. [In Fr. with Eng. sum.]

FERRARI, T. J., PIJL, H., AND VENEKAMP, J. T. N. 544
1957. Factor analysis in agricultural research. Netherlands Jour. Agr. Sci. 5(3): 211–221.

This investigation of factors in the bot. comp. of grassland includes a special appl. of factor analysis to the spring growth of grass.

GOODALL, D. W. 545

1953. Objective methods for the classification of vegetation. II. Fidelity and indicator value. Austral. Jour. Bot. 1(3): [434]–456, illus.

A new index of fidelity is described, based on the ratio of frequencies for the spp. in 2 communities. The importance of significance tests in determining characteristic spp. is emphasized. The value of a sp. as indicator of a particular community is taken as the ratio of the frequency in that community to the frequency elsewhere within the area studied. An index to express this is proposed. The value of discriminant functions in enabling vegetation samples of uncertain affinities to be allotted to 1 of several possible communities is demonstrated. An example is given in which this technique has been used to determine whether 1 community can be regarded as intermed. between 2 others, or has special features of its own. The paper is illus. by data taken from pubs. of the Zürich-Montpellier school, and by original data collected in the Victorian Mallee.—Auth. sum.

GOODALL, D. W. 546

1954. Objective methods for the classification of vegetation. III. An essay in the use of factor analysis. Austral. Jour. Bot. 2(3): [304]–324, illus.

The possibilities of using the statis. technique of factor analysis in describing variations in plant communities are explored. This method enables the variations to be treated as continuous, instead of resulting in a separation of the stands studied into a limited no. of discrete assocs. or other synecological categories. It further provides a means for testing whether such separation can be objectively justified. It may often facilitate the recognition of the complexes of environmental factors which mainly determine differences in vegetation, and provides a means of estimating the relative value of the various spp. as indicators of these environmental complexes. In the present paper, the "principal axes" technique of factor analysis is applied to the analysis of data for % cover for 14 spp. in the Victorian Mallee. It is shown that their distrib., in so far as it does not depend on factors peculiar to individual sp., can be represented in terms of at most 5 orthogonal "factors." The 2 most important "factors" are interpreted in terms of catenary changes in the vegetation. Other less common spp. not included in the analysis show high correlations with these "factors." In units of 1.28 ha. there is no evidence that more than 1 continuously varying population is represented in the area; but in units of 25 sq. m. the majority of quadrat records fall into 1 or other of 2 principal categories, representing the valley and ridge communities. The potential value of factor analysis in plant sociol., and difficulties in its appl. to this field, are discussed.—Auth. sum.

HORIKAWA, Y., AND ITOW, S. 547

1958. The vegetational continuum and the plant indicators for disturbance in the grazing grassland. Jap. Jour. Ecol. 8(3): 123–128. [In Jap. with Eng. sum.]

Nineteen stands in a grazed grassland at Sayôto in the Chûgoku Mountains were investigated for the distributional pattern of plant populations and the indicator plants for disturbance. Each stand was sampled with 250 quadrats (20×20 cm.), and the quantitative relations of the plant populations were expressed as frequency percentages. The distributional interchange of 4 principal spp. was tested by the method of leading dominant, and the adaptation no. for these spp. was decided. To express the numerical distance between the treated stands, the frequency index of each stand was calculated by the following formula:

$$\text{Frequency index} = \frac{(a\times 1)+(b\times 2)+(c\times 3)+(d\times 4)}{a+b+c+d}\times 100$$

in which *a*, *b*, *c*, and *d* are the frequency % of *Miscanthus sincensis*, *Arundinella hirta*, *Zoysia japonica*, and *Plantago asiatica*, respectively. The resulting index ranges from 100 to 400, and in this study from 133 to 390. The treated stands were arranged along the numerical order of the index.

HOSOKAWA, T. 548

1955–56. An introduction of 2×2 table methods into the studies of the structure of plant communities. (On the structure of the beech forests, Mt. Hiko of S.W. Japan). Jap. Jour. Ecol. 5(2): 58–62, 1955; 5(3): 93–100; 5(4): 150–153, 1956. [In Jap. with Eng. sum.]

Critical discussions are presented of Cole's index (Cole 1949), Goodall's Indicator Value (Goodall 1953), and Goodall's objective method of grouping plant communities (Goodall 1953), all based on 2×2 table treatments of statistics. Goodall's indicator value index is modified by the auth. so as to indicate it in a range of coefficient values between

+1.00 and −1.00. The structure of the beech forests on Mt. Hiko is studied by means of 2×2 table methods. χ^2 values of the major component spp. are shown with their values of Cole's Index. According to a modification of Goodall's method (1953), 4 different kinds of plant communities are distinguished in the stand of Sasamorpheto-Fagetum crenatae of Mt. Hiko; the *Sasa nipponica* group, *Rhododendron metternichii* group, *Fagus crenata* group, and *Fraxinus spaethiana* group. Each group seems to correspond to "Facies" in the Braun-Blanquet concept.

HOSOKAWA, T., OMURA, M., AND NISHIHARA, Y. **549**
1957. Grading and intergradation of epiphyte communities. Jap. Jour. Ecol. 7(3): 93–98.

The modified method of classifying vegetation assumes that any plant group lacking spp. significantly correlated either positively or negatively is of homogeneous construction. By 4 procedures under this method epiphyte vegetation is classified objectively into homogeneous groups by its floristic comp. This is done by making use of interspecific correlation based on the frequency of major component spp. and indicator value of significance level (Goodall 1953, Hosokawa 1955–56). These groups would then be integrated into an appropriate no. of groups of higher rank using "Quotient of Similarity" (QS) (Sörensen 1948), which is based on the frequency of component spp. Several yrs. of varied studies of corticolous vegetation in the beech forests of Mt. Hiko, SW. Japan, have resulted in recognition of 4 distinct communities of epiphytes that are strongly developed there.

HUGHES, R. ELFYN. **550**
1954. The application of multivariate analysis to (a) problems of classification in ecology; (b) the study of the interrelationships of the plant community and environment. Cong. Internatl. de Bot., Paris, Raps. et Commun. (1954), Sect. 7: 16–18.

NUMATA, M. **551**
1961. Statistical methodology in plant ecology. Inst. Internatl. de Statis. Bul. [Hague] 38(4): 547–553. [Fr. sum.]

PONYATOVSKAYA, V. M. **552**
1961. On two trends in phytocoenology. Vegetatio [Hague] 10(5/6): 372–385.

Review of the ideas that vegetation is (1) composed of more or less discrete units which are groupings of plants or (2) continuously varying assemblages of plants which are best considered as individuals. The rev. is thorough and includes Russ., west. European, and Amer. literature. Almost contemporaneous expression of the "individualistic concept of the plant community" occurred in several places in all 3 areas. Elaborations of this viewpoint by Ramenski, Negri, Gleason, and more recently by Curtis and Whittaker are reviewed (that by Braun-Blanquet is added.). In concl., the 1st view is said to be most accurate, but there is not necessarily absolute contrast between them. The 2 trends must be synthesized for progress in the study of vegetation. The original article was in Bot. Zhur. [Moscow] 44(3): 402–407, 1959. The translator has added notes amplifying the orig. and a brief rev. of a symposium on "Math. anal. of plant communities" at the Ninth Internatl. Bot. Cong. in Montreal. The same dichotomy in vegetation studies was evident, perhaps related to overriding interest in ecol. versus vegetation classification. Dahl pointed out the reciprocal relation between these 2 activities. Use of the individualistic and community approach to vegetation by the same investigator is reviewed. It is concluded that floristic stand surveys are the basic data for vegetation studies.—Biol. Abs.

VASILEVICH, V. I. **553**
1960. On application of statistical methods for characterizing plant associations. Leningrad Univ. Vest., Ser. Biol. 2: 64–70. [In Russ. with Eng. sum.]

WILLIAMS, W. T., AND LAMBERT, J. M. **554**
1961. Nodal analysis of associated populations. Nature [London] 191(4784): 202.
See also **20, 23, 133, 143, 385, 393, 425, 500, 503, 505, 506, 508, 509, 513, 515–518, 521–523, 526, 527, 534, 535, 537.**

ROOT SAMPLING AND SOIL SAMPLING

ANDERSON, DUWAYNE M., AND BINNIE, R. R. **555**
1961. Modal analysis of soils. Soil Sci. Soc. Amer. Proc. 25(6): 499–503, illus.

The statis. elements of petrographic modal analysis are reviewed. The appl. of this procedure to soils and unconsolidated sediments is discussed and justified. Application of this method to obtain more complete quantitative estimates of mineralogical comp.

and pore space of soils should facilitate progress under the present system of soil classification and promote the use of objective criteria in new classification schemes.—Biol. Abs.

BOURGET, S. J., ELRICK, D. E., AND TANNER, C. B. 556
1958. Electrical resistance units for moisture measurements: Their moisture hysteresis, uniformity, and sensitivity. Soil. Sci. 86(6): 298–304.

Six types of elect. resistance units were evaluated for measuring soil moisture. Although gypsum units were preferable at high tensions, nylon-gypsum units were probably best at low tensions. A fiberglass gypsum unit developed by the auth. made the best compromise.

BROADFOOT, WALTER M., AND BURKE, HUBERT D. 557
1958. Soil-moisture constants and their variation. U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 166, 27 pp., illus.

For the most commonly used constants, values under specific soil and cover conds. are given.

CLINE, MARLIN G. 558
1944. Principles of soil sampling. Soil Sci. 58(4): 275–288.

The soil is treated as a statis. population that is vertically and horizontally divisible into homogeneous sampling vols. The no. of sampling units required to represent a homogeneous sampling vol. can be estimated from the range or variance by the relation of t values to the standard error and the maximum sampling error permissible. Though complete randomization is necessary for estimates of fiducial limits, incomplete randomization gives an unbiased estimate of the mean. Compositing is an efficient means of obtaining adequate nos. of sampling units for objectives that require only an estimate of the mean. The relation of subsampling error to maximum particle size and size of subsample is discussed.

CLINE, MARLIN G. 559
1945. Methods of collecting and preparing soil samples. Soil Sci. 59(1): 3–5.

For soil sampling methods are given (a) to represent an area for estimates of mean values, variability, and significance and (b) to represent a soil type. A procedure for preparation of samples is presented.

DAGNELIE, P., EVRARD, R., AND MANIL, G. 560
1956. [Pedological and statistical considerations on the sampling of soil for analysis.] Sixth Internatl. Cong. Soil Sci. Trans., Sect. E, 1956: 303–307. [In Ger. with Ger. and Eng. sum.]

DOWNES, R. G., AND BECKWITH, R. S. 561
1951. Studies in the variation of soil reaction. I. Field variations at Barooga, N.S.W. Austral. Jour. Agr. Res. 2(1): [60]–72, illus.

A study has been made of the variability of soil reaction, in the field, on Barooga Field Sta., N.S. Wales, and on portion of a nearby property. Soil samples were taken at 2 depths, 0–4 in. and 4–8 in., at 4-chain intervals according to a rectangular grid. Other samples were taken at 1/2-chain intervals on restricted areas, and at 1-ft. intervals on grids 4 ft. by 3 ft. Differences of more than 3 pH units have been found for samples taken in 1 continuous area of a single soil type, and differences in excess of 2.5 pH units for individual samples taken 4 chains apart. The differences between individual samples at distances of 1/2 chain and 1 ft. were found to be as large as 1.2–2.0 pH units and 0.6–1.1 pH units respectively. The standard deviation of the differences between adjacent points was considerably smaller in the samples spaced at 1-ft. intervals.—Auth. sum.

FOX, WILLIAM E., AND PAGE-HANIFY, D. S. 562
1959. A method of determining bulk density of soil. Soil Sci. 88(3): 168–171, illus.

Methods of determining bulk density are discussed and evaluated. The requirements of an accurate method of determination are stated, and the design and use of an apparatus suitable for use on a soil free of stones described. Results of a field test of the apparatus are given.—Auth. sum.

GOHLKE, A. F., AND BAUMGARDNER, M. F. 563
1961. Statistical evaluation of the analytical techniques employed in the Purdue soil analysis laboratory. Ind. Acad. Sci. Proc. (1960) 70: 248–253, illus.

This study has indicated that numerous factors present in the routine now used are sources of variation between duplicates of the same soil sample. Numerous additional factors remain to be investigated. When all the factors causing variation have been studied and corrected, closer duplication should result.—Biol. Abs.

HAMMOND, LUTHER C., PRITCHETT, WILLIAM L., AND CHEW, VICTOR. 564
1958. Soil sampling in relation to soil heterogeneity. Soil Sci. Soc. Amer. Proc. 22(6): 548–552.

IMPENS, I. 565
1962. Some methods for calculating potential evaporation (free water, bare soil) and evapotranspiration (grass) from climatological data. Comparison with direct measurements. Ghent Landbouwhogesch. en de Opzoekinssta. Meded. 27(1): 57–88. [In Flem. with Eng. sum.]

Data obtained using a no. of formulae for calculating evaporation from bare soil and a free water surface and evapotranspiration from grass were compared with expt. values determined at Ghent. The methods of Albrecht and of Haude considerably underestimated potential evapotranspiration. Kalweit's method, which is similar but uses a correction factor based on measurements throughout N. Germany, gave much better results. The Blaney-Criddle method gave completely false estimates of free water evaporation and much too high values for potential evapotranspiration. Estimates of potential evapotranspiration from Turc's formula were 10–20% lower than observed values and closely correlated with them, while those for evaporation from bare soil were almost 30% too low. Penman's formula gave almost exact estimates for evaporation from bare soil, overestimated free water evaporation by about 20%, and underestimated potential evaporation by about 20%; the formula was considered to contain too many local constants. Where a correction coefficient proposed by Makkink involving the length of the grass was introduced, estimates of potential evaporation from Penman's formula more closely approximated to the expt. values. Thornthwaite's formula gave the best estimates of potential evapotranspiration. Estimates of free water evaporation by means of an evaporation balance and a screened Piche evaporimeter, using the appropriate reduction factors, were very close to the actual value. Makkink's simplified formulae based on those of Penman overestimated free-water evaporation by 40%, but gave close estimates for potential evapotranspiration when corrected for grass length.—Herb. Abs.

LULL, HOWARD W., AND REINHART, KENNETH G. 566
1955. Soil-moisture measurement. U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 140, 56 pp.

Of the 13 methods outlined, only gravimetric, elect.-resistance, and tensiometer methods are commonly used. Consistency tests and penetrometers are useful for approxs. only. The air picnometer is speedy but less accurate than other methods. The nuclear method using radioactive material involves measuring the slowing down of neutrons emitted into the soil, but is still largely expt. A sect. on soil-moisture variation and sampling is included. Equipment used for the various methods is illus.

MCINTYRE, D. S., AND TANNER, C. B. 567
1959. Anormally distributed soil physical measurements and nonparametric statistics. Soil Sci. 88(3): 133–137, illus.

Some examples of anormally distributed measurements of soil physical properties have been found. The frequent occurrence of anormal distribs. indicates that nonparametric statis. methods will be useful in many soil physical invests. There are some physical measurements (e.g., air permeability, penetrability, and infiltration velocity) for which parametric methods will not always give valid concl. unless transformations are made. Nonparametric methods can often be used directly for simple and rapid tests, particularly in simpler expts. The underlying principles of nonparametric statis. are less rigid and the methods more easily grasped. Thus speed of testing, plus simplicity of conds. governing the use of nonparametric statis. tests, will justify their appl. on many occasions. The occurrence of anormal distribs. in these measurements emphasizes that the usual statis. methods should be used with full observance of the precautions stressed by professional statisticians. Blind crank-turning, a common practice, is to be avoided.—Auth. sum.

MARSHALL, T. J., AND STIRK, G. B. 568
1950. The effect of lateral movement of water in soil on infiltration measurements. Austral. Jour. Agr. Res. 1(3): [253]–265, illus.

The effect of lateral movement on minimum infiltration capacity was examined using small flooded plots of various sizes without buffer zones and using small sprayed and flooded plots surrounded by wetted buffer zones. When no buffer zones were used, the minimum infiltration capacity of a given soil decreased with increasing size of plot and there was a corresponding increase in the fraction of appl. water remaining beneath the plot at the concl. of the trial. An expression for the relation between plot size and lateral movement is discussed. Although buffer zones around flooded plots effected some reduction in lateral movement, the measurements were subj. to considerable error and the method was considered unduly cumbersome for routine work. In a spray infiltrom-

eter procedure, a sprayed buffer zone surrounding a small test plot was found to be effective on the soils examined. When all data from flooded plots with and without buffer zones were examined, it was found that the minimum infiltration capacity of a soil varied inversely with the fraction of appl. water remaining beneath the plot at the concl. of a trial. When the minimum infiltration capacity was multiplied by the corresponding value of this fraction, the effect of lateral movement was reduced considerably. It is shown that results from small plots then approx. more closely to those to be expected from large ones and there is also a reduction in variability due to causes other than variation in size of plot. Limitations in the use of this correction factor are discussed fully and the general limitations of infiltration data derived from small plots are briefly considered.—Auth. sum.

MERRIAM, ROBERT A., AND KNOERR, KENNETH R. 569
1961. Counting times required with neutron soil-moisture probes. Soil Sci. 92(6): 394–395, illus.

Statistical theory of radiation counting is used to derive the relation between the error of moisture determination with a neutron probe and the counting time under different levels of soil moisture. The equation derived is $E=\pm K(Pv/S\cdot t)$ where E is the error in % soil moisture by vol., K is the no. of standard deviations (1.96 for the 95% probability level), Pv is the % soil moisture by vol., S is the change in the count rate per unit change in Pv, and t is the length of counting period in mins. It is concluded that 1 counting interval can be used for measurement at all levels of soil moisture from 0 to 50 Pv. A counting time of 2 mins. is recommended for most field measurements of soil moisture.—Biol. Abs.

RAUPACH, M. 570
1951. Studies in the variation of soil reaction. II. Seasonal variations at Barooga, N.S.W. Austral. Jour. Agr. Res. 2(1): [73]–82, illus.

The seasonal and spatial contribs. to the variation in reaction of 2 Australian soils have been examined. Experiments described show seasonal effects to be slight and spatial variation contribs. large. Exchangeable Na from soluble salt variations is shown to give rise to the differences in reaction upon 1 soil while Ca and Mg relationships may, among other factors, be responsible for those on the other.—Auth. sum.

RAUPACH, M. 571
1951. Studies in the variation of soil reaction. III. Variations at the Waite Agricultural Research Institute. Austral. Jour. Agr. Res. 2(1): [83]–91, illus.

Variations in reaction and total soluble salts of a red-brown earth from S. Australia have been assessed. Seasonal changes are discernible for reaction but are largely masked by spatial variations even over small areas. The amplitude of the seasonal changes is of the order of 0.15 of a pH unit, the soil returning to the same pH value during the succeeding season. Spatial variations have been found for organic carbon, N, clay, and exchangeable cations over small areas. Data have been presented to show that while the mean soil reaction does not vary widely, there is a variation in the variance of the reaction values about the mean with season. The change of the reaction status of the soil with time over a small area does not consist of a uniform increase and decrease of all the reaction values in the area but rather of a reorganization of all hydrogen ion contributing factors to give differences in dispersion about the mean value.—Auth. sum.

RAUPACH, M. 572
1954. The errors involved in pH determination in soils. Austral. Jour. Agr. Res. 5(4): [716]–729, illus.

Errors in replication of pH values of 1:5 soil-water suspensions are shown to differ significantly between routine observers and to be larger when duplicate determinations are made upon different days rather than on the same day. For the routine technique employed in these labs. the 5% fiducial limits of a single determination do not rise above ± 0.09 pH units due to the above causes. Errors due to soil variation over small distances in the field may show 5% limits as high as ± 1.3 pH units. The causes of the errors which may arise within the measuring system are considered and details are given of errors in soil systems due to the suspension effect and to lack of equilibrium between the soil and aqueous phases. Absence of equilibrium may give differences as high as 1.0 unit when measurements are made upon sedimenting alkaline suspensions; no errors occur due to this cause below pH 5. The presence of salts does not modify the differences observed. The suspension effect is relatively small. It is recommended that where possible, pH measurements be made upon soil systems with the glass electrode in the suspension and the ref. electrode in the dialysate or supernatant liquid. The description and use of a suitable electrode arrangement is given in an app. Generally pH measurements can be considered to no greater accuracy than ± 0.1 unit and quite often circumstances do not justify this precision.—Auth. sum.

SCHUYLENBORGH, J. V., AND BAVEL, W. H. M. VAN. 573
1946. [An investigation into the possibility of application of tensiometers.] Landbouwk. Tijdschr. [Wageningen] 58: 227–236. [In Dutch with Eng. sum.]

Tensiometers showed that soil moisture was much more at 10 cm. depth than at 40 cm., and that the capillary tension is a function of soil moisture, texture, and structure. It was not possible to relate these factors quantitatively. The tensiometer has proven valuable for measuring soil moisture at different depths and under natural conds. of deposition and vegetation.

SHIUE, CHERNG-JIANN, AND CHIN, NAI LIN. 574
1957. Direct use of pH values in statistical analysis of soil reactions. Soil Sci. 84: 219–224.

It is generally believed that soil reaction data in pH form should not be used for statis. analysis directly, unless the pH value is translated into corresponding normality of hydrogen ions. Several statis. tests have been made on 3 sets of soil samples taken from both cultivated field and forest plots. When the soil reaction was expressed in hydrogen ion concentration form, the data have shown lack of normality, a slow approach to normality even when grouped as means, and a dependence of the standard deviation on the mean. It is not valid to make any parametric statis. analyses with such data directly. On the other hand, data in pH form usually satisfy the assumptions underlying most parametric statis. analyses. Therefore, it is recommended that pH value should be used directly in statis. analyses, without translation into hydrogen ion concentration.

SKENE, J. K. M. 575
1960. Sampling errors in the evaluation of soil potassium and pH. Austral. Inst. Agr. Sci. Jour. 26(4): 353–354.

An invest. was made to determine the minimum sampling requirements for available K content (p.p.m. of air dry soil extracted by N/20 HCl) and pH. For K content, 140 cores/treatment or $140/N$ per plot (where N is no. of replications) are stipulated. On the site chosen, 12 cores/treatment suffice to test differences of 0.3 pH. Larger nos. of samples may be necessary where other sources of error are present.—Biol. Abs.

SLATER, C. S., AND BRYANT, J. C. 576
1946. Comparison of four methods of soil moisture measurement. Soil Sci. 61: 131–155.

Analyses of variance of soil moisture data by random sampling are tabulated. The standard deviations of moisture sampling amounted to 0.75% on the silt loam and 0.57% on the sand. These deviations include the real differences in soil moisture on different pts. of a single plot and whatever errors may have existed in making the determination.

TAYLOR, S. A. 577
1955. Field determinations of soil moisture. Agr. Engin. 36: 654–659.

The large errors reported in field studies with tensiometers, resistance units, neutron method, and gravimetric sampling largely result from real variation in moisture. Because water is removed unevenly by plants, it is removed to lower depths and to greater extent in some than in other pts. of the plot. A random sampling picks up these variations. Uneven appl. of water may greatly contribute to unequal distrib. in a plot. Even with more or less uniform appl. at the surface, any cracks, discontinuities, or marked changes in structure or texture cause unequal water penetration and distrib.

TAYLOR, STERLING A., EVANS, D. D., AND KEMPER, W. D. 578
1961. Evaluating soil water. Utah Agr. Expt. Sta. Bul. 426: 3–65, illus.

Measurements of soil moisture are of 2 kinds: those that are based upon a measurement of the energy cond. of the soil water, and those that measure the amount of water in a given mass or vol. of soil. The energy of soil water can be measured with properly calibrated tensiometers and pressure equip., vapor pressure measuring apparatus, freezing point depression, and calibrated plaster or other elect. resistance units. Air permeability of porous ceramic units shows possibilities of being calibrated to measure the matric potential of soil water, and the conductivity of ceramic cells can be successfully calibrated to give an estimate of the osmotic potential resulting from the appearance of soluble salts. The concentration of water in soil can be measured by the gravimetric or volumetric methods of soil sampling, then drying in an oven. It may also be measured with the recently developed neutron method with almost as much accuracy as with sampling methods. The errors introduced from inferring either soil moisture concentration or potential from a measurement of the other property are large. Such conversions should be made only when approx. estimates are adequate. It is much better to measure

the concentration directly when inform. concerning the amount of soil water is desired. Likewise, it is best to measure the soil moisture potential when inform. concerning availability of water to plants or movement in the soil is desired.—Biol. Abs.

TISDALL, A. L. 579
1951. Variability in soil moisture and infiltration on two riverina soils. Austral. Jour. Agr. Res. 2(2): [126]–131.

Studies of variability in soil moisture and of a method for determining infiltration were conducted on 2 irrigated soils in the Riverina region, a sandy loam of the red-brown earth group and a clay of the grey and brown soil group respectively. Coefficients of variation were high in all cases. It is concluded that the use of 16 replicates gives adequate precision in the estimate of infiltration (C.V. of 8% and 12% for the 2 soils studied). Similarly, the use of 16 gravimetric determinations, each bulked from 4 sites, would give a satisfactory estimate for soil moisture (C.V. of less than 10% for the 2 soils studied). This no. of samples is not excessive from practical considerations. Sampling for soil-moisture increment, following the type of irrig. used on these soils, should be carried out to a depth of 2 ft., but the duplication of gravimetric determinations is not warranted by the small increase in precision obtained.—Auth. sum.

TOOGOOD, J. A. 580
1956. The use of soil cores in assessing physical properties. Sixth Internatl. Cong. Soil Sci. Trans., Sect. B, 1956: 227–232. [In Eng. with Ger. and Fr. sum.]

Provided numbers of replicates are adequate, a soil-core sampler taking cores 3 in. in diameter and 3 in. long is useful in assessing physical properties of soil. Using 24 replicates the mean and standard deviation were calculated, and fiducial limits at the 5% level were derived. In all field capacity data the distribs. appeared normal so that an av. of a relatively few cores should give field capacity within 2% or 3% of true value. For field-capacity and vol.-wt. determinations 5 replicates should usually suffice. For porosity measurements more replicates are needed, and permeability determinations, particularly in heavy soils, require so many replicates that the method is better replaced by some other technique. Moisture content, especially of heavy soils at the time of sampling, has an important effect on the physical properties of the cores.

WILLIAMS, T. E., AND BAKER, H. K. 581
1957. Studies on the root development of herbage plants. I. Techniques of herbage root investigations. Brit. Grassland Soc. Jour. 12(1): 49–55.

Various methods of root sampling are reviewed for the type of inform. required. The root sampling techniques at the Grassland Res. Inst. are described with examples of sampling errors. Details of a root washing machine are given.

YOUDEN, W. J., AND MEHLICH, A. 582
1931. Selection of efficient methods for soil sampling. Boyce Thompson Inst. Contribs. 9(1): 59–70, illus.

Culvers gravelly silt loam from Broome Co., N. Y., and Sassafras loamy coarse sand from the Camden area, N. J., were sampled at 9 stas. scattered over an area of several sq. miles. At each sta. samples were collected at definite intervals and the acidity of the samples determined. The results show in each case that samples from widely separated points vary more than samples taken close together. This was also observed to hold for the lower horizons where the variation was not as great and tended to reach a maximum value characteristic of the soil type. The data analyzed statistically show the relative efficiency of various spacing for replicate samples when large areas are surveyed. Intervals as low as 10 ft., or 100 ft., were too small to constitute an effective method for sampling these areas. The sampling procedure was discussed with ref. to its appl. in crop fertility studies, soil classification, and the invest. of possible damage to soils over large areas.—Auth. sum.

See also **6.**

USE OF ANIMALS IN MEASURING HERBAGE PRODUCTION

FORAGE INTAKE AND DIGESTION STUDIES

ALDER, F. E., AND MINSON, D. J. 583
1963. The herbage intake of cattle grazing lucerne and cocksfoot pastures. Jour. Agr. Sci. [England] 60(3): 359–369.

The intake by steers of herbage from plots of lucerne (alfalfa), cocksfoot (orchardgrass)/white clover, cocksfoot/lucerne (seeds mixture), and cocksfoot/lucerne (in alternate drills) was estimated by chromic-oxide/fecal-index methods and by herbage-

sampling methods. Digestibilities were estimated by feeding herbage samples to sheep and by the *in vitro* method. The sheep trials showed that all herbages had similar digestibilities when managed in the same way and cut on the same dates. From *in vitro* analyses it was shown that cocksfoot was more digest. than lucerne and that grazing animals selected the most digest. pts. of plants. However, most of the variation in digestibility was caused by date of cutting rather than by type of sward. Cattle selected the uppermost 4 in. of lucerne and the ends of leaves and stems of cocksfoot. The mean intake of organic matter, estimated by fecal methods, was 1.76–2.38 lbs. per 100 lbs. live-wt. and was lowest for cocksfoot/white clover. By herbage sampling methods, daily intake figures were more variable and the grazing level was difficult to gage. It was considered that chromic-oxide estimation and improved methods of digestibility determination were likely to provide the most accurate method for assessing intake.—Herb. Abs.

Axelsson, Joel, and Eriksson, Sture. **584**
1950. Comparison between the accuracies of the direct and the indirect methods in digestion trials with ruminants. Uppsala Lantbrhögsk. Ann. 17: 375–395.

The standard deviation has been used as a measure of the expt. error of digest. coefficients obtained with a certain feed (the expt. feed) in trials run parallel at a sta. Data from 1,484 digest. expts. with cattle and sheep at 20 expt. stas. were collected from literature. Cattle trials were with both the indirect (Eden's indirect method) and the direct method. In each feed where 2 or more digest. expts. had been run parallel, the expt. errors of the digest. coefficients were calculated. Obtained were 306 errors of sole feed trials and 366 errors of difference trials. The results proved that in both kinds of trials the expt. error of the digest. coefficient of each nutrient decreased with an increase of content of the nutrient in the DM of the expt. feed. The decrease was most rapid at a small content. In difference trials, the expt. error of the digest. coefficient of organic matter decreased when DM content of the expt. feed increased in % of the whole ration. Comparison of expt. errors of expt. stas., methods, and animal spp. indicated that the indirect method gave less reliable digest. coefficients than the direct method, though the difference was not significant. The errors in Jarl's calculations are pointed out. Between trials with cattle and sheep, errors did not differ significantly. In the main, the reliability of the digest. coefficients was more closely connected to the precision of the work than to the spp. or methods. But since the indirect method is more expensive than the direct, it is to be recommended only where the direct method cannot be followed.—From auth. sum.

Barnett, A. J. G. **585**
1957. Studies on the digestibility of the cellulose fraction of grassland products. 1. The relation between the digestibility of silage cellulose as determined *in vitro* and silage crude fibre digestibility determined by feeding trial. Jour. Agr. Sci. [England] 49(4): 467–474, illus.

Bredon, R. M., Harker, K. W., and Marshall, B. **586**
1963. The nutritive value of grasses grown in Uganda when fed to zebu cattle. 1. The relation between the percentage of crude protein and nutrients. 2. The relation between crude fibre and nitrogen-free extract and other nutrients. Jour. Agr. Sci. [England] 61(1): 101–104; 105–108.

Using 13 samples of 5 grass spp., regression equations were calculated between CP content and the digestibility coefficients of CP, organic matter, and DM, and between the contents of crude fiber plus NFE and the digestibilities of organic matter and DM. There was a close correlation between the CP content in the feces and that in the consumed grass. From correlations with the contents of crude fiber, plus NFE (a simpler analysis than that of crude fiber only), the SE and TDN values could be calculated as accurately as was likely from full digestibility trials.—Herb. Abs.

Bredon, R. M., and Marshall, B. **587**
1962. Relation between chemical composition and nutritive value of Uganda grasses. Nature [London] 194(4829): 702–703.

The results from digestibility trials with zebu steers fed on hays made from different grasses, and on fresh grass, were expressed by 3 regression equations. If these results are confirmed in subsequent digestibility trials with a larger var. of roughages, it should mean that the cumbersome determinations of crude fiber can be eliminated and that to find the full nutritional value of a fodder it would be necessary to analyze for CP, fat, and total ash only.—Herb. Abs.

BUTTERWORTH, MILD H. 588

1963. Digestibility trials on forages in Trinidad and their use in the prediction of nutritive value. Jour. Agr. Sci. [England] 60(3): 341–346.

The chem. comp. and digestibility coefficients are given for 13 grasses, *Pueraria phaseoloides*, and silage of *Digitaria decumbens*, using Persian Blackhead wethers. The CP contents ranged from 3.2% to 20.5% and TDN contents from 43.8% to 65.9%. The CP contents were highly correlated with digest. CP, especially when corrected for crude-fiber content. At high CP levels, CP digestibility appeared to be higher than for herbage grown in temperate regions. The relationship between dietary crude-fiber level and digestibility of organic matter in these herbages also apparently differed from that in temperate spp. Values for TDN could not be predicted from chem. comp., probably owing to the high crude-fiber digestibility and the comparatively low NFE digestibility. From a comparison of values with those recommended by the National Res. Council, U.S.A., it was concluded that digest. CP values were, in general, below those required for stock, while TDN contents were adequate in most samples.—Herb. Abs.

CARBERY, M., CHATTERJEE, INDUBHUSAN, AND HYE, MD. ABDUL. 589

1934. Studies on the determination of digestibility co-efficients. I. A new method of experimentation and computation for directly obtaining the digestibility co-efficients of individual feed nutrients in a mixed ration. Indian Jour. Vet. Sci. and Anim. Husb. 4(4): 295–340.

The difficulties assoc. with the prevailing methods of calculating digestibilities of feeds in rations, either where single feeds deficient in some nutrient or where 2 or more feeds are involved in the diet, are discussed. As alternatives, a graphical method and the use of multiple regressions for determination of digestibilities of feeds are proposed. The expt. design and procedure for such tests are presented and discussed. The chief advantage claimed for both of these methods is that they enable direct calculation without having recourse to the doubtful alternative of using assumed values for a part of the ration. Results obtained by these methods have conformed to the requirement of statis. tests of significance in the case of all the ration components (DM, organic matter, CP, ether extr., crude fiber, and NFE) with the notable exception of crude fiber, possibly due to the fact that during digest. some special phenomenon, probably related to bacterial action on fats and fiber, intervenes; it reacts in such a way on the food material in the digest. tract as to effect an apparent increase in the fiber fraction of the feces or undigested residue, thereby showing an apparent decrease in digest.—Biol. Abs.

CIPOLLONI, MARY ANN, SCHNEIDER, BURCH H., LUCAS, HENRY L., AND PAVLECH, HELEN M. 590

1951. Significance of the differences in digestibility of feeds by cattle and sheep. Jour. Anim. Sci. 10(2): [337]–343.

Published data which allow the comparison of the digest. powers of cattle and sheep were analyzed statistically. Comparisons were made for the digestibility of organic matter, CP, crude fiber, NFE, and ether extr., and the contents of TDN in each of the 3 feed classes, dry roughages, silages, and concentrates. To make the comparisons fair, covariance adjustment for proximate comp. was conducted. Specific difference in the digestibility of the organic matter, crude fiber, NFE, and ether extr., and in the TDN content of dry roughages were statistically significant. For silages and concentrates, spp. differences were significant only for ether extr. The interaction, spp.-by-feeds, was significant for the digestibility of protein in dry roughages and for the digestibility of ether extr. in concentrates, indicating that the differences in the digestibility favor cattle with certain feeds and sheep with others. Other differences, although not significant, were large enough to suggest a trend. Greater accuracy will be attained if digestibility data to be used for cattle are obtained with cattle, and similarly for sheep.

CRAMPTON, E. W., DONEFER, E., AND LLOYD, L. E. 591

1960. A nutritive value index for forages. Jour. Anim. Sci. 19(2): 538–544, illus.

Lambs varying in wt. between 25.9 and 49.3 kg. showed a low C.V. in feed intake (13%) where feed intake was calculated per unit of metabolic size (wt. as $kg.^{.75}$). The intake of chopped, dehydrated legume hay cut at early flowering was 80 ±10 g./day per unit of metabolic size; this value was used as a standard forage intake. The relative intake of other forages was calculated as

$$\frac{\text{observed intake} \times 100}{80\ (W_{kg.}{}^{.75})}.$$

The relative intakes of 9 forages differing in feeding value, multiplied by their % digest. energy content, were correlated (r=0.88 to 0.94) with feeding value as measured by live-wt. gain. The use of relative intake×% digest. energy content as an index of the nutritive value of forages was proposed.—Herb. Abs.

CRAMPTON, E. W., LISTER, E. E., AND LLOYD, L. E. 592
1957. Voluntary intake of forage as a measure of its feeding value. (Abstract.) Jour. Anim. Sci. 16(4): 1056.

From the results of feeding trials with sheep, it was concluded that voluntary forage intake was a measure of rate of digest. and was a more precise criterion of the nutritive value of forage than the TDN or crude-fiber content.

CRAMPTON, E. W., AND PURDY, T. L. 593
1941. Pasture studies. XXII. Dry matter defecation as an index of forage intake by grazing steers. Sci. Agr. [Ottawa] 22(4): 242–249, illus.

Data obtained using feces collection sacs provided a quantitative record of the daily DM defecation throughout the season of 2 steers freely grazing an acre of expt. pasture land, and indicated either that there was a seasonal trend in forage consumption or a marked difference in the digestibility of the herbage consumed at different times during the season. The data also indicated that animal units were an unreliable basis of comparison in critical tests of the nutritive value of pasturage because the size of animal was not correlated with feces DM output and hence with feed intake.

CROKER, BARBARA H. 594
1959. A method of estimating the botanical composition of the diet of sheep. New Zeal. Jour. Agr. Res. 2(1): 72–85, illus.

Fragments of plant cuticle found in the feces were compared with preparations from the leaves of known plants. As the cuticle patterns, as far as studied, are characteristic for each sp., the fragments can be used to identify the plants grazed and to estimate the bot. comp. of the diet. The results presented in this prelim. study are purely qualitative. The advantage of this method is that it in no way interferes with the normal habits of the animal, and it may be used for any animals grazing on any type of pasture. —From auth. sum.

DUCKWORTH, J. E., AND SHIRLAW, D. W. 595
1958. The value of animal behaviour records in pasture evaluation studies. Anim. Behaviour [London] 6(3/4): 139–146.

From 2 field trials at the Cockle Park Research Sta. in 1949–50, in which data of animal behavior on different types of sward were compared and related to live-wt. gains, it was concluded that animal behavior records might be of use in pasture-evaluation studies, but that more basic knowledge of the subj. was required. In a further trial, an automatic recording apparatus was used with cattle, housed indoors, to investigate relationships between the jaw movements and the intake of wet matter, DM, and fiber. The results indicated that: (a) high percentages of DM and fiber restricted the wt. of wet matter consumed; (b) there was a significant negative relationship between the time spent eating and the wt. of wet matter consumed, and an indication that the greater wt. of wet matter was eaten at a faster rate of jaw movement; and (c) the highest speed of eating was assoc. with herbage with a low content of DM and fiber. It is suggested that herbage with a high content of DM and a low fiber content could be palatable and would be consumed in maximum quantities. It is concluded that before records of jaw movements can be used to determine the amount and quality of food consumed, or to indicate the efficiency of grazing, much fundamental res. on cattle housed indoors must be undertaken.—Herb. Abs.

ES, A. J. H. VAN. 596
1963. On the criticism of the determination of net energy with difference trials. Netherlands Jour. Agr. Sci. 11(1): 38–44.

The shortcomings of determining the net energy content of feeds using difference trials are discussed. In trials with low-quality hay and silage, expt. error is large, and it is suggested that the SE of one lot of hay or silage should be determined by difference and that maintenance trials should be performed alternating the above roughage with other roughages of poor quality, using nonlactating and lactating cows for the difference and maintenance trials, respectively. The SE of the poor-quality feeds can then be calculated.

FELS, H. E., MOIR, R. J., AND ROSSITER, R. C. 597
1959. Herbage intake of grazing sheep in south-western Australia. Austral. Jour. Agr. Res. 10(2): [237]–247, illus.

Estimates of the intake of pasture organic matter by grazing sheep were made for 2 types of pasture, clover-dominant and grass-dominant, at 3 growth stages. These estimates were made from fecal N index equations which were derived from data on penned sheep. One of the equations was found to be remarkably close to Lancaster's (1954) regression of feed/feces ratio on % fecal N content. The dry mature clover pasture was anomalous, and a separate "local" regression was derived for it. Organic matter intakes

for grazing sheep of about 110 lbs. body wt. ranged from 900 to 1,300 g./day, except on dry clover pasture, where the intake was only about 700 g./day. Contrary to common belief, subterranean clover was eaten at least as readily as grass during the growing season. Evidence is presented that sheep grazing on pastures with a total N content of 2.5% or less select material of higher than av. N content, whereas if the N content of the pasture exceeds 3.5%, there is no such selection.—From auth. sum.

FORBES, E. B., ELLIOTT, RALPH F., SWIFT, R. W., AND OTHERS. **598**
1946. Variation in determinations of digestive capacity of sheep. Jour. Anim. Sci. 5(3): 298–305. (James, W. H., and Smith, Vivian Frances, joint auth.)

In a study of variation in determinations of digest. capacity of sheep, 22 yearling Merino wethers were used in a digest. expt. with clover-timothy hay as the only feed. The standard deviation of the values determined for digestibility of the nutrients of the hay was reasonably low except for lignin as determined by difference. A table is presented giving the standard errors and the minimum difference required between determinations with 1–10 sheep for odds of significance of 19 to 1. While the no. of sheep required per expt. treatment depends on the permissible variability of results, 5 sheep per treatment are sufficient for usual purposes if the expt. technique is efficient and if the sheep have been successfully treated for parasites of the alimentary tract.

FRENCH, M. H. **599**
1961. Observations on the digestibility of pasture herbage. Turrialba [Costa Rica] 11(2): 78–84. [Sp. sum.]

The probs. and value of digestibility trials for determining the quantities of digest. nutrients in herbage are discussed. The literature is reviewed regarding the relations between the contents and the digestibility of organic matter, crude fiber, lignin, NFE, and CP of herbage in temperate and tropical regions, under different climates, and at different maturity stages. In countries where invests. in this field are just beginning, regression equations should be used for calculating the nutritive value of forage.

GLOVER, J., AND DUTHIE, D. W. **600**
1958. The nutritive ratio/crude-protein relationships in ruminant and non-ruminant digestion. Jour. Agr. Sci. [England] 50(2): 227–229, illus.

In both ruminant and nonruminant digest., the nutritive ratio of a feed is shown to be very significantly related to the CP content of that feed. This confirms that there is a relation between the total CP and digest. protein in a ruminant feed, and strongly suggests that there should also be a relation between these 2 components in nonruminant feeds.—From auth. sum.

GLOVER, J., AND DUTHIE, D. W. **601**
1958. The apparent digestibility of crude protein by non-ruminants and ruminants. Jour. Agr. Sci. [England] 51(3): 289–293, illus.

The apparent digestibility of CP by the nonruminants, pigs, horses, rats, man, and rabbits, is shown to be related to the CP content of the feed, and the form of the relation is similar to that for ruminants. With nonruminants the apparent digestibility of CP is markedly depressed by the crude-fiber content of the feed, whereas with ruminants the depression is only slight. The relevant equations show that pigs are much more sensitive to crude fiber than horses and rabbits, and both the latter react more markedly to crude fiber than do the ruminants. Despite the apparently significant differences between the equations for the ruminant and nonruminant herbivores, it is shown that over the normal range of CP and crude-fiber content in feeding-stuffs suitable for herbivores, the apparent digestibility coefficient of CP is similar for all. In other words, despite different abilities to cope with crude fiber, the herbivores as a class digest CP in normal feeds to much the same extent. On the other hand, the pig, an omnivore, is shown to be very markedly affected by the crude-fiber content of such feeds.—From auth. sum.

HARKER, K. W., TORELL, D. T., AND VAN DYNE, G. M. **602**
1963. Botanical examination of forage from esophageal fistulas in cattle. (Abstract.) Jour. Anim. Sci. 22(3): 850.

The accuracy is assessed of a method for determining bot. comp. of undigested herbage (*Brachiaria decumbens* and *Ipomoea batatas*) by means of spot observs. under a microscope.

JOBLIN, A. D. H. **603**
1962. The use of grazing-animal observations in the early stages of pasture evaluation in the Tropics. I. The measurement of relative palatability. Brit. Grassland Soc. Jour. 17(3): 171–177.

An observational technique for measuring pasture palatability is described; with this method a palatability index is constructed to indicate the spp. selected by stock under

specified chosen conds. The index differentiates these spp. from others that stock are prepared to eat when selections are more limited. The potential usefulness of this index in the initial testing of tropical pasture spp. is discussed. Results are reported from two 3-yr. expts. where the method was used. Coefficients of variation in individual grazings ranged from 13.5% to 22.2%, with expt. means of 19.2% and 18.3%. *Hyparrhenia rufa* and *Cenchrus ciliaris* were the most consistently palatable of the grasses offered.

KASTELL, A. **604**
1961. The estimation of digestibility of crude protein by artificial methods. Bodenkultur [Vienna] Ser. A 12(3): 247–253. [In Ger. with Eng. sum.]

Various pepsin preparations are compared for artificial evaluation of CP digestibility.

KING, W. A., LEE, J., WEBB, H. J., AND RODERICK, D. B. **605**
1960. Comparison of 6- and 10-day collection periods for digestion trials with dairy heifers. Jour. Dairy Sci. 43(3): 388–392.

KIVIMÄE, ARNOLD. **606**
1960. Estimation of the digestibility of grassland crops from their chemical composition. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 466–470. [In Eng. with Eng., Fr., and Ger. sum.]

The results are reported of a statis. study of the data from digestibility trials with sheep fed 58 batches of artificially dried red clover and timothy herbage. The accuracy in estimating the digestibility of organic matter and protein by the content of crude fiber, lignin, protein, and methoxyl in the herbage varied according to the spp., stage of growth, and time of cutting. The digestibility of organic matter in red clover was estimated best by lignin and crude fiber, followed by protein and methoxyl. For timothy, methoxyl and lignin gave the best estimate. Digestible protein in red clover was estimated equally well by crude fiber, lignin, and protein, whereas in timothy, protein gave the best estimate.

LAMBOURNE, L. J., AND REARDON, T. F. **607**
1962. Use of "seasonal" regressions in measuring feed intake of grazing animals. Nature [London] 196(4858): 961–962, illus.

LESPERANCE, A. L., BOHMAN, V. R., AND MARBLE, D. W. **608**
1960. Development of techniques for evaluating grazed forage. Jour. Dairy Sci. 43(5): 682–689.

Samples of hay obtained from esophageal and rumen fistulas in yearling steers contained more crude fiber and less NFE and total energy than did samples of the same hay not fed to the animals. Grazing trials with these animals indicated that bot. analysis of fistula samples was possible.

LESPERANCE, A. L., BOHMAN, V. R., MARBLE, D. W., AND OTHERS. **609**
1959. The development of techniques for evaluating grazed forage. (Abstract.) Jour. Anim. Sci. 18(3): 1173. (Jensen, E. H., and Madsen, R., joint auth.)

In rotational grazing studies, using steers with esophageal and rumen fistulas, the protein content of the grazed herbage decreased by 4.7% over a 2–3 wk. period, while that of crude fiber increased by 4.9%. During the grazing period, the % of grass in the feed increased and that of clover decreased, indicating that selective grazing was occurring.

LOFGREEN, G. P. **610**
1953. The estimation of total digestible nutrients from digestible organic matter. Jour. Anim. Sci. 12(2): 359–365.

A method is presented which permits the calculation of TDN from the digest. coefficient of organic matter. The method consists of the following steps: Conduct digest. trial on feed or feeds; determine moisture, ash, and ether extr. on feeds; determine moisture and ash on feces; calculate the digestibility of the organic matter; calculate the conversion factor, F, according to the formula $F=M(.01+.000125E)$, where M is the % organic matter in the feed and E is the % ether extr. in the organic matter; and determine TDN by multiplying the digestibility of organic matter in % by the conversion factor, F. The TDN values determined by the suggested method in 50 digest. trials agreed closely with those determined by the conventional method. The method has important advantages—it is simple and quick.

LUCAS, H. L. **611**
1943. A method of equalized feeding for studies with dairy cows. Jour. Dairy Sci. 26(11): 1011–1022, illus.

A method of equalized feeding is presented which prevents biases in ration comparisons, and simultaneously increases precision by allowing more uniform persistency among animals. The method consists of periodically changing the concentrate intakes

of all animals on an expt. regardless of ration exactly the same % as their respective initial concentrate intakes. Meanwhile the roughage portion of the ration is maintained constant for each animal. The method may be appl. with either the continuous or changeover trials. When using equalized feeding and about 20 animals, differences of 3-1/2–5% and 2–3% likely could be demonstrated as significant in the continuous and changeover trials, respectively.

McDonald, P., and Purves, D. 612
1957. The estimation of feed intake by sheep on a silage diet. Brit. Grassland Soc. Jour. 12(1): 22–29.

The results of 19 digestibility trials with sheep on different silages have been reported. From these data and from the results of 40 other trials with sheep, it has been shown that Lancaster's method of calculating feed intake can be applied to silages when the CP content is within the range studied (9–24% of the DM). For silages in this category, no advantage has been obtained by considering the N content of the silage DM in calculating feed intake. The digestibility of CP and Lancaster's "constant" have both been correlated with the CP content of the silage DM for the 59 trials considered (r=0.767 and r=0.452, respectively). Although it has been unnecessary to consider the protein content of silage in calculating DM intake when feeds containing 9–24% CP in the DM are used, evidence indicates that this factor is of considerable importance when herbage of low protein content is fed. The equation, % digestibility of

$$\text{CP}=91.57-\frac{314}{\%\ \text{CP in herbage DM}},$$

which has been derived from the silage data considered, has been valid when compared with the results of trials with fresh herbage and well-preserved hays of low protein content. The results of this work indicate that Lancaster's method is suitable for estimating the feed intake of animals engaged in self-feeding of silage, provided the silage has been well preserved.

Moir, R. J. 613
1961. A note on the relationship between the digestible dry matter and the digestible energy content of ruminant diets. Austral. Jour. Expt. Agr. and Anim. Husb. 1(1): 24–26, illus.

The digest. energy content (y, in calories/g.) of a wide range of foodstuffs for ruminants may be accurately estimated from the % DM digestibility (x) by the regression $y=0.0462x-0.158$ (r=0.98). Thus, DM digestibility itself is a simple and accurate description of the digest. energy content of foodstuffs for ruminants.

Morgan, A., and Beruldsen, E. T. 614
1931. Sampling technique as applied to irrigated pasture in regard to botanical composition and carrying capacity under different grazing systems. Victoria Dept. Agr. Jour. 29: 36–45.

A method determining, by sampling technique, the effect on (a) productivity and (b) bot. comp. of an irrigated pasture, of a system of rotational grazing as compared with a nonrotational system, is suggested. A method of determining, by an extension of the sampling technique described, the amount of herbage consumed per sheep per day is put forward. By a comparison of the % of each major sp. present on the 1/12-acre plots before and after grazing, provided the statis. standards for significance of the differences are satisfactory, the spp. preferences of the sheep under the 2 grazing systems may be deduced, compared, and correlated with factors external to the pasture.—Herb. Abs.

Norris, J. J. 615
1943. Botanical analyses of stomach contents as a method of determining forage consumption of range sheep. Ecology 24(2): 244–251.

Botanical analyses of the stomach contents of 19 sheep were made to determine the accuracy of the method as a measure of the diet of grazing animals. The sheep were starved 24 hrs., fed weighed amounts of various forages, slaughtered, and the stomach contents removed. The contents were washed, screened, and dried, and a sample of 2% of the total was analyzed. Recognizable particles of each forage were picked out and weighed to determine the % by wt. of each sp. Fragmentary material, too small to warrant separation, was grouped as unseparated material. The amount of each forage found in the stomach was then compared with the amount in the ration as a test of accuracy. Wide variability between the amount of each forage fed to the animals and the amount found in the stomach throws considerable doubt upon the value of stomach analyses as a quantitative measure of diet of grazing animals. Varied amounts of material from previous feedings remain in the stomach and confuse the analyses.

Differentials in the digestibility of different forages and variations in the digest. abilities of sheep were found. From a qualitative standpoint, stomach analyses show some promise and may be used, in connection with other methods of food-habit studies, to compile lists of plant spp. eaten by grazing animals. However, the results throw great doubt upon the accuracy of the method as a means of determining the actual amount of each forage making up the diet of ruminants. Chemical analysis of stomach contents compared to that of forage consumed showed results even more variable than those from bot. analysis, and it is doubtful if this method is of any value as an index to the comp. of the diet of grazing animals.—Biol. Abs.

RAVEN, A. M., AND ROBINSON, K. L. **616**

1957. Studies in the determination of the digestibility of perennial ryegrass. 1. The determination of digestibility and retention of nutrients using a conventional method. 2. Digestibility coefficients and food intake as determined by a conventional method and by faecal index methods. North. Ireland Min. Agr. Res. and Expt. Rec. (1955) 5: 53–73.

REID, J. THOMAS, AND KENNEDY, W. KEITH. **617**

1956. Measurement of forage intake by grazing animals. Seventh Internatl. Grassland Cong., Palmerston North, Proc. 1956: 116–121.

The various techniques that have been developed to determine forage intake are discussed. Refinement of the methods for sampling feces followed by evaluation of other materials as external indicators offer the most promise for improving the accuracy of measuring forage intake by grazing animals.

RICHARDS, C. R., HAENLEIN, G. F. W., CALHOUN, M. C., AND OTHERS. **618**

1962. Date of cut vs. the combination of crude fiber and crude protein as estimators of forage quality. Jour. Anim. Sci. 21(4): 844–847. (Connolly, J. D., and Weaver, H. G., joint auth.)

The relations of dates of cutting of 22 alfalfa and grass hays grown in Del. to their digestibilities were calculated. The procedures used in this study could be appl. to west. hay crops.

SCHNEIDER, BURCH H., AND LUCAS, HENRY L. **619**

1950. The magnitude of certain sources of variability in digestibility data. Jour. Anim. Sci. 9(4): 504–512.

A compilation of published digestibility data was studied statistically. Total error of within-feed variance may be divided roughly as follows: 25–45% is assoc. with variation in proximate comp., 20–40% with auth., 20–35% with samples, and 10–25% with trials. Variability in digestibility of a given nutrient tends to be inversely related to the % of that nutrient in the feed. Especially high variances were noted for digestibilities of ether extr., of CP in certain roughages, and of crude fiber in concentrates. Digestibility "by-difference" gave much higher values for certain components of variance than did the method in which feeds are fed alone. Certain spp. of animals digest certain nutrients more variably than do others. Av. digest. coefficients should be adjusted for proximate comp. in applying them to particular samples. More of the variance could be related to feed comp. if nutrients other than those in proximate analyses were considered. Accurate av. digestibility data can only be obtained if a feed is studied by a relatively large no. of auth., each investigating several samples of that feed. Only 2 or 3 trials are needed per sample. Coordinated and cooperative studies seem the best for attaining this end.

SCHNEIDER, BURCH H., LUCAS, HENRY L., PAVLECH, HELEN M., AND CIPOLLONI, MARY ANN. **620**

1950. The value of average digestibility data. Jour. Anim. Sci. 9(3): [373]–379.

Using published data for 5 classes of feeds (hays, other dry roughages, green soiling crops, silages, and concentrates) fed to 4 spp. of animals (cattle, sheep, goats, and swine), the value of av. digestibility data in the assessment of the nutritive value of particular samples has been studied by statis. methods. The criterion of value used was the ratio of the between- and within-feed variances for digest. coefficients and TDN. The ratio measures the relative increase in precision with which nutritive value is assessed if one uses separate digest. coefficients for each kind of feed as compared to disregarding digestibility or assuming that all feeds in a class have the same av. digestibility. The increases in precision if separate digest. coefficients are used may be expected to be moderate to marked for almost all nutrients in all feeds. If digestibility is adjusted for proximate comp., the increases in precision may be expected to be reduced, but they remain substantial. The effects of nutrients other than those included in proximate comp. could not be examined. It was concluded that applying av. digest. coefficients for a given feed to particular samples of that feed is warranted even though a high within-feed variability is very common.

Smith, E. F., Young, V. A., Holland, L. A., and Fryer, H. C. 621
1959. A comparison of two grass sampling methods for digestibility trials conducted on pastures. Jour. Range Mangt. 12(6): 306–308.

In 3 trials plot clipping and hand plucking to simulate grazing were compared. With hand plucking, an attempt was made to pluck vegetation similar to that which steers were grazing. The CP, crude-fiber and ash contents, ether extr., and NFE of the samples were compared. Variation between trials was high, but the 2 methods appeared to give different results. Hand-plucked samples tended to be higher in CP and lower in crude fiber than clipped samples, indicating that plot clipping does not measure the comp. of the forage being grazed.

Sosulski, F. W., and Patterson, J. K. 622
1961. Correlations between digestibility and chemical constituents of selected grass varieties. Agron. Jour. 53(3): 145–149.

Data are presented on the chem. comp., digestibility, and consumption for the following hays (harvested at anthesis in 1956–57): Latar and S.143 orchardgrass (*Dactylis glomerata*), the bromegrasses Manchar (*Bromus inermis*) and Russian (*B. tomentellus*), Alta tall fescue (*Festuca arundinacea*), and Amurense intermediate wheatgrass (*Agropyron intermedium*). Russian bromegrass was the most digest. in both yrs. Latar was more digest. than S.143 orchardgrass and had a lower lignin content. There was a significant correlation between CP and lignin contents in both yrs. ($r=+0.837$ in 1956 and $r=+0.921$ in 1957). Lignin was also correlated significantly with 3 components of digestibility in both yrs. (with DM, $r=-0.884$ in 1956 and $r=-0.934$ in 1957). Protein and crude fiber, in 1956, were the only criteria significantly correlated with daily intake (for DM, $r=+0.825$ and $r=-0.906$, respectively).

Staples, George E., and Dinusson, W. E. 623
1951. A comparison of the relative accuracy between seven-day and ten-day collection periods in digestion trials. Jour. Anim. Sci. 10(1): 244–250.

Comparisons of standard deviations and losses in efficiency of apparent digest. coefficients calculated from data obtained from trials with steers involving 7- and 10-day collection periods showed a comparable degree of accuracy, the short period showing an efficiency loss of less than 1.1% for all nutrients tested except for the 6.83% loss for NFE. The significance of this larger loss is difficult to interpret as the conventional method of NFE determination for roughages is poor.

Swift, R. W., and Bratzler, J. W. 624
1959. A comparison of the digestibility of forages by cattle and by sheep. Pa. Agr. Expt. Sta. Bul. 651, 5 pp.
See also **1, 28, 283–285, 304, 307, 311, 318.**

FACTORS AFFECTING FORAGE INTAKE AND DIGESTIBILITY

Andersen, P. E., Reid, J. T., Anderson, M. J., and Stroud, J. W. 625
1959. Influence of level of intake upon the apparent digestibility of forages and mixed diets by ruminants. Jour. Anim. Sci. 18(4): 1299–1307.

Cook, C. Wayne, and Harris, Lorin E. 626
1950. The nutritive value of range forage as affected by vegetation type, site, and state of maturity. Utah Agr. Expt. Sta. Bul. 344, 45 pp., illus.

During the summer grazing season of 1946, sheep range in the mountains of north. Utah was studied to determine the effect of vegetation type, site, and stage of growth on the nutritive value of range forage. Favorable and unfavorable sagebrush and aspen sites were examined. Site conds. and stage of growth significantly affected the nutritive content of range forage. Sites indirectly affected the chem. content of plants and plant pts. through soil and plant devlpmt., water runoff, intensity of shade, and other environmental factors. Plants growing on aspen areas had a higher content of protein, P, and ash than those on sagebrush areas. The C content of plants or plant pts. differed little between aspen and sagebrush types. Unfavorable sites and aspen types generally produced a higher cellulose to lignin ratio. Vegetation type did not appear to influence crude-fiber content markedly. However, aspen types favored a more rapid seasonal increase in crude fiber than sagebrush types. There was no decided seasonal change in NFE and other carbohydrates. The relative amounts of stem and leaf produced accounted for some of the differences in chem. comp. between spp., and also for some of the seasonal changes in comp. of the various plants. Evidently the nutrient content of the forage is influenced by many interdependent factors, and the result is the additive of mass effect of all factors operating simultaneously.

COOK, C. WAYNE, STODDART, L. A., AND HARRIS, LORIN E. 627
1953. Effects of grazing intensity upon the nutritive value of range forage. Jour. Range Mangt. 6(1) : 51–54, illus.

During the winter grazing seasons of 1949 to 1952, digest. studies were conducted on typical saltbush ranges of Utah to evaluate the factors affecting the nutritional value of the foraging animal's diet. As util. increased, the content of the more desirable nutrients in the available forage decreased, and, in addition, the digestibility of these nutrients was lowered markedly. With intensive util. the animals were forced to consume the less nutritious portions of the plants; thus, the available nutrients frequently were not adequate to meet the demands of the grazing animals.

CRAMPTON, E. W. 628
1937. The relation of the lignin and cellulose content of pasture herbage in its nutritive value. Amer. Soc. Anim. Prod. Proc. 1937: 351.

Available data show that there may be no constant relation between any constituent of the commonly used feeding-stuffs analysis and the live-wt. gains made by rabbits fed on diets of clipped, dried pasture herbage. It is postulated that lignification is an important cause of the decrease in feeding value of pasture herbage during adverse seasons, and that the failure of the analysis consistently to predict the feeding value of such forage is partly because it does not partition the fat-N-ash-free fraction according to its chief biologically significant groups.

CRAMPTON, E. W. 629
1939. Pasture studies. XIV. The nutritive value of pasture herbage. Some problems in its estimation and some results thus far obtained at Macdonald College. Sci. Agr. [Ottawa] 19(6) : 345–357.

This paper is chiefly a critical discussion of the methods commonly used to estimate the nutritive value of pasture herbage. The limitations of certain fractions of the standard feeding-stuffs analysis as satisfactory criteria of feeding value are especially emphasized and illus. by results obtained from rabbit feeding trials at Macdonald Col. and by data published in the literature. The usual feeding-stuffs analysis (chem.) does not partition the organic material of a feed into biol. units; hence, its value in predicting feeding value is necessarily uncertain. As a possible impr. in this respect for pasture herbage, a modification in the analyt. plan is proposed whereby the "carbohydrate" fraction is to be separated into (1) lignin, (2) cellulose, and (3) other carbohydrate instead of the present groups—crude fiber and NFE. Data are presented indicating that lignification of the herbage increases from spring to midsummer and then decreases as cooler seasonal conds. occur, and that the nutritive value of the herbage is negatively correlated with the lignin trend. The need for "pilot" animals in studying the nutritive value of pasture herbage is stressed, and the possibility of using rabbits is discussed.

CRAMPTON, E. W., AND FORSHAW, R. P. 630
1939. Pasture studies. XV. The intra-seasonal changes in the nutritive value of pasture herbage. Sci. Agr. [Ottawa] 19(12) : 701–709.

The limitations of the standard feeding-stuffs analysis as an indicator of the feeding value of pasture herbage, as measured by the growth of rabbits, are shown. The modified feeding-stuffs analysis proposed by Crampton and Maynard is used to explain the observed changes in nutritive value. A steady decline in growth-promoting value and digestibility of herbage from spring until midsummer and a complete recovery in both respects in the fall-grown material is noted. Marked differences in nutritive value may exist between herbage representing only 10 days of growth, according to the period of the season in which it is grown. The effect of small increases in lignin upon the digestibility of the various feed fractions indicates that it is not only the amount of lignin, but also the mode of deposition, that determines the extent of its effect upon digestibility and nutritive value of pasture herbage.

CRAMPTON, E. W., AND JACKSON, I. R. C. 631
1944. Pasture studies. XXVI. Seasonal variation in chemical composition of pasture herbage and the relation to its digestibility by steers and sheep. Jour. Anim. Sci. 3(4) : 333–339, illus.

Improvement in nutritive value has been claimed for different treatments in many pasture studies because of a resulting increase in protein and/or decrease in fiber content of the herbage. Data presented here indicate that such concl. are unwarranted. Neither of these proximate principles differs significantly in its digestibility from the other or from that of the total DM. Furthermore, changes in either fraction during the season are either not correlated, or are correlated contrary to the expected concomitant changes in the digestibility of the DM eaten. The digestibility of pasture herbage DM

usually steadily declines from values of about 75% for early spring grass to 60% some 6 wks. later. Then digestibility may rise again, further decline, or remain at the mid-summer level. The level apparently does not depend on chem. changes indicated by standard feeding-stuffs analysis or its modifications herein described, but closely parallels local conds. of moisture and temp.

Drori, D., and Loosli, J. K. 632
1959. Influence of fistulation on the digestibility of feeds by steers. Jour. Anim. Sci. 18(1): 206–210.

Eighteen single digest. trials were conducted with 3 intact and 3 rumen-fistulated steers fed 3 rations: (1) all hay, (2) all concentrate and (3) hay plus concentrate. Two simultaneous 3×3 Latin squares were employed. The differences between digest. coefficients obtained with intact and fistulated steers were not significant at the $P=0.05$ level. Nonadditive digestibility was not apparent; the digest. coefficients of the mixed ration (3) were in good agreement with those computed for this ration from the single-feed rations (1) and (2).—Auth sum.

Garrigus, W. P., and Rusk, H. P. 633
1939. Some effects of the species and stage of maturity of plants on the forage consumption of grazing steers of various weights. Ill. Agr. Expt. Sta. Bul. 454, 66 pp., illus.

The devlpmt. of a satisfactory sack and harness for collecting the feces of freely grazing steers has permitted use of the predetermined relation between DM consumption and DM defecation for measuring, with a probable accuracy of 94–97%, the forage consumption of steers grazing at will on uniform forage. For each of certain forages, the intake of each steer was related to the calculated amount of that forage required to maintain the steer's energy balance. The actual consumption by the various steers grazing on the different forages, expressed in terms of % of maintenance requirement, was: 5-wk.-old Kentucky bluegrass, *Poa pratensis*, 270%, av. of 5 expts.; quarter-bloom red clover, *Trifolium pratense*, 237%, av. of 4 expts.; mature red clover, *T. pratense*, 224%, av. of 4 expts.; ground reed canary grass, *Phalaris arundinacea*, 182%, av. of 4 expts.; late bromegrass, *Bromus inermis*, 139%, av. of 4 expts.; and full-bloom alfalfa, *Medicago sativa*, 129%, av. of 5 expts. The digestibility of the DM from red clover did not significantly differ in the 2 stages of maturity nor in the rates with which they were consumed. No definite relation was found between size of steer and rate of consumption. An accurate check on the generally accepted clipping method revealed an apparently inherent error of 57%.

Groenewald, J. W., Myburgh, S. J., Laurence, G. B., and Louw, J. G. 634
1950. Digestibility of lucerne hay with special reference to experimental technique in digestion trials. Onderstepoort Jour. Vet. Sci. and Anim. Indus. 24(1/2): 67–86, illus.

Five steers were used to determine the digest. coefficients of DM, CP, and crude fiber of alfalfa hay during 5 separate feeding periods. The period has no influence on the coefficient of CP, but there is some evidence of a period influence on the coefficients of digest. of DM and crude fiber.—Auth. sum.

Hercus, Barbara H. 635
1960. Plant cuticle as an aid to determining the diet of grazing animals. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 443–447, illus. [In Eng. with Eng., Fr., and Ger. sum.]

The results are given of a no. of expts. in New Zeal. on different types of herbage. The tests investigated the possibility of determining the bot. comp. of the diet of sheep by identifying fragments of plant cuticle in the feces. All the spp. ingested could be identified, and some idea of the proportion of cuticle derived from each could be obtained. Such factors as age and size of animal, size of bite, amount of rumination, rate of passage and digestibility of the feed, and previous feeding history influence the breakdown of plant cuticle more than do differences between plant spp. The size of fragment required for identification varied between spp. In the one expt. carried out, there was some agreement between the count of undigested fragments in the feces and estimates of herbage digestibility on the basis of fecal N content. Other ways in which this technique could give useful inform. are suggested.

Holmes, W., Jones, J. G. W., and Drake-Brockman, R. M. 636
1961. The feed intake of grazing cattle. II. The influence of size of animal on feed intake. Anim. Prod. [Edinburgh] 3(3): 251–260.

Langlands, J. P., Corbett, J. L., and McDonald, I. 637
1963. The indirect estimation of the digestibility of pasture herbage. III. Regressions of digestibility on faecal nitrogen concentration: Effects of species

and individuality of animal and of the method of determining digestibility upon the relationships. Jour. Agr. Sci. [England] 61(2): 221–225.

MINSON, D. J., AND KEMP, C. D. **638**
1961. Studies in the digestibility of herbage. IX. Herbage and faecal nitrogen as indicators of herbage organic matter digestibility. Brit. Grassland Soc. Jour. 16(1): 76–79.

Data from 291 digest. trials have been used to derive regression equations relating the organic-matter digestibility of herbage to the % N of its DM and to the % N in the organic matter of the resulting feces. The residual errors are very high, and deviations from the lines are not randomly distributed but have a seasonal trend. The seasonal biases have been calculated, and the inclusion of mo. of cutting somewhat improves the 2 regressions. Monthly regressions have also been calculated, but the errors are still too high for many practical purposes.

PEARCE, G. R., VERCOE, J. E., AND FREER, M. **639**
1962. The establishment of faecal nitrogen-digestibility regressions for animals grazing irrigated pasture. Jour. Agr. Sci. [England] 59(3): 397–402.

The regression of the ratio of feces output to fodder intake against the % of fecal N, obtained from trials in which a peren. ryegrass/cocksfoot/white clover sward was cut to ground level and fed to sheep and cattle, did not conform to similar regressions for the "top" (mainly leaf) cuts and "bottom" (mainly stem) cut taken in spring and autumn from the same pastures. It is suggested that, owing to selectivity by grazing animals, considerable errors may arise when regressions derived by using swards cut to ground level are appl. to grazing animals.—Herb. Abs.

RAYMOND, W. F., EYLES, DUDLEY E., AND CAUKWELL, V. G. **640**
1949. Cold storage of pasture used in digestibility experiments. Brit. Grassland Soc. Jour. 4(2): 111–114.

Possible errors and difficulties in the conventional digestibility trials with cut herbage are considered. A method is described in which sufficient herbage for a complete digestibility expt. is cut and sampled on 1 day and then stored at 0° F. The frozen grass after thawing is readily eaten by sheep. A digest. disturbance occurred only for 1 sheep, which scoured for a few days during 1 feeding trial. The DM digestibility figs. obtained from these expts. closely agreed between animals. Freezing affects the DM and total N content of herbage less than 1%, as compared with figs. obtained by immediate ovendrying. The possible effects of freezing on digestibility are being investigated.

RAYMOND, W. F., HARRIS, C. E., AND HARKER, V. G. **641**
1953. Studies on the digestibility of herbage. I. Technique of measurement of digestibility and some observations on factors affecting the accuracy of digestibility data. Brit. Grassland Soc. Jour. 8(4): 301–314.

Details are given of the digest. equip. and technique used in a study of the digestibility of cold-stored herbage. The techniques of DM determination and chem. analysis used are described. Factors affecting the accuracy of digestibility data, including the duration of the feeding period and the no. of animals used, are considered. Digestibility data on herbage are likely to continue to be of much value until more knowledge on the measurement of the nutritive value of herbage is obtained.

RAYMOND, W. F., HARRIS, C. E., AND HARKER, V. G. **642**
1953. Studies on the digestibility of herbage. II. Effect of freezing and cold storage of herbage on its digestibility by sheep. Brit. Grassland Soc. Jour. 8(4): 315–320.

The effect of freezing and cold storage of fresh herbage at 0° F. has been studied in 4 expts. The first 2 expts. indicated a small drop in the digestibility of herbage after cold storage. Later expts. indicated that these 1st comparisons might not be strictly valid, and showed that there was no significant change in the digestibility by sheep of the DM, organic matter, and N in herbage during cold storage.

RAYMOND, W. F., HARRIS, C. E., AND KEMP, C. D. **643**
1954. Studies in the digestibility of herbage. V. The variation, with age, of the ability of sheep to digest herbage, with observations on the effect of season on digestive ability. Brit. Grassland Soc. Jour. 9(3): 209–220.

A no. of expts. have been conducted, using frozen herbage, hay, and dried grass, to compare the digest. abilities of sheep of different ages. Because of unequal nos. of age groups and sheep in different expts., a combined statis. analysis of all the data has not been practicable, but a trend showing digest. ability to increase with age has been found. Regression analysis on the data showed an av. increase of about 1 unit of

digestibility per yr. from lambs to 2-yr.-olds. An increase in digest. efficiency with age was not found in all the expts., and the data are inadequate to allow digestibility data based on 1 age group to be compensated for use with another age group. It was not possible to show which fractions of herbage feeds are more efficiently digested by older animals. To study whether the digest. efficiency of individual sheep increased with age, digest. expts. with the same sheep were carried out at intervals during the yr. on the same feed. While these also indicated an increase in digest. efficiency with age, a possible seasonal cycle in digest. ability was indicated. These data, together with those from other sources, have suggested that the digest. efficiency of sheep decreases during the winter and rises during the following summer. The possible interrelation with fluctuations in rumen flora content is noted.

RAYMOND, W. F., HARRIS, C. E., AND KEMP, C. D. 644
1955. Studies in the digestibility of herbage. VI. The effect of level of herbage intake on the digestibility of herbage by sheep. Brit. Grassland Soc. Jour. 10(1): 19–26.

Published data suggest that while the digestibility of concentrates and mixed rations decreases with increase in level of feeding, no such effect is found with dried roughages. Little evidence is available on the effect of level of feeding on the digestibility of bulky fresh feeds. As the level of herbage intake in the field is generally higher than that possible in digestibility expts., it is important to know whether level of intake has any effect on herbage digestibility. To study this effect, frozen herbage was fed in 6 expts. The 1st of these was a crossover trial, whereas in the remaining 5, 2 groups of similar sheep were fed simultaneously at low and high levels of intake (approximately 80:100). In all the expts. DM digestibility (%) decreased as level of herbage intake increased. This was 0.1 in expt. 1, and varied from 0.3 to 2.7 in the remaining expts., with a weighted av. of 1.06. A similar difference in digestibility between high levels of indoor feeding and field intake levels is likely. This is probably small in comparison with other errors in many expts., but it needs to be considered in more critical expts. Net util. of herbage feeds is likely to decrease more than digestibility as level of feeding is increased. The importance of avoiding selective feeding in digestibility studies of this type is discussed.

TAYLER, J. C. 645
1959. A relationship between weight of internal fat, "fill," and the herbage intake of grazing cattle. Nature [London] 184(4704): 2021–2022.

TAYLER, J. C., AND DERIAZ, R. E. 646
1963. The use of rumen-fistulated steers in the direct determination of nutritive value of ingested herbage in grazing experiments. Brit. Grassland Soc. Jour. 18(1): 29–38, illus.

A rumen-fistulated steer was used for the collection of samples of freshly swallowed herbage in a grazing-mangt. expt. on a peren. ryegrass sward. Diurnal and seasonal changes in the *in vitro* digestibility of the herbage selected by the grazing animal were studied under both strip- and continuous-grazing methods of mangt. There was no appreciable change in digestibility as the sward was grazed down from upper to lower layers under strip-grazing mangt. in Apr. and May. In June to Oct. a within-day fall in digestibility was found, much of which was attributable to an increase in the amount of old dead herbage grazed from the lower regions of the sward. Dead herbage taken in by the grazing steer was considerably lower in digestibility in Aug. than in May. The *in vitro* digestibility of herbage samples, cut to ground level before and after grazing in a strip-grazed treatment, fell markedly as the proportion of dead herbage in the sample increased, giving a high negative correlation. In a continuous-grazing mangt., there was no pattern of diurnal variation, and the seasonal variation in digestibility of the ingested herbage was less than in strip grazing. The implications of these results are discussed in relation to indirect methods of digestibility determination (fecal-index technique), the measurement of herbage intake, and to some aspects of grazing mangt.—Herb. Abs.

See also **28, 593, 619, 682.**

INDICATOR METHODS IN DIGESTION STUDIES

ALDER, F. E., TAYLER, J. C., CHAMBERS, D. T., AND OTHERS. 647
1960. The herbage intake of beef cattle. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 447–450. (Richards, J. A., and Rudman, J. E., joint auth.) [In Eng. with Eng., Fr., and Ger. sum.]

Estimates, using fecal index techniques, were made of the herbage intake of cattle at pasture during Apr. to Oct. of 1955–59. Hereford-cross steers, 3 mos. to 2.5 yrs. old,

were used. The DM intakes of animals agreed reasonably closely with the TDN requirements of fattening cattle. The results of these expts. are discussed in relation to the accuracy of techniques.

ANTHONY, W. BRADY, PARKS, PAUL F., MAYTON, E. L., AND LANGFORD, W. R. **648**
1958. Evaluation of pasture swards by determining through use of chromogens-chromic oxide the seasonal variations in dry matter intakes and digestibilities by yearling beef steers. (Abstract.) Jour. Anim. Sci. 17(4): 1207.

Average daily digest. DM intakes by yearling steers on swards of *Lespedeza cuneata, Paspalum dilatatum/Trifolium repens, Dactylis glomerata/Medicago sativa,* and *Cynodon dactylon/T. incarnatum* were 8.68, 8.16, 8.89, and 6.77 lb., respectively, during the 1st grazing season, and 8.69, 9.54, 8.95, and 8.11 lb. during the 2nd. During the 1st yr., but not during the 2nd, the total amount of digest. DM consumed per acre for each sward, as calculated by the Cr_2O_3 method, was appreciably different from the estimated TDN consumption, as calculated from constants for maintenance and live-wt. gain. Digestibility coefficients and protein digestibility were lowest for *L. cuneata* forage.—Herb. Abs.

ANTHONY, W. B., AND REID, J. T. **649**
1958. Methoxyl as an indicator of the nutritive value of forage. Jour. Dairy Sci. 41(12): 1715–1722, illus.

Studies were made to determine the relation between the digestibility of DM and the fecal methoxyl content, and between the digestibility of forage and its methoxyl content. Different grass/legume mixtures were used as forage, either grazed, or cut and fed at different stages of maturity. The coefficients of digestibility of the cut forage were determined by conventional digestibility trials and those of the grazed forages by the chromogen technique. The digestibility of the DM of cut forage was highly significantly correlated ($r=-0.83$) with its methoxyl content. The methoxyl content of forage appeared to be of use as an index of relative digestibility for selecting between similar forages of widely differing digestibility.—From auth. sum.

ARCHIBALD, J. G., BARNES, H. D., FENNER, H., AND GERSTEN, B. **650**
1962. Digestibility of alfalfa hay and reed canary grass hay measured by two procedures. Jour. Dairy Sci. 45(7): 858–860.

ARCHIBALD, J. G., FENNER, H., OWEN, D. F., AND BARNES, H. D. **651**
1961. Measurement of the nutritive value of alfalfa and timothy hay by varied techniques. Jour. Dairy Sci. 44(12): 2232–2241, illus.

ARCHIBALD, J. G., OWEN, D. F., JR., FENNER, H., AND BARNES, H. D. **652**
1958. Comparison of chromium ratio and lignin ratio techniques for determination of digestibility of hays. Jour. Dairy Sci. 41(8): 1100–1103.

Digestion coefficients for DM, protein, energy, crude fiber, and NFE from 16 individual trials show that the chromium trioxide method for determining digestibility of forages gave somewhat more uniform results than did the lignin method, as indicated by generally lower standard errors of the mean values.—Auth. sum.

BRADLEY, N. W. **653**
1959. An evaluation of chromic oxide as an indicator for digestibility of beef cattle rations. Diss. Abs. 19(11): 2704.

BRADLEY, N. W., FORBES, R. M., ALBERT, W. W., AND OTHERS. **654**
1958. Use of the chromic oxide method for determining digestible energy and protein in complete pelleted steer rations. (Abstract.) Jour. Anim. Sci. 17(4): 1199. (Mitchell, G. E., Jr., and Neumann, A. L., joint auth.)

Chromic-oxide excretion patterns of 6 steers were compared when indicator was administered by capsule or orally as a pt. of a complete pelleted ration fed at 8 a.m. daily during 12 24-hr. collection periods for each method, with fecal collections being made at 2-hr. intervals. The chromic-oxide concentration in the individual fecal samples, expressed as a % of the mean 24-hr. concentration, varied from 57% to 208% when administered by capsule but only from 73% to 155% when administered in the pelleted ration. The general shape of the 2 excretion patterns was similar. Eight steers, fed the complete pelleted ration with indicator at 8 a.m. daily, were used in a 7-day collection period to compare the total collection method with the 8 and 10 a.m. composited grab-sampling method. For the 2 methods, apparent digest. coefficients for energy were 71.96 ±3.40 and 72.6 ±3.17 and for protein 71.60 ±3.18 and 71.88 ±3.19, respectively. The reduction in variability in chromic-oxide excretion in the pelleted ration method of administration and the similarity in the apparent digest. coefficients determined by total collection and by 8 and 10 a.m. composited grab samples would suggest a simple method for determining the digestibility of total DM or of individual nutrients in beef cattle rations under practical feedlot conds.

Brisson, G. J. 655
1960. Indicator methods for estimating amount of forage consumed by grazing animals. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 435–438. [In Eng. with Eng., Fr., and Ger. sum.]

A rev. is given of sources of error involved in the use of internal and external indicator methods for calculating the forage intake of grazing animals. Cr_2O_3 is regarded as the most promising external indicator and fecal N as the best internal indicator.

Brisson, G. J., and Pigden, W. J. 656
1958. Chromic oxide in a sustained-release pellet to reduce variation in its diurnal excretion pattern in cattle. (Abstract.) Jour. Anim. Sci. 17(4): 1200.

Chromic oxide (Cr_2O_3) was given in pellet form (1/2 Cr_2O_3+1/2 Kerr's plaster+ water) once per day at 4 p.m. to 2 steers (E–1) and 2 cows (E–2). Fresh grass was fed at 7 a.m. and 4 p.m. Rectal samples were taken at regular intervals for 5 and 7 consecutive days in E–1 and E–2, respectively. The Cr_2O_3 concentration expressed as % of the respective daily mean concentration was 100.3 ±2.5 at 7 a.m., 95.3 ±2.4 at 10 a.m., 96.5 ±2.6 at 1 p.m., 100.5 ±2.5 at 4 p.m., 100.8 ±1.7 at 7 p.m., 102.4 ±1.9 at 10 p.m., 100.2 ±1.73 at 1 a.m., and 99.0 ±1.53 at 4 a.m. The small differences between these concentrations were not statistically significant by analysis of variance. Total recovery measured only in E–1 was 100.4% for a period of 14 days preceding the rectal sampling period. There was no regurgitation of the pellets in either E–1 or E–2.

Corbett, J. L. 657
1960. Faecal-index techniques for estimating herbage consumption by grazing animals. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 438–442. [In Eng. with Eng., Fr., and Ger. sum.]

The nature and sources of errors in fecal index techniques for estimating herbage consumption by grazing animals are reviewed. A new method for administering Cr_2O_3 to animals is described; it gives coefficients of variation not greater than 5% where random sampling of feces is practiced. Four regression equations relating % herbage digestibility to % N in the organic matter of the feces are presented.

Davis, C. L., Byers, J. H., and Luber, L. E. 658
1958. An evaluation of the chromic oxide method for determining digestibility. Jour. Dairy Sci. 41(1): 152–159, illus.

Eight lactating dairy cows were used in a 10-day digest. trial in which the conventional total collection method of determining digestibility was compared with the grab-sampling technique using chromic oxide as an indicator. Variations in the excretion of chromic oxide and crude fiber at 2-hr. intervals over a 24-hr. period were studied. Statistical analysis showed no significant differences between the 2 methods of determining the digestibility of the rations. Analyses of samples from the total fecal composites for the 1st 6 days of the 10-day trial revealed coefficients of digestibility comparable to those obtained for the entire period. Considerable variations were found in the chromic-oxide content of the feces samples taken at various hrs. of the day, regardless of whether chromic oxide was administered once or twice daily. These variations make it difficult to select a sampling period which will give approx. 100% recovery for all cows for a given day; however, these data indicated this can be overcome in digest. studies by sampling the feces for a 10-day period. The hourly variations in the excretion of chromic oxide were not assoc. with the excretion of crude fiber.—Auth. sum.

Elam, C. J., Putnam, P. A., and Davis, R. E. 659
1958. The fecal excretion pattern of chromic oxide when administered to hereford heifers in a completely pelleted ration. (Abstract.) Jour. Anim. Sci. 17(4): 1199–1200.

Chromic oxide (Cr_2O_3) was mixed uniformly into a pelleted ration at 0.5% and fed to 3 Hereford heifers per treatment. Treatments were: (1) limited-fed once daily (LOD), (2) full-fed once daily (OD), (3) full-fed twice daily (TD), and (4) *ad libitum* (AL). After a 9-day prelim. period, fecal samples were collected at 3-hr. intervals for 48 hrs. Dry matter and Cr_2O_3 analyses indicated that a significant ($P<0.05$) time-concentration variation occurred in fecal Cr_2O_3. Furthermore, Cr_2O_3 excretion was influenced by the different feeding schedules. Respective peak concentrations of Cr_2O_3, expressed as % of daily mean, and times at which the peaks occurred were as follows: (1) LOD, 112% at 9 p.m., (2) OD, 108% at 12 a.m., (3) TD, 111% at 3 p.m., and (4) AL, 109% at 9 a.m. The magnitude of the variation in fecal Cr_2O_3 concentration, exhibited during a 24-hr. period, precludes the indiscriminate sampling of feces for digest. trials as regards time. However, it is thought that the individual variation exhibited by different animals fed Cr_2O_3 in pellets is less than when administered in gelatin capsules. The extremes found in individual observs. in this expt.

were low, 74%, and high, 135%. Four beef steers were fed (TD) a predominantly roughage ration which was ground, mixed with Cr_2O_3, and pelleted. Analyses of feces samples collected in the morning and afternoon for 8 days resulted in Cr_2O_3 concentrations which tended to support the type of excretion pattern found in the twice a day feeding.

FORBES, R. M. **660**
1950. Protein as an indicator of pasture forage digestibility. Jour. Anim. Sci. 9(2): 231–237, illus.

A method of calculating DM digestibility of forages from the protein content and predicted protein digestibility is presented. The data obtained are compared with data obtained by conventional and by lignin-ratio methods of determining digestibility. The av. digestibilities calculated in the various ways from data of lamb and steer trials are, in general, similar, but the slopes of the regressions of DM digestibility on lignin content are generally less when data are obtained by the "protein digestibility" method. This difference in slopes is statistically significant only for the lamb trials. The method apparently may be used with satisfactory accuracy for the determination of digestibility of DM by grazing steers. A difference in digest. capacities of cattle and sheep has been demonstrated; sheep are apparently more efficient digesters of protein in low-protein forage than are cattle. The difference disappears above 15% protein in the DM of the forage.

GREENHALGH, J. F. D., CORBETT, J. L., AND MCDONALD, I. **661**
1960. The indirect estimation of the digestibility of pasture herbage. I. Nitrogen and chromogen as faecal index substances. II. Regressions of digestibility on faecal nitrogen concentration: Their determination in continuous digestibility trials and the effect of various factors on their accuracy. Jour. Agr. Sci. [England] 55(3): 371–386.

HARDISON, W. A. **662**
1957. Indicator techniques with cattle, their usefulness and shortcomings. (Abstract.) South. Pasture and Forage Crops Impr. Conf. Rpt. 14: 30–31.

HARDISON, W. A., LINKOUS, W. N., ENGEL, R. W., AND GRAF, G. C. **663**
1959. Observations on the use of chromic oxide for estimating the fecal output of dairy animals. Jour. Dairy Sci. 42(2): 346–352, illus.

Two trials employing dairy heifers fed fresh-cut alfalfa (trial 1) or mixed hay (trial 2), and 1 trial, using lactating cows which received a complete ration (trial 3), have been conducted to study further the usefulness of chromic oxide for predicting fecal output. Total fecal collections were made during each trial. In addition, partial fecal samples were obtained at 6 a.m., 12 noon, 6 p.m., and 12 midnight on each day of each collection period. The results indicate that 3 to 7 days may be required for the indicator to reach a stable level in the feces. The mean recovery rates of chromic oxide from totally collected feces and from the combined 6 a.m. and 6 p.m. samples for trials 1, 2, and 3, respectively, were 89.4% and 89.7%, 97.5% and 96.4%, and 90.0% and 89.7%. Average daily fecal DM outgo was estimated from the chromic-oxide concentration of the combined 6 a.m. and 6 p.m. samples with an error of about 12%. Only in trial 2 were satisfactory estimates obtained.

HARRIS, LORIN E., COOK, C. WAYNE, AND BUTCHER, JOHN E. **664**
1959. Symposium on forage evaluation: V. Intake and digestibility techniques and supplemental feeding in range forage evaluation. Agron. Jour. 51(4): 226–234, illus.

The greatest prob. of measuring forage intake is assoc. with the errors of manually sampling forage and selective grazing by animals. This prob. can largely be overcome by the use of an esophageal fistula to sample a grazing animal's diet. For certain range plants a combination of the lignin ratio technique for estimating digestibility and chromic-oxide capsules as an external indicator for estimating fecal output holds promise as a means of estimating forage intake. With most other plants the use of plant chromogens or N holds the most promise as internal indicators. If chromogens or N are relied upon to determine intake and digestibility, each investigator should determine the appropriate regression equation to use under his own conds. It is evident that there is no 1 best way to sample the animal's diet. Each investigator should modify procedures to fit his conds. Energy requirements of animals and measures of the available energy of pastures should be expressed in calories per lb. or per kg. of DM, i.e., gross, digest., metabolizable, or net energy. Under most conds., digest. energy is a good energy measure. Metabolizable energy is a better measure of certain range plants than gross or digest. energy. If measurements are made in terms of TDN, digest. organic matter, or digest. DM, caloric equivalents should also be reported to allow for comparison with other values reported in the literature. To assess the

variation when feeding supps. under range conds., individual feeding in portable pens is preferred. Another method would be to use replicated groups grazing on the same area and separated for feeding by the use of cutting chutes. If supps. are fed in each of several pastures, the treatments should be replicated in more than 1 block of pastures and the supps. should be rotated within a block of pastures. Corral animals at daylight or the night before weighing and withhold feed and water. Mix animals of 1 replication or block of treatments in a holding corral. Weigh at random after the animals have had time to urinate and defecate. It is also desirable to sample the animals at random for blood or urine specimens, liver biopsy, or other animal measures. —Auth. sum.

HOLTER, J. A. 665
1959. The use of forage and fecal protein as indicators of forage digestibility. Diss. Abs. 20(6): 1934–1935.

In studies in which a wide range of forages were used, the following were evaluated: (a) the relation between the concentration of CP in the forage and the % protein digestibility and concentration of digest. protein and (b) the relation between the concentration of CP (N×6.25) in the feces and the concentration of CP and indigestible protein in the forage and the digestibility of the DM. The most accurate prediction of forage digestibility was obtained by using the concentration of protein in the feces as an index. Linear equations relating these values were evolved; separate equations for fresh, dry, and ensiled forages seemed necessary. It was concluded that protein could be used effectively under many grazing and feeding regimes as a fecal indicator of forage digestibility.

HOLTER, J. A., AND REID, J. T. 666
1959. Relationship between the concentrations of crude protein and apparently digestible protein in forages. Jour. Anim. Sci. 18(4): 1339–1349.

In a study of the relation between the concentration and digestibility of CP in forages from a wide range of plant spp. harvested at various stages of growth and in different ways, and fed to sheep and cattle, an exp. relation existed between apparent protein digestibility and the CP concentration, whereas a positive rectilinear relation existed between % CP and % digest. protein. Forage constituents appeared to be interrelated so that excretion of metabolic N by livestock was correlated with the concentration of CP in the forages. The true digestibility of protein appeared to be relatively constant regardless of the CP concentration in the forages. It was possible to predict the digest. protein content of 4 grasses heavily fertilized with N, or that of alfalfa leaf- or stem-material, with a high degree of accuracy by means of the formula: % digest. protein=% CP×0.929−3.48.

KANE, E. A., JACOBSON, W. C., AND DAMEWOOD, P. M., JR. 667
1959. Use of radioactive chromium oxide in digestibility determinations. Jour. Dairy Sci. 42(8): 1359–1366, illus.

Radioactive chromium oxide was tested as a digestibility indicator in dairy cattle by making direct comparisons of component digestibility coefficients with total collection procedure and chromium oxide ratio technique. The use of a radioactive isotope as a digestibility ref. substance was found to save time and labor and, under the conds. of this expt., to display about the same degree of precision as the 2 other methods studied. A disadvantage of using isotopes in this type of study is the increased care and expense involved in the disposal and handling of animals and excreta, as dictated by current Atomic Energy Commission and Food and Drug regulations.—Auth. sum.

KIVIMÄE, A. 668
1959. Chemical composition and digestibility of some grassland crops. Acta Agr. Scand. [Stockholm] Sup. 5, 142 pp.

The results are presented of an extensive series of analyses made during 1947–55 on lucerne, red clover, alsike clover (*Trifolium hybridum*), and timothy grown in south. Sweden. Data are given of climatic conds. during the trial period, crop phenology, expt. methods, and expt. errors. The main sect. of the paper is devoted to the chem. comp. and nutritive value of the crops during the growing season and equations of the regression of growth stage on the contents of DM, CP, ether extr., redose, inredose and redosan, NFE, crude fiber, cell-wall constituents, cellulose, lignin, carotene, ash, Ca, P, and Ca/P ratio. Further data are given on differences between the chem. comp. of tetraploid red clover vars. and Ultuna diploid red clover, between 1st- and 2nd-cut red clover, red clover and alsike clover, and the relation between the contents of different constituents in the crops during the growing season. The chem. comp. of the crops at 4 growth stages are given, with figs. for the av. comp. and the standard deviation, as a means for evaluating the accuracy of crude-fiber, lignin, and protein contents and stage of growth, as indices for estimating the nutritive value and digesti-

bility of forages and, to a lesser degree, their chem. comp. Protein gave the best results as an indicator substance, followed closely by crude fiber, though the accuracy of estimation depended on the closeness of the correlation between the indicator substances and the substance it was used to estimate. There are further sects. on seasonal and diurnal changes in chem. comp., on the digestibility of the crops, and on the digestibility of hays from north. Sweden, with particular ref. to the value of indicator substances for estimating digestibility.—Herb. Abs.

LAMBOURNE, L. J. **669**

1957. Measurement of feed intake of grazing sheep. I. Rate of passage of inert reference materials through the ruminant digestive tract. Jour. Agr. Sci. [England] 48(3) : 273–285.

Feces output for sheep varied from 100 to 400 g. air-dry wt. daily. Feed intake computations were from below 400 g. to 1,900 g. air-dry wt. daily. Markers appeared in feces 5 to 8 hrs. after dosing. Peak values at 10 to 18 hrs. declined until 60 to 70 hrs., when markers could no longer be reliably identified.

LANCASTER, R. J. **670**

1949. The measurement of feed intake by grazing cattle and sheep. I. A method of calculating the digestibility of pasture based on the nitrogen content of faeces derived from the pasture. New Zeal. Jour. Sci. and Technol. Sect. A 31(1) : 31–38.

A series of digestibility trials showed that the relationship between the wt. of pasture organic matter consumed by sheep and the total N excreted in the feces was almost constant. Based on this observ. a method of calculating organic matter digestibility from the concentration of fecal N has been developed.—Auth. sum.

MCCULLOUGH, M. E. **671**

1959. Symposium on forage evaluation: III. The significance of and techniques used to measure forage intake and digestibility. Agron. Jour. 51(4) : 219–222, illus.

The measurement of forage intake and digestibility provides a necessary measure of the intake of nutrients and the portion available for assimilation by the animal. Relative changes in DM digestibility reflect many important nutritional changes which significantly affect animal prod. These changes include intake of forage, balance of ration, and level of nutrient availability. The chromium oxide technique may be used to obtain data for comparing rations on a relative basis, but no truly satisfactory technique for critical determinations is currently available to replace hand feeding. Although lignin, N, and chromogens are all useful methods for determining digestibility, the chromogen technique is the technique of choice where it can be used.—Auth. sum.

MAJUMDAR, B. N., GUPTA, B. N., AND KEHAR, N. D. **672**

1962. Studies on indirect methods of determining feed digestibilities and herbage intakes of grazing animals. I. Use of chromic oxide as indicator for estimating faecal output of animals. Ann. Biochem. and Expt. Med. [Calcutta] 22(1) : 13–20.

MARTEN, G. C. **673**

1962. An investigation of the chromogen-chromic oxide and nitrogen-chromic oxide indicator and the TDN requirement methods in evaluating pasture forages for dairy cows. Diss. Abs. 22(11) : 3796–3797.

Using the TDN requirement as a standard of measurement, the fecal N and the fecal N/Cr_2O_3 methods gave more reasonable estimates of intake and digestibility than methods employing fecal chromogen.

MARTEN, G. C., WEDIN, W. F., AND DONKER, J. D. **674**

1960. Comparison of the clipping and chromogen-chromic oxide methods for pasture evaluation using various forage mixtures. Agron. Jour. 52(9) : 542–544.

Comparative measurements of DM consumption by grazing Holstein cows were made on 3 forage mixtures using 2 techniques, the mowerstrip clipping method and the chromogen-chromic oxide method. Experimental results may be summarized as follows. (1) Forage mixtures had little or no influence on the results. (2) No forage mixture was consistently consumed in greater quantities than others regardless of the method of measurement employed. (3) In July when moisture supply was near optimum, the chromogen-chromic oxide method showed greater overall forage consumption, while in Aug. when moisture was lacking, the clipping method showed greater consumption of DM. In June when precipitation was intermed., results were variable. (4) The chromogen-chromic oxide method was more sensitive in 8 out of 9 cases to a measurement of

DM consumption and significantly more sensitive in 4 of the 9 cases. (5) The clipping method under the conds. employed was not a reliable means of measuring DM consumption.—Auth. sum.

MARTEN, G. C., WEDIN, W. F., AND DONKER, J. D. 675
1963. A comparison of two established fecal index systems for estimating the digestibility and consumption of forages by grazing dairy cattle. Agron. Jour. 55(3): 265–268.

The N and the chromogen fecal index methods were compared in trials with dairy cows. The results from the 2 methods were highly correlated and both methods were equally sensitive statistically. The N method, however, consistently overestimated forage digestibility.—Herb. Abs.

MILLER, W. J., DONKER, J. D., MAHAFFEY, J. C., AND OTHERS. 676
1957. The effect of feeding frequency, type of roughage and method of administration on the diurnal excretion of chromic oxide, chromogens, nitrogen, dry matter and ash. Ga. Expt. Stas. Tech. Bul. (n.s.) 14, 20 pp. (Levy, I., and Dalton, H. L., joint auth.)

MINSON, D J. 677
1958. The errors involved in the measurement of herbage consumption using indicator technique. (Unpublished Ph.D. Thesis, Univ. of Reading, 1958, 215 pp., illus.)

A study was made of the cause of the large standard error of the estimate of fecal index regression equations. Between 80% and 90% of the variation was shown to be caused by differences in the type of herbage fed, the remaining variation equal to about +1 digestibility unit being assoc. with animal variation and analyt. error. When fecal index regression equations, derived indoors, are applied to field conds., additional errors are introduced by differences in level of feeding, internal parasites, and type and age of animal used. A new method for estimating the digestibility of grazed herbage, "the combined method," is suggested. The use of chromic oxide for estimating the fecal prod. of grazing animals is considered, and a method for obtaining a representative sample of feces direct from the sward is described.—Herb. Abs.

MINSON, D. J., AND RAYMOND, W. F. 678
1958. Sources of error in the use of faecal index relationships. Hurley Grassland Res. Inst. Expts. Prog. (1956–57) 10: 92–96.

PIGDEN, W. J. 679
1956. Indicator methods for measuring herbage consumption. Nitrogen as an internal indicator and its distribution in feces of grazing cows. Canada Cent. Expt. Farm, Prog. Rpt. (1950–54) :34–35.

Samples of feces from each of 3 dairy cows grazing high-quality pasture were taken every 2 hrs. from 8 a.m. to 8 p.m. and at midnight and 4 a.m. "No differences in fecal concentration of N were observed between sampling hours or between animals. However, differences were observed between days. Thus, it appears that when N is employed as an internal indicator for high-quality pastures, fecal samples can be taken from cows any time during the day, but should be taken each day in order to obtain samples that are truly representative of a given period. Further studies are in progress to determine if the same considerations apply to medium- and low-quality pastures." The constant 92, calculated from digestibility, and used in the formula for determining organic-matter digestibility coefficients of consumed herbage, is higher than the constant obtained by Lancaster, viz 83, and supports results of previous workers.

PUJSZO, K., SEIDLER, S., ZIOLECKA, A., AND ZOKIEWSKI, A. 680
1959. A comparison of conventional, silica and Cr_2O_3-index methods in digestibility studies. Rocz. Nauk Rolnicz. i Lésnych (Polish Agr. and Forest Ann.) 74–B–4: 591–602. [In Polish with Eng. sum.]

PUTNAM, P. A., LOOSLI, J. K., AND WARNER, R. G. 681
1958. Excretion of chromium oxide by dairy cows. Jour. Dairy Sci. 41(12): 1723–1729, illus.

An expt. was conducted to study the effects of feeding schedule and various ratios of forage to concentrates upon the excretion pattern of Cr_2O_3. The indicator was administered once daily to Holstein cows consuming rations containing from 35% to 100% roughage. Fecal samples were taken every 2 hrs. during the 1st 2 periods and every 3 hrs. during the last 2 periods. Chromium oxide per g. of fecal DM was determined on all samples. A symmetrical excretion pattern was observed when av. values were plotted, and an equation was fitted to the excretion curve. There was considerable variation in relative Cr_2O_3 concentration at any sampling time, indicating the importance of obtaining a large no. of samples; however, neither the feeding schedule nor

the proportion of roughage to concentrate had an influence upon the general character of the curve. It was concluded that time of Cr_2O_3 administration was of primary importance in respect to time-concentration relationships of fecal Cr_2O_3, and that so-called physiol., diurnal effects were of little importance. The data suggest that a 12-hr. sampling procedure would be more accurate than unequal fecal sampling times.—Auth. sum.

RAYMOND, W. F. 682
1948. Evaluation of herbage for grazing. Nature [London] 161(4102): 937–938. illus.

Sheep feces analyzed for DM, N, and ash showed that feed intake varied with the size of animal, but not with the grazing available. This differed from mowing-machine estimates; when feed is short, stock eat below the mowing level; when feed is plentiful, the machine overestimates consumption. The N content of feces varied with that of feed, and on a restricted plot declined over a mo., due to selective grazing of the leafiest parts 1st. Fecal N analysis would be a better index of food quality than would analysis of mowed samples.

RAYMOND, W. F. 683
1954. Studies in the digestibility of herbage. III. The use of faecal collection and chemical analysis in pasture studies (a) ratio and tracer methods. Brit. Grassland Soc. Jour. 9(1): 61–67.

Because of the limitations of cutting techniques and methods based on animal prod. data for the evaluation of pasture output, methods depending on the collection of feces from grazing animals are being studied. The use of the feed:fecal ratio technique is described. To obviate the need for total fecal collection in the field, chromic oxide may be used as an "indigestible tracer." By using chromic oxide and an "indigestible tracer" present naturally in the herbage, it is unnecessary to make total fecal collection in the field or to conduct indoor digest. trials on cut herbage. The errors likely in these techniques are considered. The most serious of these is the need for sampling of the sward for "herbage as grazed," either for chem. analysis or for digest. expts. Errors due to the indigestibility of "tracers" varying from 100% and to nonrepresentative sampling of feces are discussed. Techniques being developed which require neither herbage sampling nor the use of "indigestible plant tracers" may have advantages over the methods discussed in the present paper.

RAYMOND, W. F., KEMP, C. D., KEMP, A. W., AND HARRIS, C. E. 684
1954. Studies in the digestibility of herbage. IV. The use of faecal collection and chemical analysis in pasture studies (b) faecel index methods. Brit. Grassland Soc. Jour. 9(1): 69–82, illus.

In fecal index methods, relations between the comp. and digestibility of herbage and the chem. comp. of the resulting feces are studied. Published data on this are reviewed. Based on data from 40 herbage feeds, ranging in DM digestibility from 55.2 to 80.8, regressions have been calculated. They relate the digestibility of both dry and organic matter in herbage and the fecal contents of N, macerate crude fiber, and chromogen. The use of these regressions in predicting the digestibility of herbage grazed in the field from the comp. of the resulting feces is considered. In particular, the difference between the standard errors of the regression and of a predicated value is emphasized. The use of the indigestibility coefficient to calculate herbage intake from fecal prod. in the field leads to errors higher than those apparent in the orig. estimate of digestibility. Comparison of the present regressions with those of Lancaster and Reid shows considerable divergences. These are discussed and seem to emphasize the need for more standardized techniques. The need for a method of obtaining a representative sample of feces in the field is recognized. The fecal index method appears to offer advantages over indigestible tracer techniques. Possible imprs. in the method are discussed. Fecal analysis offers valuable inform. on day-to-day variations in quality of grazing and on the effect of mangt. on degree of selection of herbage.

RAYMOND, W. F., AND MINSON, D. J. 685
1955. The use of chromic oxide for estimating the faecal production of grazing animals. Brit. Grassland Soc. Jour. 10(4): 282–296.

A study of factors affecting the accuracy of the chromic-oxide method for estimating fecal prod. in pasture studies is reported. The method of analysis for chromium is described. Chromic oxide did not affect the digest. of herbage by sheep. The administration of chromic oxide in gelatin capsules and as a liquid drench were compared. Recovery of chromium in the feces was nearly 100% with both methods. The diurnal variation in the chromium concentration in feces was not reduced by using the drench, in which the chromic oxide particles were of low specific gravity. Fecal chromium

oxide concentrations followed no constant diurnal pattern; the latter varied with a no. of factors, including level of herbage intake and possibly herbage digestibility. Thus, a system of grab sampling at fixed times can lead to incorrect estimates of fecal prod. A method for obtaining a representative sample of feces directly from the grazing sward is described ("ring sampling"). Estimates of fecal prod. obtained by "ring sampling" closely agreed with those obtained by total collection of feces during complete grazing periods. Variations found in the diurnal excretion patterns of chromic oxide are discussed, and are related to times and method of dosing of the oxide together with variations in rates of passage of feed through the hind tract. The effects of variations in the rate of passage of feed on the daily excretion of chromic oxide in the field are discussed. Fecal prod. data estimated by the chromic-oxide method apparently may allow more valid estimates of daily herbage intake than do total collection data.

RAYMOND, W. F., MINSON, D. J., AND HARRIS, C. E. 686
1959. Studies in the digestibility of herbage. VII. Further evidence on the effect of level of intake on the digestive efficiency of sheep. Brit. Grassland Soc. Jour. 14(2): 75–77, illus.

Results are reported from 6 digestibility expts. in which frozen herbage was fed to groups of sheep at high and low levels of intake. The sheep on the high level of intake digested the DM, organic matter, N, and normal-acid fiber in the herbage less efficiently than those on the low level, confirming earlier results reported in Pt. VI of this series. This difference may result from the higher rate of passage of food through the digest. tract at the high level of intake. These results are discussed with ref. to the errors introduced into the fecal-index method for estimating the digestibility of grazed herbage.

SCAUT, A. 687
1961. La mesure de la consommation du bétail au pâturage. [The measurement of consumption by grazing cattle.] Inst. Natl. pour l'Etude Agron. Congo Sér. Sci. 91, 86 pp.

The chromogen/chromic-oxide method gave an accurate estimate of herbage consumption by grazing cattle, but it was considered suitable only for fundamental res. as cutting methods were simpler to use in cent. African conds.

SHEARER, D. A. 688
1961. Methoxyl analysis of feeds and feces: A comparison of methods. Canad. Jour. Anim. Sci. 41(2): 197–204.

SMITH, ARTHUR D., TURNER, ROBERT B., AND HARRIS, GRANT A. 689
1956. The apparent digestibility of lignin by mule deer. Jour. Range Mangt. 9(3): 142–145.

Digestion coefficients were calculated for browse spp. native to Utah and alfalfa hay fed to mule deer. Calculations were made by the direct method and by the lignin-ratio technique. No clear concl. could be drawn as to whether the apparent digest. of lignin was due to inability to isolate it or to actual digest. The lignin-ratio technique appears to be of doubtful validity on the types of forage used.—From auth. sum.

SQUIBB, R. L., RIVERA, C., AND JARQUIN, R. 690
1958. Comparison of chromogen method with standard digestion trial for determination of the digestible nutrient content of Kikuyu grass and ramie forages with sheep. Jour. Anim. Sci. 17(2): 318–321.

Results obtained using the chromogen method and standard digest. trial showed excellent agreement in the case of *Pennisetum clandestinum* but not for *Boehmeria nivea*, where the chromogen method gave low and highly variable results. Both forages were similar to legumes in CP (10–16%). The TDN content of *P. clandestinum* was 60% and that of *B. nivea* about 69%. It was concluded that the chromogen method was unsuited for determining the coefficients of digestibility of little-known, or unknown, tropical forages.—Herb. Abs.

STEVENSON, AUDREY E. 691
1962. Measurement of feed intake by grazing cattle and sheep. VIII. Some observations on the accuracy of the chromic oxide technique for the estimation of faeces output of dairy cattle. New Zeal. Jour. Agr. Res. 5(3/4): 339–345.

Possible errors in the estimation of total recovery of chromic oxide from representative feces samples were examined. Results indicate a correction factor should be appl. when estimating fecal output by chromic oxide. A modification of the chromic-oxide determination is given.

STEVENSON, AUDREY E., AND LANGEN, H. DE. **692**
1960. Measurement of feed intake by grazing cattle and sheep. VII. Modified wet digestion method for determination of chromic oxide in faeces. New Zeal. Jour. Agr. Res. 3(2): 314–319.

TROELSEN, J. E. **693**
1961. Plant chromogens as an indicator in estimating the digestibility of forage crops by sheep. Canad. Jour. Plant Sci. 41(4): 732–739.

VALLENTINE, JOHN F. **694**
1956. Use of indicator methods in range digestion trials. A review. Jour. Range Mangt. 9(5): 235–239.

VERCOE, J. E., PEARCE, G. R., AND TRIBE, D. E. **695**
1962. The estimation of the intake of grazing sheep. I. Establishment of faecal nitrogen regressions. II. Application of faecal nitrogen regressions to a group of grazing sheep. Jour. Agr. Sci. [England] 59(3): 343–353.

Regression equations for estimating organic-matter and N intake are given for wethers fed on herbage cut from Wimmera ryegrass/subterranean clover pasture. Organic-matter digestibility and intake were highest in spring (Oct.) and lowest at the end of the dry summer (Feb.-Mar.). The sheep selected herbage with a high N content, although the herbage was well chopped and mixed. For wethers grazing the same pasture, the maximum intake of organic matter, digest. organic matter, N, and digest. N occurred in spring, and there was a lower autumn peak intake. The mean organic-matter intake ranged from approx. 1,000 to 2,000 g./day. Sheep selected a diet with a high N content and high digestibility; the range in organic-matter digestibility was lower in grazed herbage than in the fed herbage.—Herb. Abs.

VIANA, J. A. C. **696**
1959. Determination of the digestibility and consumption of forage, with sheep, by means of chromic oxide and plant chromogens. Minas Gerais Univ. Esc. de Vet. Arq. 12: 137–184, illus. [In Portug. with Eng. sum.]

The results are given from 2 digest. trials with sheep (kept in individual crates in 1 trial and on pasture in the other). The digestibility of Kikuyu grass was determined by 3 methods (conventional, chromic oxide, and plant chromogens). The digest. coefficients (DM, proteins, ether extr., fiber, and NFE) produced by the 3 methods were comparable; the differences among methods were not statistically significant. In both trials there was no significant difference between the amount of feces estimated by the chromic oxide and that measured. The digestibility of the ingested DM and the concentration of plant chromogens in the excreted feces were related.

WHEELER, R. R. **697**
1962. Evaluation of various indicator techniques in estimating forage intake and digestibility by range cattle. Diss. Abs. 23(6): 1848.

The chromic oxide and fecal N techniques gave good results, whereas the chromogen pigment technique did not.

WILLIAMS, C. H., DAVID, D. J., AND IISMAN, O. **698**
1962. The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. Jour. Agr. Sci. [England] 59(3): 381–385.

A rapid and accurate absorption method for the determination of chromium in feces samples from pasture expts. using chromic oxide "markers" is described.

WOOLFOLK, P. G. **699**
1957. Use of indicator techniques with sheep. (Abstract.) South. Pasture and Forage Crops Impr. Conf. Rpt. 14: 31.

See also **28, 583, 617.**

ANIMAL PRODUCTION

BLASER, R. E., BRYANT, H. T., WARD, C. Y., AND OTHERS. **700**
1959. Symposium on forage evaluation: VII. Animal performance and yields with methods of utilizing pasturage. Agron. Jour. 51(4): 238–242, illus. (Hammes, R. C., Jr., Carter, R. C., and MacLeod, N. H., joint auth.)

Data are given on milk prod. and live-wt. gains of animals and yield of animal products per acre as influenced by the util. methods: Continuous, rotational, strip grazing, and green soiling. Utilization methods show apparent effects on rate of animal gains; however, careful analyses show that stocking rate is the causal factor. A variable stocking rate allows for selective grazing which influences animal output. Output per animal

under continuous grazing is often higher than for rotational grazing because of light stocking and herbage selection. High yield of animal prod. per acre from intensive util. practices (rotational grazing, strip grazing, and green soiling) is attributed to better plant yields under alternating rest and harvesting, and to less ungrazed residue. The higher yields under mowing as compared with grazing are attributed to harmful effects of the grazing animals on the soil and plants; hence, green soiling may be expected to produce higher yields than strip grazing. The top and bottom grazing method, where top grazers consume about half the herbage and bottom grazers feed on the residue, is discussed. This practice may be used where high gains or prod. per animal are required for the top grazers and low output per animal is satisfactory for the bottom grazers. Use of this method will result in efficient herbage util. and high animal output for top grazers and low output for bottom grazers. It may be practical to feed concentrates to maintain desired animal gains under efficient herbage util. The appls. of results to grazing expts. are discussed.

Davis, R. R., and Bell, D. S. 701
1957. A comparison of birdsfoot trefoil-bluegrass and ladino clover-bluegrass for pasture. I. Responses of lambs. Agron. Jour. 49(8): 436–440.

Mixtures of Italian birdsfoot trefoil (*Lotus corniculatus*)/Kentucky bluegrass (*Poa pratensis*) and Ladino clover (*Trifolium repens* var.)/Kentucky bluegrass were established on fertile soil in Ohio in 1952. During 3 trial yrs. the swards were grazed by cross-bred, wether lambs either continuously or rotationally with grazing periods of 10 to 16 days alternating with rest periods of 24 to 30 days. Stocking rates were adjusted by using grazer and tester animals. During the 1st grazing yr. (1953) both swards were predominantly legume. Rainfall deficiency during summer and autumn of 1953 almost eliminated Ladino clover stands. Continuous grazing gradually eliminated stands of birdsfoot trefoil, while swards subjected to rotational grazing still had good trefoil stands after 3 yrs. Data are given of observed lamb-days, live-wt. gains, and daily live-wt. gain and TDN consumption of tester animals. Year×mixture interactions were large, showing the need for data from several yrs. to give adequate comparisons between mixtures.—Herb. Abs.

Eddowes, M., and Harris, R. 702
1961. Measuring output from grassland in terms of animal production. Harper Adams Agr. Col. Tech. Bul. 5, 21 pp.

Three methods for measuring grassland output in terms of animal prod., (a) cow-equivalent days, (b) milk output, and (c) utilized SE, were compared in detail on a farm scale in 1958–60 using a predominantly autumn-calving dairy herd together with ewes and lambs. Full data are given in the form of tables and graphs. Conserved grass was expressed as potential prod. by using standard conversion factors. There was no clear relation among the 3 methods where data were compared on a field-by-field basis (7 fields were used in this study). On a farm-system basis, there was a close relation between (a) and (c). Cow-equivalent days multiplied by 10 was approx. equal to utilized SE measured in lbs. Milk output per feed acre was easy to calculate and was a useful econ. measure. Method (c) involved detailed recording and required 2 hrs./wk., compared with 0.5 hrs./wk. for method (a). It was concluded that measurement of output on a farm-system basis using method (a) as an estimate of stocking rate and method (b) as an econ. measure would be the most useful for commercial dairy farms. Such data would be most valid on specialized dairy farms where recording is not complicated by followers and/or sheep. Effects of stocking rate on prod. are discussed.—Herb. Abs.

Es, A. J. H. van. 703
1961. Between-animal variation in the amount of energy required for the maintenance of cows. Wageningen Cent. v. Landbpub. and Landbdoc. Verslag. van Landbouwk. Onderzoek. 67(5), 116 pp.

Harlan, Jack R. 704
1958. Generalized curves for gain per head and gain per acre in rates of grazing studies. Jour. Range Mangt. 11(3): 140–147, illus.

Grazing data from 14 centers were analyzed and fitted to a double exp. curve by selecting appropriate scales for live-wt. increases. This is more a nutritional than a stocking-rate curve, but emphasizes the precarious balance at the high rates and the rapidity with which gains are converted into losses with overgrazing. Curves of gain per unit-area conform to a pattern, rising to a peak at heavy grazing, and then dropping sharply. The use of the curves for estimating productivity in known ecol. areas, for interpreting vegetational changes, and for range classification is discussed.

HEDRICK, D. W. 705
1957. Rabbits as a tool in pasture and range utilization research. Jour. Range Mangt. 10(4): 180–182, illus.

Some data are given of the results of prelim. trials on the use of rabbits as grazing animals for evaluating pasture productivity. It is thought that rabbits could be of considerable value for providing a no. of different degrees of util. of pasture, without the need to devote large areas to such trials, and that rabbits leave pastures in a cond. more nearly approaching that after grazing by livestock, than does clipping.—Herb. Abs.

HINMAN, R. B. 706
1937. Live weight gains as a measure of pasture yields. Amer. Soc. Anim. Prod. Proc. 1937: 83–84.

To evaluate properly results of a pasture impr. program, live-wt. gains on similar animals supply the most accurate and accessible method of measurement. It can be fully appreciated by the practical mind, and until a better method is discovered, it is of some value to the experimentalist.

IVINS, J. D. 707
1953. The measurement of pasture output on the dairy farm. Brit. Grassland Soc. Jour. 8(4): 337–344.

The figs. for util. of SE from pasture, as a measure of pasture output, have been calculated individually for 382 dairy cows. The data vary greatly among animals and are closely related to milk prod. Apparently, the time of calving exerts a substantial effect on the rate of util. of SE from pasture, and to provide a comparable estimate of pasture productivity, corrections for time of calving must be applied to the figs. for utilized SE.

KENNEDY, W. K., REID, J. T., AND ANDERSON, M. J. 708
1959. Evaluation of animal production under different systems of grazing. Jour. Dairy Sci. 42(4): 679–685.

Lucerne/Ladino clover/smooth brome grass pasture was grazed by dairy cattle under 4 managements: (a) Strip grazing, (b) 3-paddock rotation, (c) 6-paddock rotation, and (d) zero (mechanical) grazing. When animals had strip-grazed an area equivalent to that of a paddock, cows under mangt. (b) and (c) were moved. Milk prod. per acre on (b) was as high as on other treatments. Lucerne stands declined more rapidly on (b) than on (a) or (c), but there was a corresponding increase in the stand of Ladino clover. An excellent lucerne stand was maintained on (d). It was concluded that valid comparisons between grazing systems could not be made unless forage under all treatments was fully utilized.—Herb. Abs.

KNOTT, J. C., HODGSON, R. E., AND ELLINGTON, E. V. 709
1934. Methods of measuring pasture yields with dairy cattle. Wash. Agr. Expt. Sta. Bul. 295, 20 pp.

Because of the lack of uniformity of method in measuring pasture yields with dairy cattle, the TDN yield method is recommended. This method measures results under actual grazing conds. and considers the requirements for gain in live-wt., maintenance, and milk prod., from which is deducted the nutrient content of supplemental feed consumed. The remainder represents the nutrients derived from pasture. Allowance may also be made for loss in live-wt. A standard of TDN requirements per lb. of gain in live-wt. with dairy cows of 3.53 lbs. is recommended, and the method of obtaining this amount is explained. An allowance of 2.73 lbs. of TDN for each lb. of loss in live-wt. is suggested. For converting pasture yields into carrying capacity or cow days, use of 16 lbs. of TDN is recommended for a standard cow day. Using the above method, the av. yearly yield chiefly of TDN for a pasture mixture under continuous grazing was 5,498.5 lbs. per acre; for the same mixture under rotational grazing, 5.985.7 lbs.; for a reed canary grass pasture, 5,253.6 lbs.; and for a wheat pasture, 1,875 lbs. The standard cow days were 343.6, 374.1, 328.4, and 117, respectively.

MCCULLOUGH, M. E. 710
1963. Relationship between digestible dry matter of forage and average daily gain of dairy heifers. Jour. Dairy Sci. 46(8): 861–862.

A formula relating av. daily live-wt. gain with digest. DM (DDM) content of the forage, body wt., and daily intake of DDM was derived from data obtained in 8 feeding trials. The 3 variables accounted for 67% of the variation in daily live-wt. gain.—Herb. Abs.

MORRISON, H. B., AND ELY, FORDYCE. 711
1941. Calculating pasture yields with dairy heifers as experimental animals. (Abstract.) Jour. Dairy Sci. 24(6): 515–516.

Baker, A. L., Phillips, Ralph W., and Black, W. H. 712
1947. The relative accuracy of one-day and three-day weaning weights of calves. Jour. Anim. Sci. 6(1): 56–59.

A study of wts. of 178 calves immediately before weaning, when they averaged about 232 days of age, showed no advantage in taking wts. on 3 days instead of a single wt., when uniform conds. for the calves were maintained. Calves lost some wt. during the 3 days; the av. daily wts. were 425.9, 425, and 422.9. The 3-day av. of 424.6 did not differ significantly from the wt. taken on the 1st day. After placing the wts. in classes, with 20-lb. intervals, the standard errors of single and 3-day wts. were compared. In 14 classes with 4 to 23 animals each, the standard error was lower in the 1st-day wts. in all classes than in the 2nd- and 3rd-day wts. and in the 3-day av. The standard error of the 2nd-day wts. was lower than that of the 3rd-day wts. in 9 of the 14 classes.

Baker, G. A., and Guilbert, H. R. 713
1942. Non-randomness of variations in daily weights of cattle. Jour. Anim. Sci. 1(4): 293–299, illus.

Statistical analyses are presented for 69 consecutive daily weighings of 8 head of yearling cattle. During the 1st half of the period, the animals had free access to feed and water and were weighed at 11:20 a.m.; during the last half, water was shut off at 7 p.m. and the cattle were weighed before 6:45 a.m. The analyses confirm the report of Maymone and Sircana (1930) that cyclic variations may occur in day-to-day deviations of cattle wts. Three daily wts. of 14 animals would be required to obtain the accuracy assumed for 3 daily wts., independent in a probability sense for 10 animals. Some correlation exists between deviations of the various animals due to environmental conds. When the animals had free access to water and were weighed near midday, the deviations in daily wts. were positively correlated with daily temp. range. When the animals were without feed and water at night and weighed early in the morning, no significant correlation between deviations in daily wts. and daily temp. range was found. An adequate adjustment period is necessary; shrunken wts. lessen environmental effects. More accuracy is obtained from using more animals than more wts. per animal.

Bean, H. W. 714
1948. Single weight versus a three-day average weight for sheep. Jour. Anim. Sci. 7(1): 50-54.

The data used in this study are the starting and final wts. of lambs from 5 ann. feeding projects conducted at the Ill. Agr. Expt. Sta. There were 1,335 lambs at the beginning of the expts. Each lamb was weighed on 3 consecutive days at the beginning and end of the test. The averages of each of these 3 wts. were considered the expt. wts. of the animals. The deviation of the 3-day av. from the 1st-day wt. was 1 criterion. The initial expt. wts. of 1,300 animals, or 97% of the total, were within the range represented by the 1st-day wt. ±3 lbs. The final expt. wts. for 99% of the total lambs were within the range of the 1st-day wt. ±2 lbs. This study also shows that in the initial wts. the mean sq. for the 3-day av. is 4.2% less than the mean sq. for the 1st-day wts., while in the final wts. it is 2.1% greater. The lot wts. obtained on the 1st day were not significantly different from those obtained from the 3-day averages. The extra work involved in weighing on 3 consecutive days did not result in increased accuracy; therefore, it did not produce the intended results. Continuing the practice of weighing an expt. animal on 3 consecutive days does not seem justifiable.

Brothers, Don G., and Whiteman, J. V. 715
1958. Variation in growth rate between selected like-sexed twins as compared to randomly selected like-sexed lambs. (Abstract.) Jour. Anim. Sci. 17(4): 1144.

Variances between selected like-sexed twin lambs were compared to variances among randomly selected like-sexed lambs of similar wt. to estimate the expt. efficiency obtainable by the use of twins in growth studies. The lambs were all of similar breeding and were raised under similar conds. at the Fort Reno Expt. Sta. over a 3-yr. period. Nineteen pairs of male and 13 pairs of female twins within 6, 4, and 2 lbs. of each other were selected when they weighed approx. 50 lbs. Like-sexed random lambs within the same wt. ranges were also selected simultaneously. Average daily gains to marketing, carcass yields, and grades were obtained. Twin efficiency values were calculated for these characteristics by the mean sq. comparisons among random individuals within pairs of twins. The efficiency values for daily gain were 1.68, 3.70, and 5.42 for males and 2.00, 1.62, and 2.14 for females when pairs were selected within 6, 4, and 2 lbs. of each other, respectively. Values for carcass grade were 1.84, 1.70, and 1.51 for males and 6.12, 7.48, and 9.44 for females. For carcass yield the

males had values of 1.17, 1.00, and 1.60 for the 6-, 4-, and 2-lb. selection ranges. The values for females were all less than 1. Although quite variable, these estimates indicate selected like-sexed twin lambs may be useful in reducing the expt. error.

ELLIS, GEORGE F., JR., CARTWRIGHT, T. C., AND SMITH, J. P. 716
1962. Comparative accuracy of weekly weights and consecutive daily weights of beef cattle. Tex. Agr. Expt. Sta. Prog. Rpt. 2226, 5 pp.

HODGSON, R. E., AND KNOTT, J. C. 717
1942. Accuracy of live weights of dairy cows on pasture. Jour. Dairy Sci. 25(2): 161–169.

The expt. error, the standard deviation of daily trends, and the standard error of 3-day initial and final live wts. of cows on pasture were determined by analyses of variance. The expt. error of 46 wt. groups was 14 lbs., with a range of 7 to 28.3 lbs. The standard deviation of day-to-day trends of the groups of cows averaged 7.7 lbs., with a range of 0.5 to 20.8 lbs. The standard error of the live wts. of cows weighing about 1,200 lbs. averaged only 2.2 lbs. The expt. error, standard deviation of daily trends, and standard error of the initial and final wts. were about the same.

IVINS, J. D., AND MORGAN, J. T. 718
1957. Note on the extent and significance of losses in live weight of inwintered cattle on turning out to grass in spring. Brit. Grassland Soc. Jour. 12(1): 19–21.

A trial designed to examine the significance and extent of losses in live wt. of inwintered cattle turned out to grass in spring is described. The results obtained for 2 pairs of identical twin cattle suggest that most of the loss in live wt. after a 14-day grazing period could be related to differences in the contents of the alimentary tract.

KOCH, ROBERT M., SCHLEICHER, E. W., AND ARTHAUD, VINCENT H. 719
1958. The accuracy of weights and gains of beef cattle. Jour. Anim. Sci. 17(3): 604–611.

Analysis of the 3 initial and 3 final wts. of 582 calves for full and shrunk conds. was presented. Shrunk wts. were influenced less by fluctuations in fill and were considered a more accurate measure of wts. and gains. The use of 3-day av. wts. was effective in reducing fluctuations in fill. The av. of 3 wts. or at least 2 wts. is recommended for use where comparisons of individuals are concerned. Animal differences were large in comparison to residual variation. Adjusting the no. of animals to obtain the accuracy needed was the most effective way of reducing variation for comparisons of groups of animals.—Auth. sum.

KOGER, MARVIN, AND KNOX, J. H. 720
1945. The effect of sex on weaning weight of range calves. Jour. Anim. Sci. 4(1): 15–19.

The weaning wts. of steer and heifer calves grown under range conds. were observed for a period of 8 yrs. The mean wts. of the 2 sexes corrected for difference in weaning age were 443 lbs. for 419 steers and 411 lbs. for 444 heifers. Steers were heavier than heifers every yr. The difference in favor of steer calves was highly significant. The difference in wt. of sexes was tabulated for the offspring of 12 bulls, 10 of which were related. Steers were heavier than heifers for all sires. The sex × sire within yr. interaction was small, indicating that sex differences did not vary significantly among sires.

MANNING, H. L., AND WILLIAMS, E. 721
1950. A note on the estimation of liveweight of cattle in Uganda. East African Agr. Jour. 16(2): 94–96.

An estimate of wt. of Teso cattle with appropriate confidence limits has been derived from a linear regression formula.

MEYER, J. H. 722
1962. Removing sources of error in lamb feeding experiments. Jour. Anim. Sci. 21(1): 127–131.

Variation is caused by composition of the body and wt. of the gastro-intestinal contents.

MOTT, G. O. 723
1959. Symposium on forage evaluation: IV. Animal variation and measurement of forage quality. Agron. Jour. 51(4): 223–226, illus.

The output per animal or animal performance is the unit of measure of greatest interest in measuring forage quality. Measurements of digestibility and rate of intake contribute to a better understanding of animal performance. The expt. errors associated

with quality measurements have as their source both pasture and animal variation. The main source of error is assoc. with the variation between animals with respect to rate of gain. Other factors that may increase the expt. errors or bias the results in grazing trials are variations in grazing pressure, failure to consider differences in previous treatment of the animals, and weighing errors. Absolute wts. or true gains in wt. are essential for studies involving efficiency of feed util. Weighing errors assoc. with the cyclic variations in daily wts. of animals introduce only a small bias into treatment comparisons for trials over a single season.

PATTERSON, R. E. 724
1947. The comparative efficiency of single versus three-day weights of steers. Jour. Anim. Sci. 6(3): 237–246.

Variances for initial and final wt. and for gains are segregated into their components. The variations due to errors in weighing feedlot steers constitute about 0.4% of the variance between animals for 3-day initial wts. and about 1.18% for single-day initial wts. Corresponding values for 3-day final wts. and single-day final wts. are 0.33% and 0.97%, respectively. The reduction of the expt. error due to the 2 extra weighings is thus 0.79% for initial wts. and 0.65% for final wts. The variations due to errors in weighing constitute 1.16% of the variance between animal gains based upon 3-day wts., and 3.41% for single-day wts. The reduction in the variance between animals (expt. error) due to the 4 extra weighings is thus 2.27%. The reduction for 2-day wts. is 1.7%, and the reduction of the variance of 3-day wts. over 2-day wts. is 0.58%. Likewise, only relatively small reductions in the size of the variance between animals resulting from extra weighings were found for both the winter and summer pasture-grazed steers. The precisions gained by weighing more than once at the beginning and end of a test can be relatively costly. In these expts. the same precision as obtained from 3-day wts. would have been expected from single-day wts. if the no. of animals had been increased only slightly. Thus, data from 11 animals with single-day wts. would be expected to be slightly more efficient than those from 10 animals with 3-day wts.

PHILLIPS, R. W., AND BRIER, G. W. 725
1940. Estimating weights of lambs at a constant age. U. S. Dept. Agr. Cir. 541, 16 pp., illus.

Through a statis. treatment of the growth data for lambs of different breeds, the following formula was derived for estimating the wt. of lambs at a constant age:

$$Z\left(\frac{20-A}{X-A}\right)=Y,$$

in which Y is the estimated wt., Z the actual wt. at the actual age X, 20 a constant age (any other constant age can replace 20), and A the age intercept, i.e., the point at which a line representing the slope of the growth curve in the vicinity of the constant age intercepts the age axis. Two shortcut methods for estimating wts. are outlined: (1) The wt. of the lamb is simply multiplied by a predetermined factor; (2) the estimated wt. is read directly from a chart designed for that purpose.

PHILLIPS, RALPH W., AND STOEHR, JOHN A. 726
1945. The accuracy of measurements and weights of sheep. Jour. Anim. Sci. 4(3): 311–316, illus.

Results of 6 studies to determine the accuracy of measurements of sheep are presented. In 5, accuracy of wt. was also determined. Measurements that appear to be most accurate, and that measure characteristics which experimenters may desire to study, include ht. at withers, length from midfront of scapula to pin bones, width at shoulders, depths of chest and middle, circumferences of chest and middle, and circumference of foreshank. Measurements obtained from animals in fleece or from enlarged photographs are generally less accurate than measurements on sheared animals. The difficulties of interpreting measurements in terms of carcass or other values are pointed out. This study indicates that many measurements are reasonably accurate, and some external measurements will undoubtedly be of use in interpreting the results of many expts. Little has been done to determine the relation between external measures and scores and the characteristics of the carcass or measures of the real productive ability of the animal. There is need for much study on this phase of measuring performance. To avoid unnecessary work, the measurements in any study should be limited to those for which definite use is planned in the expt. under consideration, until more is known of the relation between external measures and merit of the animal.

RUBY, ELLIS S., BLUNN, C. T., BROUSE, E. M., AND BAKER, MARVEL L. 727
1948. Relation of initial weights and subsequent gains of weaning calves. Jour. Anim. Sci. 7(3): 279–282.

Data from calf wintering and grazing trials conducted at the Valentine substation

from 1927 to 1946 were analyzed. The period consisted of 2 pts., winter and summer. Relations between initial wt., wt. at the close of the winter period, final wt., winter gains, and summer gains were determined. The discussion was on an intra-lot basis because several rations were fed during the winter. Results in general showed a closer relation between contiguous wt. and gains than between wt. and gains separated by an interval of the feeding period. The correlation between winter gains and summer gains was negative, indicating that high winter gains were followed by lower summer gains. In general, animals with the heavier initial wts. for either the winter or summer period were heavier at the end of the summer period but their superiority in wt. had decreased. Animals which made the greater winter gains tended to make the lower summer gains.

SWART, J. H. **728**
1962. The influence of treatment prior to weighing on the live weights of sheep. So. African Jour. Agr. Sci. 5(1): 95–102. [Eng. sum.]

FECAL COUNT

ARNOLD, JOSEPH F., AND REYNOLDS, HUDSON G. **729**
1943. Droppings of Arizona and antelope jack rabbits and the "pellet census." Jour. Wildlife Mangt. 7(3): 322–327, illus.

Using hand-reared, captive jackrabbits, the auth. studied the effect of age, sex, size, spp., and type of food on the no. and wt. of pellets voided. Pellet no. remained constant, on the av., irrespective of age, sex, size, or spp. of rabbit. The age and wt. of mature animals did not affect the wt. of pellets voided. Changes in character of the forage consumed caused marked variation in pellet wts. but not in pellet nos. A highly significant linear relation was found between pellet wt. and wt. of food consumed. With suitable sampling methods, pellet wts. can be used to determine the amount of range forage removed by jack rabbits. Pellet counts may be used to estimate fluctuations in rabbit nos. since they are less affected by the character of the forage eaten than are pellet wts.

BENNETT, LOGAN J., ENGLISH, P. F., AND MCCAIN, RANDAL. **730**
1940. A study of deer populations by use of pellet-group counts. Jour. Wildlife Mangt. 4(4): 398–403.

Year-round pellet-group counts of white-tailed deer (*Odocoileus v. virginianus* and *O. v. borealis*) in several forest types in Pa. indicated that such counts can be used for determining approx. deer populations, deer movements, and the util. of forest types by deer. The counts were made monthly during the spring and summer on 1/10-acre quadrats and on strips 11 ft. wide and varying from 700 to 2,640 ft. in length.

MINSON, D. J., TAYLER, J. C., ALDER, F. E., AND OTHERS. **731**
1960. A method for identifying the faeces produced by individual cattle or groups of cattle grazing together. Brit. Grassland Soc. Jour. 15(1): 86–88. (Raymond, W. F., Rudman, J. E., Line, C., and Head, M. J., joint auth.)

The use of high-density polyethylene cubes and polystyrene cubes for marking individual droppings produced by grazing cattle is described.

PETERSEN, R. G., LUCAS, H. L., AND WOODHOUSE, W. W., JR. **732**
1956. The distribution of excreta by freely grazing cattle and its effect on pasture fertility. I. Excretal distribution. Agron. Jour. 48(10): 400–444.

Of the hypothetical functions studied, the most accurate for describing excretal frequency-distribs. over long periods was the negative binomial distrib. function. The proportion of pasture covered by 0, 1, 2 . . ., excretions during a grazing period appears to depend primarily on the mean excretal density at the end of the period. Mean excretal density varies directly with the length of the period, no. of animals and the area covered by the individual excreta, and varies inversely with the size of the pasture. The proportion of the pasture covered by 0, 1, 2 . . ., excretions appears to be practically independent of the size and shape of the pasture.

RINEY, THANE. **733**
1957. The use of faeces counts in studies of several free-ranging mammals in New Zealand. New Zeal. Jour. Sci. and Technol. Sect. B 38(6): 507–532, illus.

Records taken in a zoo of the daily no. of defecations for 4 mammal spp. showed: red deer, 10–0; fallow deer, 11–3; goat, 10–5; and brush tailed possum, 6–3. The size and shape of fecal pellets for each sp. are described. It is shown that location affects the drying rate of the pellets, and thus the accuracy with which pellet age can be subjectively assessed. In the field, the technique described is designed to provide an

index to the density of animals to show numerical trends in populations. It involves careful examination of milacre plots situated at regular intervals along lines in selected pts. of the study environment. Results are expressed as no. of defecations per 100 plots. Basic assumptions in the use of pellet techniques both for censusing and as a density index are discussed. Field trials designed to explore limitations of the technique show: (1) That 1 observer can duplicate the results of another (to within 5 defecations per 100 stas.); (2) that differences in the no. of feces along a line are commonly assoc. with differences of animal habitat and with changes in season. Numbers of defecations along a line can be expressed either as no. of plots containing 1 or more defecations or as total no. of defecations. Feces count techniques can be used to give: (1) A description of the habitat preferred by each of several mammalian spp., (2) a record of differences in seasonal use of habitats based on changes in seasonal distrib. of the feces, (3) an objective measure of substantial population fluctuations following shooting operations. An analysis of variation of feces counts for all sample lines run in a drainage gives a measurement of the evenness of the distrib. of a sp. in the drainage. Increases in coefficients of variation following hunting are interpreted as discontinuity of hunting effort, the persistence of this discontinuity as indirect evidence of localized movement. The use of short-term 10-sta. lines is described as a means of quickly obtaining objective inform. during rapid field surveys. Several practical appls. to mangt. are discussed, and the need for general agreement on some uniform way of expressing records of fecal droppings is emphasized.—From auth. sum.

ROBINETTE, W. LESLIE, FERGUSON, ROBERT B., AND GASHWILER, JAY S. 734
1958. Problems involved in the use of deer pellet group counts. North Amer. Wildlife Conf. Trans. 23: [411]–425, illus.

These studies have shown that increased sampling of deer pellet groups is necessary with a decrease in area of unit being sampled, with a decrease in pellet group density and in decreased uniformity of pellet group distrib. Circular plots were found to be more efficient sampling units than strip plots. The 100-sq.-ft. circular plot was found to be more efficient than the 0.01-acre circular plot where pellet group densities of 300 or more/acre prevailed. The use of plots smaller than 100 sq. ft. is not advised because of the possible influence of bias in plot location. Surveys indicated the optimum spacing (considering time and accuracy) of transects to be about 20 chains with 100-sq.-ft. circular plots spaced from about 4 to 12 chains apart along the transects. Optimum transect and plot spacing, however, will vary considerably from one survey to another. Much less sampling is required to establish deer herd trends than for a census, a factor which may prove of value to administrators faced with limited budgets.—From auth. sum.

ROGERS, GLENN, JULANDER, ODELL, AND ROBINETTE, W. LESLIE. 735
1958. Pellet-group counts for deer census and range-use index. Jour. Wildlife Mangt. 22(2): 193–199.

Daily defecation rate for Rocky Mountain mule deer (*Odocoileus h. hemionus*) was studied in typical winter range pastures at Little Hills Expt. Sta., Colo., from 1951 to 1955. Pastures were stocked lightly to moderately. Average overwinter daily defecation rate was about 15 groups. A lower fig. is suggested for depleted ranges. Counts on plots previously cleared of pellets agreed closely with those on uncleared plots. Factors affecting recorded defecation rates and the intensity of sampling needed for use in deer census work are discussed.

TAYLOR, R. H., AND WILLIAMS, R. M. 736
1956. The use of pellet counts for estimating the density of populations of the wild rabbit, *Oryctolagus cuniculus* (L.). New Zeal. Jour. Sci. and Technol. Sect. B 38(3): 236–256, illus.

A technique is described for estimating rabbit populations from the density of fecal pellets on the ground. The method involves 2 steps: (1) estimating the no. of pellets present, and (2) relating the no. of pellets to the no. of rabbits by measuring the rate at which pellets decay, and the no. of pellets produced daily by individual rabbits. The theory and field procedure of sampling methods devised to measure the density of pellets and their decay rate are given. Attempts made to determine the mean no. of pellets produced per rabbit per day resulted in a fig. of 820 being accepted for the wild rabbit in New Zeal. The results from several trials carried out during the devlpmt. of the method are discussed, and an example is given of its practical appls.—Auth. sum.

WALLMO, O. C., JACKSON, A. W., HAILEY, T. L., AND CARLISLE, R. L. 737
1962. Influence of rain on the count of deer pellet groups. Jour. Wildlife Mangt. 26(1): 50–55.

On 4 study areas in Tex. estimates of density of populations of deer (*Odocoileus*

spp.) were based on samples of abundance of fecal droppings. Radical fluctuations in density of droppings indicated that some factor other than population change was involved. On Black Gap Area 91% of marked groups of fecal pellets were washed away by rain in 4 mos. On Black Gap and Del Norte Areas there was a significant negative correlation between density of pellet groups and no. of heavy rains during sampling intervals. On Sierra Diablo Area, which had heavier vegetative cover, and Dockery Area, which had level terrain, correlations were not statistically significant but influence of rainfall was empirically evident. Abundance of fecal droppings on range is a faulty index to deer population level when washing rains occur during sampling interval.—Biol. Abs.

JOINT ANIMAL-VEGETATION RESPONSE

BERULDSEN, E. T., AND MORGAN, A. 738
1937. Irrigated pastures—rotational grazing. Yield sampling and botanical analysis. Victoria Dept. Agr. Jour. 35: 94–103.

Ten acres were divided into 2 pastures of 2.5 acres and 10 of 0.5 acre for the study of rotational systems of grazing. The 2.5-acre pastures were grazed alternately every 10 days, and the 0.5-acre pastures changed daily. Periodic bot. surveys and yield samplings were carried on to determine amount and quality eaten as well as relative palatability of component spp. Principle of stocking was to put on enough stock to graze out a pasture in the specified time. Yield sampling was by cutting 25 to 28 sq. link samples located at random within each 0.5 acre to the ground level before grazing and 35 samples after grazing. A hand-operated shearing machine was used. Clippings were composited, ovendried, cleaned, and analyzed. A difficulty of this method was in clipping to ground level, particularly in wet weather before and after grazing. Total amount eaten by 89-lb. ewes was 7.8 lbs. of green herbage (80% moisture) per day. This was low compared with Cockayne's 24 lbs. and Stapledon and Jones' 11.3 lbs. for 130- to 137-lb. sheep. In the trial, consumption varied from 3.5 to 22 lbs. Considering high nutrient value of feed eaten, 7.8 lbs. for a growing sheep seems adequate using Woodman and Evans SE of 1.08 lbs. per day for a 114-lb. sheep. Consumption is highest in spring and summer and markedly affected by cold rainy weather. At all times the herbage eaten was of very high value, always higher in protein and lower in fiber than that left. When small amounts were eaten, the small leafy portion was taken; when larger amounts were taken, stemmy material was also eaten. Yield sampling is so drastic in its action that the same unit cannot be clipped twice in succession; on small areas severe detriment may occur where periodic clippings are frequent.

BOER, F. DE, AND WILLEMSEN, W. 739
1960. Factoren voor het omrekenen tot grootvee-eenheden. [Factors for calculating stocking rate in terms of cattle units.] Landbouwvoorlichting [Hague] 17(7): 326–328.

The av. daily requirements in SE of calves, milking cows, bulls, store cattle, horses, foals and sheep have been used to calculate conversion factors (given) for the adjustment of stocking rate to dairy-cow equivalents. These factors are considered important in determining the herbage yield from grazing land.—Herb. Abs.

BRANDT, P. M., AND EWALT, H. P. 740
1939. Pasture yields as measured by clip plots and by grazing dairy cows. (Abstract.) Jour. Dairy Sci. 22: 451–452.

Yield from 8.72 acres of mixed grass and *Trifolium repens* pasture grazed for the 5th consecutive season has been measured. The grazing method yielded about 5% TDN less than the clip plot method which is considered a satisfactory means of determining pasture yield.

BRYANT, H. T., AND BLASER, R. E. 741
1961. Yields and stands of orchard grass compared under clipping and grazing intensities. Agron. Jour. 53(1): 9–10.

This article questions evaluating pasture spp. by clipping in order to simulate grazing. A 3-yr. study showed 35% more yield in clipping than in grazing.

BUTLER, G. W., AND JOHNS, A. T. 742
1961. Some aspects of the chemical composition of pasture herbage in relation to animal production in New Zealand. Austral. Inst. Agr. Sci. Jour. 27(3): 123–133.

CASTLE, M. E. 743
1953. Grassland production and its measurement using the dairy cow. Brit. Grassland Soc. Jour. 8(3): 195–211.

An orig. evaluation technique, designed for measuring the output of pasture in terms of the wt. of milk produced per acre, has been described. The results obtained by use of this technique in 3 consecutive yrs. have been given. In 1949, 1950, and 1951 output was 4,460, 5,530, and 4,660 lbs. of milk per acre respectively. Of the 2 swards recorded, the ryegrass yielded 18.7% more milk than the cocksfoot sward. The milk-producing value of the sward declined with advancing season and averaged 25.1 lbs. per day over the 3 yrs. The prod. of DM from the ryegrass and cocksfoot swards averaged 6,630 and 6,840 lbs. per acre respectively over the 3-yr. period. The av. ann. appl. of artificial fert. was equivalent to 6.4 cwt. per acre. The apparent mean daily consumption of DM was 2.9 lbs. per live cwt. in 1949 and 1950 and 2.5 lbs. in 1951. The total output of the ley determined from the nutrient requirements of the stock averaged 25.1 cwt. of utilized SE per acre per yr. Output calculated from the herbage data was 9 to 23% higher than that calculated from the animal data. The evaluation technique and some practical implications arising from the trial have been discussed.

CORY, V. L. 744
1930. Methods of determining forage preferences of stock. Ecology 11(4): 760–763.

As opportunity affords, range livestock show preferences in feeding upon the various forage plants. Noting and recording the time devoted to feeding upon the various spp. of forage plants gives a rather accurate measure of the forage preferences of stock for that particular range and for similar ranges under similar conds. Any such study should be conducted at regular intervals over many consecutive mos. where grazing is continuous, or for a no. of consecutive grazing seasons where grazing is seasonal. The changes of vegetation and the trends of these changes may be measured by surveys of grazed areas at intervals of yrs., or by comparison of grazed areas with inclosed, ungrazed areas of sufficient size to include fair samples of the native vegetation. The survey of vegetation changes is complementary to the measurement of forage preferences of stock through accurate observ., and, together, these 2 methods furnish a basis for the study of range mangt. probs.

COX, C. P., FOOT, A. S., HOSKING, Z. D., AND OTHERS. 745
1956. The direct evaluation of pasture in terms of the milk production of individually grazed cows. Brit. Grassland Soc. Jour. 11(2): 107–118. (Line, C., and Rowland, S. J., joint auth.)

The possibilities of pasture evaluation in terms of milk prod. have been examined experimentally, using individually grazed cows on a ryegrass-clover ley. A significant linear relation between mean milk yields and estimated DM intakes over a 3-wk. period was obtained. Under the conds. of this expt. it was found that the relation between milk yields and estimated fresh-herbage intakes was also linear, the correlation coefficient being as high as that between milk yields and DM intakes. An intake-output equation was calculated in the form,

$$y=0.2900x_1+0.0117x_2+2.1139x_3$$

where y=DM intake, x_1=fat-corrected milk yield, x_3=live-wt. gain, all in lbs. per day, and x_2=live wt. in lbs. The precision of estimates of DM intake using sample herbage cuts and DM determinations has been examined. The nos. of cows required in comparative expts. with 2 treatments to give a 95% chance of detecting given differences between mean yields of milk and fat-corrected milk have been estimated.

CRAMPTON, E. W., AND FORSHAW, R. 746
1939. Pasture studies. XVI. The nutritive values of Kentucky blue grass, red top, and brome grass. With particular reference to the relation between the chemical composition of the herbages and the live weight gains made by the animals subsisting thereon. (Abstract.) Amer. Soc. Anim. Prod. Proc. 32: 375–376.

DAVIES, R. O., MILTON, W. E. J., AND LLOYD, J. R. 747
1950. Pasture productivity in Mid-Wales. I. Experimental methods of measurement. Empire Jour. Expt. Agr. 18(71): 203–217, illus.

Different methods of measuring pasture productivity on perm. and reseeded pasture over a period of 3 yrs. are discussed. Methods are: (1) 3-wk. period growth measurement of caged grass after trimming, (2) difference between yields of untrimmed, caged areas and adjacent grazed areas after 3 wks. caging, and (3) wts. of sheep and lambs at beginning and end of the above periods.

Davis, R. R., and Bell, D. S. 748
1957. Relationships of lamb response and measurements from caged samples in a comparison of birdsfoot trefoil-bluegrass and Ladino clover-bluegrass for pasture. Agron. Abs. 49: 70.

Davis, R. R., and Bell, D. S. 749
1958. A comparison of birdsfoot trefoil-bluegrass and Ladino clover-bluegrass for pasture: II. Yield of herbage and relationships to lamb response. Agron. Jour. 50(9): 520–524.

During 1953–55, *Lotus corniculatus/Poa pratensis* pasture yielded more forage than *Trifolium repens* var./*P. pratensis* pasture when their DM yield was estimated by using grazing cages. A greater herbage yield was obtained under continuous grazing by lambs during the 1st yr., and under rotational grazing during subsequent yrs. Forage samples from pasture including *T. repens* contained more N during 1953, only. After 1953, rotationally-grazed pasture contained more N than that continuously grazed. There was a close relation between DM yield and animal-carrying capacity and between the % of N in the forage and daily gain of lambs, but not between yield and animal gain/acre.—Herb. Abs.

Deeny, M. C. 750
1958. An investigation into utilized grassland production on ten farms in North County Dublin. Brit. Grassland Soc. Jour. 13(4): 247–254.

Utilized grass prod. on 10 small farms in N. Co. Dublin has been estimated using (a) the method adopted by the Brit. Grassland Soc. Sub-Committee on the assessment and recording of the utilized output of grassland, and (b) a live-wt. increase method using Woodman's figs. At the beginning of the grazing season all the grazing animals on each farm were weighed. At the same time the records for method (a) were begun. Altogether 169 animals and 12 sheep were weighed during Mar.-Apr. Animals sold during the period of invest. were weighed, where possible. The results obtained using the 2 methods have been compared. Average % difference on 10 observs. was 11.3% with a variation of ±3.7%. On farms 1–5, where only mature stock were kept, the % difference was 9.9% ± 2.2%. On farms 6–10, where animals of all categories were grazed, the % difference averaged 12.8% ±2.2%. In all cases the live-wt.-increase method gave the higher estimated yield. The techniques used to estimate utilized grassland prod. are discussed. Total output varied between 26.5 cwt. and 9.0 cwt. of utilized SE per acre. The significance of the findings is discussed and the value of the methods is considered.

Giöbel, G. 751
1935. Metoder för försöksmässigt bedömande av gräsmarkernas avkastning. Några erfarenheter om hittils använda försöksmetoder. [Methods for estimating in experiments the yield of grass fields. Some experiences of experimental methods employed hitherto.] Nord. Jordbrugsforsk. [Helsinki] 1935(5): 820–837.

Reference is made to the defects of the older method of taking a larger or smaller no. of cuts from marked-out and fenced-in areas of pastures, and also to the influence of the grazing animals on the character of the ley stand. A description is given of 3 of the methods tested by the Sw. Grassland Soc. to determine the amount of grass prod. with retention of the grazing character of the ley; viz, the util. of control cages, plot trials on grazed folds with cutting of certain portions immediately before and after grazings, laying out of trials in 2 or more complete replications which are alternately grazed and cut. Cutting trials afford much greater possibilities for accurate comparisons between a no. of moments than the trials with grazing animals only. The writer believes, however, in view of the not unimportant defects inherent in both methods, that both processes should be tested side by side so that it might be possible gradually to obtain comparable figs. for cutting and grazing.

Hein, Mason, A., and Henson, Paul R. 752
1942. Comparison of the effect of clipping and grazing treatments on the botanical composition of permanent pasture mixtures. Amer. Soc. Agron. Jour. 34(6): 566–573.

Studies were made at Beltsville, Md. Grasses common to the N. humid region and white clover in 8 mixtures were used in a study comparing frequent clipping with a lawn mower to grazing with sheep. The clipped plots were mowed to a ht. of 1.25 in. whenever the growth reached a ht. of 4 to 6 in. The grazed areas were pastured when the grass reached a similar ht., using sufficient animals to graze the mixtures uniformly in 3 days or less. The results were measured by making 5 random counts on each plot with the inclined point quadrat. Readings were made in the spring and fall during

the course of the expt. and results reported as to the relative frequency of each sp. Under grazing the relative frequency of Kentucky bluegrass, redtop and white clover was greater while orchard grass remained unchanged by clipping or grazing. The sheep, however, refused to graze the latter grass as closely as other spp. In general the clipping treatments were more severe than grazing, as evidenced by the lower total relative frequency of the grasses under clipping.—Biol. Abs.

IVINS, J. D., DILNOT, JEAN, AND DAVISON, J. 753
1958. The interpretation of data of grassland evaluation in relation to the varying potential outputs of grassland and livestock. Brit. Grassland Soc. Jour. 13(1): 23–28.

When livestock are used to measure the output of pasture, the potential output of the animal is on occasions lower than that of the grassland so that this may determine the yields of animal products which are obtained, regardless of pasture type and treatment. The implications of this are discussed in relation to the interpretation of data of grassland evaluation, and also in relation to maximum util. of grass.—Auth. sum.

JONES, I. R., EWALT, H. P., AND HAAG, J. R. 754
1937. A comparison of pasture returns from actual grazing and clip plot methods. Jour. Dairy Sci. 20(7): 420–421.

The study was made during the pasture season Apr. 30 to Oct. 1 on a 15-acre irrigated *Trifolium repens* and grass pasture, which was divided into three 5-acre pastures for rotational grazing. The data presented show that prod. of TDN estimated by the clip plot method is much higher than the actual returns from pasturing with cattle, and that cattle appear to utilize only about 75% of luxurious pasture herbage as measured by the clip plot method.

KIDDER, RALPH W. 755
1946. A proposed method of measuring pasture yields with grazing cattle. Jour. Anim. Sci. 5(2): 187–193.

A proposed adaptation of the indirect method of measuring pasture yields with grazing cattle is described, based on the Morrison feeding standard of 7.93 lbs. of TDN per day for maintenance of a 100-lb. cow and that the maintenance requirement for animals of other wts. is proportional to the 0.73 power of the live wt. The av. nutrient requirement for daily maintenance of animals of any wt. can be calculated by the formula $\frac{W^{0.73}}{19.53}$ = TDN. An analysis of 3 Fla. steer-feeding expts. by this method shows that 330 steers consumed an av. of 3.15 lbs. of TDN for each lb. gain in live wt. Considering the no. of variables involved, the difference is not great between this and 3.53, the accepted factor for gain in wt. Using this method, the amount of grass consumed by grazing steers has been closely estimated and has been found to be within the range of ann. yields of grass previously reported from this sta.

LARGE, R. V., AND SPEDDING, C. R. W. 756
1957. The growth of lambs at pasture. I. A comparison of growth on long and short ryegrass swards. Brit. Grassland Soc. Jour. 12(4): 235–240, illus.

For these expts., gang mowing proved to be better than varying the stocking rate as a method of maintaining short swards (ht. index of 1 to 2 in.); the latter method gave differential effects in the lamb wts. arising from parasitism. The long-grass swards (ht. index of 2 to 7 in.) were the very lightly grazed control plots. It was not until mid-June that there was any difference in ht. index or quality of the treated or control plots. The difference in ht. of sward was not accompanied by marked differences in growth of lambs. Experience showed that, for this type of expt., the taller swards should be grazed by means of frequently moved folds and that the introd. of the stock should be delayed until differences in sward ht. have been established. [For ht. index, *see* Spedding and Large (1957).]—Herb. Abs.

LASSITER, C. A., MORRISON, H. B., FERGUS, E. N., AND SEATH, D. M. 757
1956. The effect of continuous vs. alternate grazing and the effect of barn manure on production and digestibility of bluegrass pasture as measured by grazing dairy heifers. Ky. Agr. Expt. Sta. Bul. 642, 15 pp.

The pastures studied consisted mainly of Kentucky bluegrass (*Poa pratensis*) and white clover (*Trifolium repens*). The 1st series of trials reported were carried out during 1936–48 to compare continuous and rotational grazing systems. Two rotationally grazed pastures, each of 2.9 acres, were used, with 2-wk. grazing periods followed by 2-wk. resting intervals. Mean TDN yields on pastures continuously and rotationally grazed were 2,290 and 2,284 lbs. per acre, respectively. There was a close positive relation between pasture productivity and total seasonal rainfall and an inverse

relation between productivity and mean temp. during May 1 to Sept. 30 (72° F. during these trials). In a 2nd series of trials, continuously-grazed pastures were top dressed with 0, 3, 6, or 9 tons of dung per acre. Mean ann. forage yields, as calculated from the wt. gains of grazing dairy heifers, were 2,161, 2,443, 2,585, and 2,650 lbs. TDN, respectively. The av. CP contents of the forage and the apparent digestibility of the forage, as determined by the fecal chromogen and forage methods, were not materially affected by the dung treatments. The av. DM content of the forage was slightly reduced by dung appls. The discrepancies between the results of TDN calculations based on cage clippings and on grazing heifers are discussed.

LINEHAN, P. A., AND LOWE, J. 758
1946. The output of pasture and its measurement. Brit. Grassland Soc. Jour. 1(1): 7–35.

Grass output on 66.3 acres of young ley was measured by (a) periodic clippings according to the movable cage method, and (b) periodic weighings of 100 bullocks from Mar. 23, 1945, to June 28, 1945, and 34 bullocks from Aug. 13, 1945, to Sept. 5, 1945. The 2 methods were compared by computing the nutrients supplied by the grass as measured by clippings and the nutrients that were necessary for the maintenance and live-wt. increase of the stock. Total output by the movable cage method differed from that based on animal weighings by only 6.8%. The coefficient of correlation for the yields obtained for the 8 grazing periods is 0.885. The coefficients of variability averaged 26% for clips inside the caged areas and 58% for cuttings on the outfield grazed areas. Auth. suggest that a major source of error in the movable cage method is the taking of cuttings too infrequently during periods of rapid herbage growth. The output per acre up to Sept. 5 was 3.85 cwts. of live-wt. increase in 132 animal grazing days. For the entire season up to Oct. 31 the grass output was 24.6 cwts. of SE per acre, of which about 70% was obtained by mid-June. Grazing was very thorough, about 80% of the grass available in each grazing period being consumed by stock, and only some 1.73 cwts. of DM per acre being left uneaten at the end of each grazing period. The severe early season defoliation is felt to be partially responsible for the extreme falling-off in growth in midsummer, and for casualities among the plants which were noted at this time. Total productivity would probably have been higher for the season had the herbage been further forward in growth at the beginning of the grazing periods and not so severely defoliated at the ends of the grazing periods. The expt. results agree substantially with those obtained on different type pastures and with other kinds of livestock by many workers.

LINEHAN, P. A., LOWE, J., AND STEWART, R. H. 759
1947. The output of pasture and its measurement. Part II. Brit. Grassland Soc. Jour. 2(3): 145–168.

Grass output on 102.4 acres of young ley was measured in the 1946 season by (a) periodic clippings according to movable cage methods I and II, and (b) periodic weighings of 120 bullocks from Apr. 16 to Apr. 24, 119 bullocks from Apr. 25 to May 29, 132 bullocks from May 30 to July 20, 88 bullocks from July 21 to Aug. 26, and 68 bullocks from Aug. 27 to Sept. 18. The 3 methods were compared by computing the nutrients supplied by the grass as measured by clippings and the nutrients that were necessary for the maintenance and live-wt. increase of the stock. Total output by the 2 movable cage methods differed from that based on animal weighings by 18.2% in the case of cage method II and by 49.0% in the case of cage method I. The coefficient of correlation between individual period yields as measured by cage method II was 0.74, while that between period outputs by animal and output from cage method I also was 0.74. The evidence suggests that cage method I has a large error when growth is rapid and where the length of the grazing period is prolonged. The formula for cage method II seeks to allow for the difference in yield between the grass permitted unimpeded growth in cages during the grazing period and that subject to defoliation outfield. Collecting the data for the expt. periods in 1945 and 1946, the relative yields, taking output by animal method as 100, are by cage method II, 95; and by cage method I, 128. The apparent consumption data of grass per animal per day as measured by cage method II agree better with grass consumption data reported by other workers than do those computed by cage method I. The coefficients of variability averaged 25% for clips inside the caged areas, 30% for the pregrazing cuts, and omitting 1 anomalous reading, 48% for cuttings on the outfield grazed areas. These figs. have to be regarded as minimum estimates of error since the sampling sites were not chosen entirely at random. Output per acre up to Sept. 18 was 3.20 cwt. of live-wt. increase in 164 stock grazing days. For the entire season up to Nov. 1 the grass output by cage method II was 28.2 cwt. of SE per acre, of which only 41% was obtained by mid-June. By deliberate intent grazing was not as thorough as in 1945, about 4 1/2 cwt. of DM per acre being left uneaten at the end of each grazing period.

The data support the view that grassland productivity under the conds. of this expt. can be higher with long rest periods and lenient defoliation. On the whole the results to date agree that the movable cage method provides a good measure of pasture output.

LINEHAN, P. A., LOWE, J., AND STEWART, R. H. 760
1952. The output of pasture and its measurement. Part III. Brit. Grassland Soc. Jour. 7(3): 73–98.

Measurement of grass output on 102.4 acres (1947) and 92.7 acres (1948) of young leys was continued in 1947 and 1948 by: (a) periodic clippings according to clip methods 1, 2, and 3, and (b) periodic weighings of store bullocks which varied in no. from 80 to 132 during the grazing seasons. The 4 methods employed are compared by computing the quantities of nutrients supplied by grass as measured by clippings with those calculated to have been necessary for maintenance and live-wt. increase of the stock. Total output by clip method 2 in 1947 was identical with that based on animal weighings, while yields by clip methods 1 and 3 differed from that based on animal weighings by +29% and −37% respectively. Output by the same clip methods in 1948 differed from that based on animal weighing by +7% in the case of clip method 2, +39% for clip method 1, and −30% in the case of clip method 3. Summarizing for the 4 yrs. of the trial, output by method 2 was 1% higher, by method 1, 32% higher, and by method 3, 31% lower than yields based on animal weighings. The coefficients of correlation between total ann. yields by clip methods 2, 1, and 3, and those derived from animal weighings (each based on 4 readings) were 0.95, 0.93, and 0.92 respectively. Correlation for the 40 individual grazing periods was not so satisfactory, the coefficient being 0.62 in the case of method 2. The variance attaching to grass consumption yields from clippings from each sample site by clip method 2 amounted to some 51% in 1947 and 45% in 1948, the av. approximating to 50%. As measured by clip method 2, 25.5 lbs. DM in 1947, and 30.2 lbs. DM in 1948, and over all 4 yrs., 27.6 lbs. DM were consumed per animal per day. These figs. appear to be reasonable for the class of stock under trial and are in line with results reported by other workers, and hence are construed as evidence of the validity of clip method 2. On the whole, it is concluded that the grass clip method 2 employed in this expt. provides a good measure of pasture output under conds. parallel to those obtaining in this trial. Output per acre by clip method 2 amounted to 22 cwt. SE in 1947 and 31 cwt. SE in 1948 (the latter fig. includes 11 cwt. SE harvested as silage). These figs. compare with 26 cwt. SE and 19 cwt. SE per acre in 1946 and 1945 respectively. Measured live-wt. increase over the expt. periods and estimates derived from grass yields during the remainder of the season indicate an ann. live-wt. gain of 4.4, 3.8, 4.0, and 4.9 cwt. per acre during the seasons 1945, 1946, 1947, and 1948, respectively. The av. live-wt. gain per animal per day over the 4 seasons of the trial was 2.7 lbs. but higher figs. were obtained at the beginning of each grazing season, while a marked reduction was nearly always evident in the mo. of July. Under the system of grassland mangt. employed it was possible, on the av., to supply a full ration of grass for about 0.6 mature bullocks per acre during the mos. of Apr., July, Aug., and early Sept. but a stocking rate of about double this fig. was possible during the mos. of May and June. Although not reflected in reduced output over the 4 seasons, there was a progressive decline in the contrib. of the principal sown grasses to the sward. At the end of the trial, however, peren. ryegrass was still the dominant sp. present. Earliest spring growth was obtained on swards containing Italian ryegrass which were fertilized early in the season. Data over the 4 seasons support the view that higher grassland productivity can be secured by long rest periods and lenient defoliation. Dealing with the relation of grass consumed to live-wt. gain secured, altogether 464 2 1/2-yr.-old bullocks (46,748 cattle grazing days) made a measured live-wt. gain of some 54 tons, consuming, as estimated by clip method 2, 2,987 tons green grass, equivalent to 560 tons DM and 321 tons SE. Thus, as measured, on the av., 1 lb. of live-wt. gain was produced by 6 lbs. of SE, 10.5 lbs. of DM or almost 56 lbs. of green grass.—Auth. sum.

MORRISON, H. B., AND ELY, FORDYCE. 761
1946. Clippings vs. grazing by dairy heifers as means of estimating yield of bluegrass pastures. Jour. Dairy Sci. 29(7): 393–405.

Yield of a Kentucky bluegrass pasture in terms of TDN per acre was calculated from clipping with a lawn mower and from grazing with dairy heifers during 5 seasons, 1940–44 inclusive; the grazing season ranged from 168 to 210 days. Calculated yield from grazing was higher than that from clipping in each of the 5 seasons. The calculations from clipping were 50.1%, 48.1%, 56.4%, 91.1%, and 82.1% of those from grazing in 1940, 1941, 1942, 1943, and 1944, respectively. The av. calculated yield from clipping was 68.5% of that from grazing. The maximum, minimum and av. yields of TDN calculated from clipping were 2,218, 889, and 1,578 lbs. per acre respectively, and from grazing

2,615, 1,849, and 2,305 lbs. The av. daily amount of TDN furnished by the pasture for an entire season ranged from 4.88 to 12.36 lbs. per acre as calculated from clipping, and from 10.16 to 13.59 lbs. as calculated from grazing. The trend of the curves for calculated yield obtained by clipping and grazing with heifers were, in general, quite similar, although a pronounced change usually occurred in the grazing curve 2–3 wks. later than in the clipping curve. The data indicate that the clipping method of measurement may be used in a prelim. way to evaluate variables in expt. mangt. of Kentucky bluegrass pastures.

NEENAN, M., CONWAY, A., AND MURPHY, W. E. 762
1959. The output of Irish pastures. An application of the B.G.S. method for determining the yield of pastures on individual farms. Brit. Grassland Soc. Jour. 14(2) : 78–87.

During 1956 and 1957, an attempt was made to assess the output of Irish pastures using methods proposed by a subcommittee of the Brit. Grassland Soc. The best results were obtained when output was determined on a single field, rather than on the whole farm basis. The yields showed highly significant correlations with both bot. comp. and nutrient status of the pastures. The results agreed with the findings of others working on similar grasslands. Auth. suggest that the method might be useful in a program of either advisory work or surveys concerned with grassland impr.

PETERSEN, R. G., WESWIG, P. H., AND COWAN, J. R. 763
1958. Measuring palatability differences in tall fescue by grazing sheep. Agron. Jour. 50(3) : 117–119.

The study was designed to find a method of objectively rating a large no. of tall fescue genotypes for their palatability to grazing animals. Twenty genotypes were grazed for 2 days by 12 sheep on each of 5 separate occasions. In 3 of the trials, samples of forage were taken from each plot before and after grazing to estimate the amount of forage consumed during the trial. On each of the 5 occasions the grazing behavior was observed for periods of varying length. The clipping method generally gave unreliable consumption estimates primarily because of sampling errors. By using an observational technique consistent differences in the apparent palatability of the 20 selections were measured. The technique consisted of allowing 12 sheep to graze for 2 days and recording, at 5-min. intervals from 7:00 to 10:00 a.m., the no. of sheep grazing on each plot. Relative palatability was then expressed as the total no. of times the plot was grazed during the observational period. The largest palatability differences among the 20 genotypes were observed during the flush growth period in the spring. The clipping and observational methods were compared. The observational method appears advantageous for assessing palatability in the small plot stage.—From auth. sum.

RAYMOND, W. F. 764
1957. The measurement of pasture output. Nutr. Soc. Proc. [Cambridge] 16(1) : 20–25, illus.

In a review of systems of pasture evaluation, the importance of seasonal distrib. of herbage yield, the necessity for data on herbage consumption in relation to animal prod. and the indirect methods in use for the estimation of pasture output are considered.—Herb. Abs.

RHOAD, A. O., AND CARR, R. B. 765
1945. Measuring productive capacity of pastures through maintenance studies with mature steers. U.S. Dept. Agr. Tech. Bul. 890, 20 pp.

By controlling at weekly intervals (1) the area that a fixed no. of mature steers could graze, (2) the no. of steers on a fixed area of pasture, and (3) the daily consumption of green forage by steers in dry lot, and from quantitative and qualitative analyses of clippings from pastures, it was determined, over 3 grazing seasons, that mature steers consumed for maintenance 49.7 lbs. of green forage furnishing 13.02 lbs. of DM, 1.17 lbs. of digest. protein, and 8.77 lbs. of all TDN daily per 1,000 lbs. of live wt. The av. wt. of the steers throughout the 3 grazing seasons differed from the 3-day initial wts. by 3.1%, 1.6%, and 0.3% under methods (1), (2), and (3). The prod. of forage on 3 pastures computed from clippings was 26%, 44.7%, and 68.3% greater than the prod. computed from consumption in dry lot and carrying capacity of expt. pastures.

RICHARDS, J. A. 766
1960. The productivity of commercial and pedigree varieties of grasses. (Unpublished Ph.D. thesis, Edinburgh Univ., 264 pp., illus.)

The invest. was designed to study the reasons why, when comparing swards of commercial and pedigree vars., the results obtained by clipping are not always born out by animal live-wt. gains. The assessment was made on an ann. basis, not over the

grazing season only. Several spp. of grasses, grown as pure stands and mixed with white clover, were used in order to lengthen the grazing season and to compare the live-wt. potential of a grass sward and a grass/clover sward. Both sheep and cattle were used. Sheep shears modified for sampling herbage to ground level were used, so as to obviate grazing below sampling ht. Sampling herbage under grazing and under cutting gave comparable results. In cattle, live-wt. gain appeared to have been influenced more by quantity than quality of herbage. In ewe lambs, quality and clover content of the sward were more influential than quantity, which was important only when quality differences were small. Intake expts. with these ewe lambs indicated that they ate more DM and that this caused the greater live-wt. gains. Grass vars. differed both in persistence and prod. within sp.; this prevents generalizations being made. The usually less persistent commercial vars. are consequently invaded to a greater extent by weeds and clovers. Clover content in the sward differs with spp. and vars. under the same mangt. and tends to complicate results when more than one sp. are used. Differential prod. and util. suggest that more than 1 rate of stocking should be used. A comparison of the sampling techniques with other standard methods showed that sample size can be reduced without loss of accuracy. Sampling to ground level may also increase yields over Tarpen cuttings by 30% on each occasion, and, under suitable conds., by consecutive sampling on an ann. basis, by as much as 50%.—Herb. Abs.

Robinson, R. R., Pierre, W. H., and Ackerman, R. A. **767**
1937. A comparison of grazing and clipping for determining the response of permanent pastures to fertilization. Amer. Soc. Agron. Jour. 29(5): 349–359.

The response of pastures to fert. and lime treatments as measured by grazing was compared with the response as measured by (1) clipping perm. plots and (2) clipping by the "difference-method," i.e., obtaining the difference between the yields of temporarily enclosed areas and the corresponding grazed areas. Although the yields obtained by clipping perm. plots showed a progressive decrease relative to the yields obtained by grazing, there was a high correlation in any 1 yr. between the yields from clipping and the yields from grazing. Auth. suggest a method whereby the clipped yields can be expressed in terms of grazing units.

Salcedo, Luis Fernandez. **768**
1932. Sobre valoración de pastos. [On the evaluation of pastures.] Agricultura [Madrid] 4: 76–79.

A simple method of calculating the yield of pastures is described. A certain sum, called the "coefficient," is calculated as the value of the pasture grazed in a day by an animal, varying according to its sp., age, etc. For example, the coefficient for a bull of 4 yrs. or over is taken as 0.55 pesetas, for a milk cow, 0.40 pesetas, for a heifer, 0.35 pesetas, for a yearling calf, 0.25 pesetas, etc. A record is kept of the no. and class of cattle grazed, of the dates of entry into the pasture and of leaving it. The no. of grazing days is then multiplied by the no. of cattle of each class individually, and the result multiplied by the coefficient for the class in question, this giving in pesetas the partial yield of the pastures. The results thus obtained for each class are added together, giving the total yield of the pastures.—Herb. Abs.

Schultz, E. F., Jr., Langford, W. R., Evans, E. M., and others. **769**
1959. Relationship of beef gains to forage yields. Agron. Jour. 51(4): 207–211. (Patterson, R. M., and Anthony, W. B., joint auth.)

A quadratic relation was demonstrated between forage yield and live-wt. gain where steers and heifers were grazed on pastures of *Cynodon dactylon*, *Paspalum notatum*, and *P. dilatatum/Festuca pratensis/Trifolium repens* mixtures.

Sears, P. D. **770**
1943. Pasture-plot measurement techniques. New Zeal. Jour. Sci. and Technol. Sect. A 25(5): 177–190.

A system is described whereby a return of droppings is made in proportion to actual plot yields. This method gives more correct data on total yields as well as on bot. comp., compared with mowing and grazing without return of droppings, which gave too little grass growth, and the free return of stock droppings, which unduly favors plots with good ryegrass strains, even when the clover content may be poor.

Stapledon, R. G., and Jones, Martin G. **771**
1927. The sheep as a grazing animal and as an instrument for estimating the productivity of pastures. Welsh Plant Breeding Sta., Aberystwyth, Bul., Ser. H 5: 42–54.

During seasons in 1925 and 1926, sheep weighing from 122 to 137 lbs. consumed

9.8, 16.7, and 24.2 lbs. of green herbage and 2.6, 2.6, and 3.4 lbs. of herbage dry wt. Calculated back from the dry wt. figs., the sheep consumed 11.3, 11.3, and 14.8 lbs. of green herbage per day, using the same moisture content of the herbage.

WEIR, W. C., AND TORELL, D. T. 772
1959. Selective grazing by sheep as shown by a comparison of the chemical composition of range and pasture forage obtained by hand clipping and that collected by esophageal-fistulated sheep. Jour. Anim. Sci. 18(2): 641–649.

Hand-clipped forage from rangeland and from irrigated and nonirrigated pasture not previously grazed contained an av. of 4.1% less protein and 3.5% more crude fiber than forage consumed by sheep grazing the same areas. On similar pastures previously grazed by sheep, hand-clipped forage contained 3% less protein and 0.9% more crude fiber than forage consumed by sheep.

WILLOUGHBY, W. M. 773
1958. A relationship between pasture availability and animal production. Austral. Soc. Anim. Prod. Proc. 2: 42–45.

In an expt. with Merino sheep grazing *Phalaris*/subterranean clover pasture, the maximum rate of live-wt. gain was attained only when at least 1,400 lbs. dry wt. of green material was available per acre. The results are discussed in relation to pasture util.—Herb. Abs.

WOLTON, KAREN M. 774
1963. An investigation into the simulation of nutrient returns by the grazing animal in grassland experimentation. Brit. Grassland Soc. Jour. 18(3): 213–219.

An expt. compared mowing with the return of excreta and mowing with the return of clippings as methods for simulating the return of nutrients by grazing animals in expts. where grazing is impractical. These treatments were appl. to a pure grass and to a grass/clover sward. Both methods gave herbage nearer in yield and comp. to that resulting from natural grazing than did mowing with no return, but neither was suitable for sites outside expt. stas. Although the N return in excreta was rather inefficiently used, it appeared to be the major factor in increasing yield on the grass sward and in changing the grass/clover balance on the mixed sward. The return treatments had a marked effect on the K nutrition of both swards, and the results suggest that omitting the grazing animal from trials assessing K fert. requirements may invalidate the results.

See also **7.**

STATISTICAL THEORY AND METHOD

FREQUENCY DISTRIBUTIONS

TRANSFORMATIONS OF VARIATES

ANSCOMBE, F. J. 775
1948. The transformation of Poisson, binomial and negative-binomial data. Biometrika [London] 35(3/4): 246–254.

Transformations having the effect of approximately normalizing Poisson, binomial, and negative-binomial variables are given to within a constant appearing in each transformation. Optimum values of the constants are defined as those which make the variance of the transformed variable most nearly constant, with obvious appl. in the technique of analysis of variance. Asymptotic formulas are given for the 1st 4 moments and for the efficiency in estimating the original parameters for transformed variables of each of the 3 types. A table gives numerical results for representative values of the parameters of each type.

ARRUDA, H. V. DE. 776
1959. Square root transformation in the analysis of certain field experimental data. Bragantia [Brazil] 18(3): 15–19. [In Portug. with Eng. sum.]

BARTLETT, M. S. 777
1947. The use of transformations. Biometrics 3(1): 39–52.

The transformations useful on raw statis. data are summarized, with particular ref. to the analysis of variance. The various reasons for transformation are outlined, and the type of data for which each transformation is appropriate is discussed. Considerations are given to the sq.-root, log, inverse-sine, and probit transformations, as well as to that of expected normal scores. Illus. are used.

Bliss, C. I. 778
1938. The transformation of percentages for use in the analysis of variance. Ohio Jour. Sci. 38(1): 9–12.

Transformations of value in expt. data measuring % germination, % mortality, etc., are given.

Bross, Irwin D. J. 779
1958. How to use ridit analysis. Biometrics 14(1): 18–38.

In many scientific studies in the biol. and behavioral sciences the response variables fall in the "borderland" between dichotomous classifications and refined measurement systems. Sometimes the response variable is a subjective scale (e.g., "minor," "moderate," "severe") and other times the response variable is numerical but the measurement system is heavily dependent upon details of protocol. These "borderland" response variables may not be adequately analyzed by either of the 2 traditional families of statis. techniques (i.e., the χ^2 and t-test families). In this situation ridit analysis serves as a "missing link" between the 2 traditional families. In ridit analysis a specified class of individuals is chosen as the "identified distrib." and the other series are considered relative to this identified distrib. The ridit for a given category is simply the proportion of individuals in the lesser categories plus 1/2 of the proportion of individuals in the category itself. Once the transformation has been made the data may be analyzed along the lines of the usual t-test families. The use of the ridit transformation is illus. on data from a study of automotive crash injuries.—Auth. abs.

Clark, Andrew, and Leonard, Warren H. 780
1939. The analysis of variance with special reference to data expressed as percentages. Amer. Soc. Agron. Jour. 31(1): 55–66, illus.

It is necessary to apply a transformation, $p=\sin^2\theta$, to certain types of discrete and % data where it is proposed to combine the data for the determination of a generalized standard error. Bunt data originally published by S. C. Salmon are employed to illus. the transformation which indicates that most of the data are sufficiently homogeneous to admit combined treatment. A sampling technique of using the plant rather than the head is recommended. Homogeneity tests are necessary if a generalized standard error is to be a valid measure of variability in the aggregate data.

Cochran, W. G. 781
1938. Some difficulties in the statistical analysis of replicated experiments. Empire Jour. Expt. Agr. 6: 157–175.

A case is given where variances of different treatments are widely different and should not be pooled. The degrees of freedom by individual treatment comparisons are partitioned in this case. Several types of special treatment are illus. such as where widely variable data can be discarded (e.g., check plots which are of no direct value as to effects of ferts.) and transformations. The sq.-root transformation for small nos. and the Poisson distrib. as well as the inverse-sine transformation for data in binomial distrib. are discussed. The use of the log transformation when the variance is proportional to the sq. of the mean (or the standard error of mean) and the use of transformations in factorial expts. are discussed.

Ghurye, S. G. 782
1949. Transformations of a binomial variate for the analysis of variance. Indian Soc. Agr. Statis. Jour. 2(1): 94–109.

Transformations of the binomial variate which reduce considerably the variation in the variate even for such small values as $n=10$ are discussed. The sq.-root transformation seems satisfactory for estimating the variability. The inverse-sine transformation does not appear to be accurate enough. The solution of the prob. was attempted by the actual evaluation of the variance for different values of p in different inverse-sine transformations for $n=10$, 15, and 20. There is an appreciable difference in the constancy of variances even for $n=20$ between the different transformation tests. For $n=10$, the inverse transformation in which $0.2/n$ is added when the variate $x=0$, and is subtracted for all other values of the variate, appears to be the best transformation. For $n=15$, the inverse transformations are made by increasing or by decreasing the variate by $0.2/n$ when the variate $x=0$ and 1, respectively.

Haldane, J. B. S. 783
1937. The approximate normalization of a class of frequency distributions. Biometrika [London] 29(3/4): 392–404.

By a change of the variable it is possible to make a no. of probability distribs. approx. very closely to normality. The transformations may be used where the integral of the distrib. is not tabulated.

IRWIN, J. O. 784
1943. A table of the variance of $\sqrt{x}$ when x has a Poisson distribution. Roy. Statis. Soc. Jour. 106(2) : 143–144.

Let $\mu=\sqrt{x}$. The auth. shows that the variance of μ is 1/4 for large samples. A table is given containing the values of the variance of $\sqrt{x}$ for various values of μ, the mean. This variance is almost equal to 1/4 for small values of the mean. This table gives values of the variance of the sq. root of x for values of μ equal to 0.0, 0.1, 15, 20, 50, 100, and ∞.—Biol. Abs.

RAO, C. RADHAKRISHNA. 785
1958. Some statistical methods for the comparison of growth curves. Biometrics 14(1) : 1–17.

Tests for comparison of av. growth curves for groups of individuals treated differently have been developed. Some of these tests are exact and useful when the sample size is small. An attempt is made to transform the time axis in such a way that av. rate of growth is uniform, to the extent possible, with respect to the new time metameter for each group. The differences between groups in the rates of growth so defined are subj. to a test. The adequacy of a common transformation for all groups is also examined. Tests appropriate for large samples have also been derived. Other topics discussed are the factor analytic models for individual growth curves and discrimination of growth curves when observs. are taken continuously.—Auth. abs.

UPHOLT, WM. M. 786
1942. The use of the square root transformation and analysis of variance with contagious distributions. Jour. Econ. Ent. 35(4) : 536–543.

The possibility of bias and the power of the analysis of variance and related tests were investigated in a hypothetical expt. for the case in which the data follow a contagious distrib. and are transformed by adding 1/2 and extracting the square root before applying the analysis. The transformation introduces a bias but in reasonable cases this bias is not sufficient to invalidate the analysis. The type of distrib. and possible effects of treatments may result in such a great generalized error term that the analysis has very little power to detect rather large differences in means that may occur. At least until more powerful tests are available for such cases, analysis of variance of the transformed data may be a satisfactory guide for the experimenter if not too much reliance is placed on the results.—Biol. Abs.

UPHOLT, WM. M. 787
1944. The power of the analysis of variance with the Poisson distribution. Jour. Econ. Ent. 37(5) : 717.

A previous paper described a hypothetical expt. that showed the sq.-root transformation and analysis of variance to have a low power when applied to contagious distribs. The present paper describes a similar expt. to show the power of this statis. procedure to be much greater when appl. to Poisson distribs., the case for which it was designed.

WADLEY, F. M. 788
1943. Statistical treatment of percentage counts. Science 98: 536–538.

Standard methods discussed have some limitations in appl. to enumeration data of the % count type. However, where percentages are based on adequate and similar nos., where they are between 10% and 90%, and where individuals succeeding and failing each total 20 or more in a treatment, these methods may be used. With more extreme percentages, a transformation may be of help, and larger total nos. may be needed.

See also **574, 872.**

CONTAGIOUS DISTRIBUTIONS

ARCHIBALD, E. E. A. 789
1948. Plant populations. I. A new application of Neyman's contagious distribution. Ann. Bot. [London] (n.s.) 12(47) : [221]–235, illus.

The discussion is based on data from about 10,700 quadrats from 5 maritime and 2 grassland communities. Neyman's contagious series brings into prominence a fundamental issue, viz, that plant populations are more likely to show contagion or grouping of individuals in a heterogeneous manner rather than a distrib. at random, the hypothesis of contagion being that when 1 individual of a sp. is present other individuals of the same sp. are also likely to occur. In adapting Neyman's series for the analysis of plant populations, 2 parameters are defined: m_1 is proportional to the mean no. of groups per unit area of the field, and m_2 is proportional to the mean no. of individuals

per group. The 1st term of the series is given by $P(x=0)=e^{-m_1(1-e^{-m_2})}$, and subsequent terms by $P(x=k+1)=$

$$\frac{m_1 m_2 e^{-m_2}}{k+1} \sum_{t=0}^{t=k} \frac{m_2{}^t}{t!} P(x=k-t).$$

In cases where a Poisson series failed to fit because there were too many empty quadrats, Neyman's series gave a good fit; it also clearly portrayed the bimodal nature of the distrib. The relative variance is used as a quick and reliable test for randomness. From the 56 spp. examined it appeared that it is unusual for "frequent" or "abundant" spp. to be distributed at random.—From auth. sum.

ARCHIBALD, E. E. A. 790
1950. Plant populations. II. The estimation of the number of individuals per unit area of species in heterogeneous plant populations. Ann. Bot. [London] (n.s.) 14(53) : [7]–21, illus.

Data for the no. of individuals per unit area for 27 spp. from the observ. of 9,340 quadrats is discussed. It is shown that Thomas' Double Poisson series will give a good estimate of the density of individuals in heterogeneous populations in which the variance is significantly greater than the mean. The estimate is given by the 2 parameters of the series which can be obtained by observ. from the no. of quadrats with no individuals and the no. of quadrats with only 1 individual where $P(0)=e^{-m}$ and $P(1)=e^{-(m+\lambda)}$, and m is the estimated mean no. of clusters per quadrat and λ is the estimated no. of units per cluster additional to the 1st unit. The estimated mean no. of individuals per quadrat is equal to $m(1+\lambda)$. Tables for the estimated parameters and the estimated mean density together with their standard errors are given in the App.—Auth. sum.

BARNES, H., AND STANBURY, F. A. 791
1951. A statistical study of plant distribution during the colonization and early development of vegetation on china clay residues. Jour. Ecol. [London] 39(1) : 171–181.

A brief rev. of the recent literature on the distrib. of individuals of a given sp. suggests that data collected under relatively simple habitat conds. would be of interest. Distributions of individual plants colonizing on china clay residues were plotted. Results are given for a no. of plants, and the agreement with the Poisson, Neyman, and Thomas series examined. Some plants are randomly distributed; others show aggregation. Neyman's and Thomas' series show close agreement since they are based on the same premises. Since the parameters of the latter are more readily interpreted in terms of plant distrib., it would seem the more useful series. The agreement between actual plant clusters, estimated in an arbitrary manner, and those determined from the Thomas parameters is satisfactory for the particular quadrat sizes used. In all cases the quadrat size was sufficient to contain a complete cluster. The devlpmt. of vegetation takes place by spread of "islands" of rush and grass. At this stage the distrib. becomes highly contagious, the "islands" forming a series of separate but similar communities.

BEALL, GEOFFREY, AND RESCIA, RICHARD R. 792
1953. A generalization of Neyman's contagious distributions. Biometrics 9(3) : 354–386.

Contagious distribs. have been found to apply to situations where populations initially exist in randomly scattered clumps and where subsequent outward movements of individuals within clumps are not independent. They have been appl. widely to distribs. of insects or microorganisms in their natural environments. Neyman originally proposed 3 types of contagious distribs. which did not fit all expt. data. These auth. generalized Neyman's distribs. and in some cases found better fits to data previously poorly fitted by Neyman's distribs. The generalized distrib. is derived and appl. to many different sets of expt. data. Comparisons with Neyman's distribs. are made on the basis of χ^2 goodness of fit tests. A particular case is worked out in detail to illustrate the nature of the computations.

BLISS, C. I. 793
1953. Fitting the negative binomial distribution to biological data. Biometrics 9(2) : 176–196.

BLISS, C. I., AND OWEN, A. R. G. 794
1958. Negative binomial distributions with a common k. Biometrika [London] 45(1/2) : 37–58, illus.

COLE, LAMONT C. 795
1946. A theory for analyzing contagiously distributed populations. Ecology 27(4): 329–341.

Under natural conds., living organisms are usually contagiously distributed in space, i.e., contrasted to random distrib., too many infertile samples and too many large groups of organisms are encountered. Contagiousness is attributable to any or all of the following factors: inappropriate sample size, sample heterogeneity, common origin of the individuals, and active aggregation. The hypothesis is advanced that many contagious distribs. may be interpreted as composed of various-sized groups of organisms with these groups distributed as units in a Poisson distrib. The mean no. per sample of groups containing x organisms is designated m_x, and the mean no. of groups per sample as m_0. For the total frequency distrib. then, $m_0=\Sigma m_x$, $m=\Sigma x m_x$, and $\sigma^2=\Sigma x^2 m_x$. Tentative computational methods are developed for determining the m_x values and several empirical distribs. are fitted by this means, thus indicating the structure of a population which, under the postulated random process, would yield the observed distribs. This theory of contagious distribs., if tenable, opens many possibilities for population analysis.

ERICKSON, RALPH O., AND STEHN, JOHN R. 796
1945. A technique for analysis of population density data. Amer. Midland Nat. 33(3): 781–787, illus.

The distrib. of *Clematis fremontii* var. *riehlii* on glades in the Ozarks can be regarded as consisting of 2 component distribs.: an "econ. distrib." for favorable portions of the glade, and an "adventitious distrib." for unfavorable portions. A method is demonstrated for fitting 2 Poisson curves to the field data, which permits calculation of means, etc. The method is applicable to distrib. data for certain other plants.

FISHER, R. A. 797
1941. The negative binomial distribution. Ann. Eugenics [Cambridge] 11(2): 182–187.

The cases of the positive and negative binomial distribs., in spite of their algebraic similarity, are very different in their appls. and in the statis. probs. to which they give rise. With the negative binomial we ordinarily require to estimate the exp. in addition to the mean of the distrib. This can be done from the 1st 2 moments, but the process has been recognized as inefficient. In this note the theoretical efficiency is calculated to make it easy to judge in practical cases whether a more exact fitting by maximal likelihood is required.

FISHER, R. A. 798
1953. Note on the efficient fitting of the negative binomial. Biometrics 9(2): 197–200.

GURLAND, JOHN. 799
1958. A generalized class of contagious distributions. Biometrics 14(2): 229–249.

This paper develops by considerations of probability generating functions some generalized families of contagious distribs. on the basis of a biol. model similar to that of J. Neyman, Ann. Math. Statis. 10: 35–57 (1939). One of these generalized families contains as a particular case the family of contagious distribs. developed by G. Beall and R. R. Rescia, Biometrics 9: 354–386 (1953). Some examples are given to illustrate how such a generalized family may be fitted to actual data. It is further shown that the limiting distrib. of the family considered by Beall and Rescia is a Polya-Aeppli distrib. and consequently a simpler formula is available for computing the probabilities. Other limiting distribs. of the generalized family which contains that of Beall and Rescia are also obtained.—Auth. abs.

GURLAND, JOHN. 800
1959. Some applications of the negative binomial and other contagious distributions. Amer. Jour. Pub. Health 49(10): 1388–1399, illus.

The negative binomial distrib. is discussed in its relation to the binomial and Poisson distribs. Some math. models which lead to it are also discussed. These include the compound Poisson and generalized Poisson distribs., and it is shown how the gamma and log distribs. become involved in these representations. Further, a model based on true contagion is shown to yield the negative binomial as a limiting case. Other compound and generalized distribs. distinct from the negative binomial, but based on some of the models which lead to it, are presented and fitted along with the negative binomial to some medical data. A few remarks on estimation and fitting are also included.

KATTI, S. K., AND GURLAND, JOHN. 801
1961. The Poisson Pascal distribution. Biometrics 17(4) : 527–538.

On the basis of the properties discussed, it is observed that the Poisson Pascal distrib. acts as a bridge between the Neyman Type A and the negative binomial distribs. and may be used with advantage when the latter distributions are inadequate to represent the population accurately. From the tables of efficiency, it is clear that in the region of tabulations at least 1 of the *ad hoc* methods of estimation suggested has high efficiency. It is believed that, in practice, (λ, p, k) will not be far beyond the region of tabulation and that 1 of these methods can be used without too much loss of inform.

KATTI, S. K., AND GURLAND, JOHN. 802
1962. Some methods of estimation for the Poisson binomial distribution. Biometrics 18(1) : 42–51.

From the efficiency shown, it is clear that the minimum χ^2 method using the 1st 2 factorial cumulants and the log of the zero frequency can be used as a reasonable substitute for the highly complex asymptotically efficient methods, such as the maximum likelihood method, throughout the region of tabulation. Since for values of parameters lying beyond this region the Poisson binomial can be approximated by simpler distribs., developing efficient methods for those regions seems superfluous.

PIELOU, E. C. 803
1962. Runs of one species with respect to another in transects through plant populations. Biometrics 18(4) : 579–593.

ROBINSON, P. 804
1954. The distribution of plant populations. Ann. Bot. [London] (n.s.) 18(69) : 35–45, illus.

In studying the distrib. of plant spp. in sample quadrats it may be assumed that the individuals are aggregated into groups showing a Poisson distrib., while the no. of individuals in each group follows a log distrib. The resulting compound distrib. of individuals per quadrat is the negative binomial. Evidence is produced to show that the distribs. calculated on this basis agree with those actually obtained in the cases examined.

SHUMWAY, ROBERT, AND GURLAND, JOHN. 805
1960. A fitting procedure for some generalized Poisson distribution. Skand. Aktuarietidskr. [Uppsala] Haft 1/2: [87]–108.

SHUMWAY, ROBERT, AND GURLAND, JOHN. 806
1960. Fitting the Poisson binomial distribution. Biometrics 16(4) : 522–533.

The fitting of the Poisson binomial distrib. by maximum likelihood is considered. The maximum likelihood and recurrence relations are rewritten in terms of ratios of Poisson factorial moments, and these ratios are tabulated for values of the parameters when $n=2$. A simple example illustrates the computational procedure and shows how the labor in fitting may be much reduced by using the tables.

SKELLAM, J. G. 807
1955. Quadrat sampling from the mathematical standpoint. Linn. Soc. London, Proc. (1952–53) 165(2) : [95]–102, illus.

SKELLAM, J. G. 808
1958. On the derivation and applicability of Neyman's Type A distribution. Biometrika [London] 45(1/2) : [32]–36, illus.

SPROTT, D. A. 809
1958. The method of maximum likelihood applied to the Poisson binomial distribution. Biometrics 14(1) : 97–106.

The method of maximum likelihood to estimate a and p is appl. to the distrib.

$$P(k)=e^{-a}\sum_{t=0}^{\infty}\frac{a^t}{t!}\binom{nt}{k}p^k q^{nt-k}$$

to give the equations $n\hat{a}\hat{p}=\bar{k}$ and $L(\hat{p})=\sum a_k F(k)-N=0$, where $F(k)=\dfrac{(k+1)P(k+1)}{n\hat{a}\hat{p}P(k)}$ and $\hat{a}$ and $\hat{p}$ are the estimates of a and p and a_k is the observed frequency of k. If $\hat{p}'$ is an approx. solution, then a closer approx. is $\hat{p}''=\hat{p}'-L(\hat{p}')/L'(\hat{p}')$, where it is shown

$$L'(\hat{p}) = \sum a_k F(k) \left[\frac{1}{\hat{p}} - \frac{1}{n\hat{p}} - \left(1 + \frac{\hat{q}}{n\hat{p}}\right) n\hat{a}\Delta F(k) \right].$$

The large sample variances of $\hat{a}$ and $\hat{p}$ are also derived. It is shown that estimation by the method of moments is inefficient unless $p \leq .1$ and that estimation by the method of sample zero frequency remains reasonably efficient for considerably larger values of $p (p \leq .3)$.

THOMAS, MARJORIE. **810**

1949. A generalization of Poisson's binomial limit for use in ecology. Biometrika [London] 36(1/2): 18–25.

The Poisson situation is generalized by considering a no. of primary points distributed over an area and a random no. of secondary points assoc. with each primary point. The area is divided into squares and the probabilities that a sq. contains 0, 1, 2, . . ., points are calculated, assuming that the nos. of primary points per sq. and of secondary points per primary point are independently Poisson distributed. Estimates are obtained for the 2 parameters by the method of moments and by maximum likelihood. The latter estimates depend only upon the relative nos. of squares containing no or 1 point. It is shown that the maximum likelihood estimates are not much worse than the moment solutions when there are many squares containing no points or 1 point.

THOMPSON, H. R. **811**

1954. A note on contagious distributions. Biometrika [London] 41(1/2): 268–271.

THOMSON, GEORGE WILLIAM. **812**

1952. Measures of plant aggregation based on contagious distribution. Mich. Univ. Lab. Vert. Biol. Contribs. 53, 16 pp.

The contagious distribs. of Neyman and Thomas, fitted to quadrat frequency data for *Solidago rigida*, *Liatris aspera*, and *Lespedeza capitata* from an old-field community, gave respective fits of excellent, fair, and very poor. The size of the contagious distrib. "clusters" of the math. model, 1 to 2 plants per cluster, had little relation to the obvious major clumping evident to the eye but is more likely related to local clumping effects. A comparison of the observed major clumping with that shown by various measures of dispersion indicated that *Lespedeza* was most clumped, *Solidago* least clumped, and *Liatris* intermed., but none of these measures indicates the actual size of the clump involved. Size of clump appears to be a new prob. demanding further res. An app. gives a method for calculating the individual terms of the contagious series by means of direct calculation of polynomials instead of by the use of summations.

WADLEY, F. M. **813**

1950. Notes on the form of distribution of insect and plant populations. Ent. Soc. Amer. Ann. 43(4): 581–586.

Several theoretical distribs. applying to populations of organisms per unit area are described and examples of fitting are shown. The distribs. are fitted to a no. of cases of field populations of *Ribes* bushes, wireworms, and Japanese beetle larvae. The negative binomial was more successful than the contagious distrib. and the Poisson series.

See also **786, 1040.**

OTHER FREQUENCY DISTRIBUTIONS

BIRNBAUM, ALLAN. **814**

1954. Statistical methods for Poisson processes and exponential populations. Amer. Statis. Assoc. Jour. 49(266): 254–266.

The Poisson process and exp. distrib. are described, and examples of their occurrence in practice are given. Methods are presented for constructing interval estimates of the parameters of the distribs., for making 1-sided tests of hypothesis, and for computing confidence intervals for the ratio and the difference of such parameters. A method is also given for comparing 3 or more Poisson processes.

BOND, T. E. T. **815**

1947. Some Ceylon examples of the logarithmic series and the index of diversity of plant and animal populations. Ceylon Jour. Sci. Sect. A., Bot. 12(4): 195–202, illus.

The auth. applies a modification of Willis' "hollow curve" to the Ceylon flora and fauna. The "index of diversity," as controlling the relations between the no. of spp. in a population and its size, is illus. by considering the weed flora on a manurial expt. with tea on St. Coombs estate. An apparent discrepancy between the observed and calculated densities of individual plants per unit area is attributed to a peculiarity in bot. comp. of the flora as affected by the system of weeding.

HALDANE, J. B. S. 816
1941. The fitting of binomial distributions. Ann. Eugenics [Cambridge] 11(2): 179–181.

A binomial law can readily be fitted to observed data by the method of maximum likelihood.

HARTLEY, H. O. 817
1958. Maximum likelihood estimation from incomplete data. Biometrics 14(2): 174–194.

This paper is concerned with the fitting of frequency distribs. to counts which are "incomplete." The most important cases of incompleteness covered are: (1) "Missing Frequencies" (Truncation). These arise for instance when the "zero-class count" cannot be observed. An example of this kind is dealt with in detail and is concerned with a chromosome breakage study (Sampford, 1955, Biometrika [London] 42: 58) in which susceptible cells showing no breakage are not distinguishable from cells not susceptible to breaks. (2) Grouped or Pooled Frequencies (Censoring). These arise for example when the no. of counts exceeding a tolerance value have all been pooled in 1 group. The fitting of frequency distribs. to such data by the method of maximum likelihood is considerably simplified by a new iterative procedure akin to the missing plot technique in analysis of variance. Trial values are estimated for the missing frequencies and these estimates are iteratively improved by their maximum likelihood estimates until, at convergence, the solution agrees with the (computationally more complex) solution of the maximum likelihood equations. New methods for estimating the variances of maximum likelihood estimates are also developed and illus. with numerical examples.—Biol. Abs.

KER, JOHN W. 818
1954. Distribution series arising in quadrat sampling of reproduction. Jour. Forestry 52(11): [838]–841.

MOORE, P. G. 819
1954. A note on truncated Poisson distributions. Biometrics 10(3): 402–406.

The auth. presents a quick method for estimating the parameter in a Poisson distrib. under all types of sampling truncation likely to occur in practice. He points out that the estimate will have a larger standard error than the corresponding maximum likelihood estimate.—Biol. Abs.

NUMATA, M., AND SUZUKI, K. 820
1958. Experimental studies on early stages of secondary succession. III. Jap. Jour. Ecol. 8(2): 68–75. [In Jap. with Eng. sum.]

Experiments for analyzing the developmental process of plant communities on 1-m. perm. quadrats from 1954 to 1957 are reported. The expt. treatments of the quadrats at the beginning are by exchanging the soil (to exchange the surface soil for the subsoil) and by burning the soil (to burn the surface soil 5 cm. deep). Burned-soil plot: The floristic comp. shows a yearly change of the dominants *Setaria-Digitaria-Bromus*, which differs from that of early stages of a normal successional change in this place: *Ambrosia-Erigeron* (*Imperata-Miscanthus*). The dominance-rank relations and comp. curve show the differentiation of spp. groups and their devlpmt. Exchanged-soil plot: The floristic comp. of the 1st yr. is similar to that of the 2nd yr. on the burned-soil plot. The yearly change of dominants is *Digitaria-Ambrosia-Artemisia-Vicia.* The dominance-rank relation and comp. curve seem to show a devlpmt. of plant population from Williams' L-type to Preston's S-type. Distribution type: As a stochastic process in the distrib. of the no. of individuals in a quadrat, the Poisson type related only to the quadrat size a and the geometrical progression type related to a and the no. of individuals appeared in a quadrat n are recognized. Time effect and area effect: The distrib. type varies as the size of quadrat, and varies with time as the geometrical progression type—Poisson type—Polya-Eggenberger type—binominal type—normal type. —Biol. Abs.

OTTESTAD, PER. 821
1934. A contribution to the study of some statistical problems in plant-sociology. NYT Mag. [Oslo] 74: 51–69.

The following prob. is examined: Within a larger area (B), n specimens of a certain sp. exist. What is the probability (s_x) of recording a certain no. (x) of specimens within a test-area (b) selected at random? Assuming that the area B is homogeneous (statistically), theoretical examinations lead to the hypergeometrical frequency function:

$$s_x = f(x) = \frac{\binom{x}{n}\binom{B-n}{b-x}}{\binom{B}{b}}.$$

This theoretical result has been verified by an examination of the quantitative occurrence of *Potentilla erecta*. The individual no. of this sp. within smaller test-areas showed very good agreement with the hypergeometrical frequency function. Further the paper deals with the prob.: Within the area (B), k spp. exist. What is the probability of recording a certain no. (y) of these spp. within a test-area (b) selected at random? If the spp. are distributed over the area (B) in accordance with the very same frequency law, the probability of recording any y spp. within a test-area is given by the binomial frequency function:

$$s_y = \phi(y) = \binom{k}{y} p^y (1-p)^{k-y}.$$

The paper also gives a survey of the statis. methods by means of which it can be determined whether a given statis. series can be represented by the binomial function, Poisson's function, and the hypergeometrical function.—Auth. abs.

PRESTON, F. W. **822**

1948. The commonness, and rarity, of species. Ecology 29(3): 254–283.

Random samples of ecol. or taxonomic assemblages indicate that the universes from which they are drawn have, at least approximately, the form of an ordinary Gaussian curve drawn upon a log base (a "lognormal" curve). The sample has the same general form as the universe, but is decapitated. The exact relation between sample and universe is explored, and the Raunkiaer Law of Frequency explained, as is Williams' Law of Collection Enrichment. There is a remarkable tendency for the dispersion constant "a" to be not far from 0.2 in a great variety of biol. universes. Various appls. of the theory are made to rather inaccessible populations, such as the Nearctic avifauna in its entirety. The findings seem reasonable in all cases.

QUENOUILLE, M. H. **823**

1949. A relation between the logarithmic, Poisson and negative binomial series. Biometrics 5(2): 162–164.

Relations between log, Poisson, and negative binomial series are demonstrated by means of generating functions on the assumption that the no. of groups observed on any 1 occasion is distributed in the Poisson form, so that the probability of observing n groups is $P(n \text{ groups}) = \frac{e^{-m}m^n}{n!}$.

SCHREK, ROBERT, AND LIPSON, HENRY I. **824**

1941. Logarithmic frequency distribution. Human Biol. 13(1): 1–22.

The routine methods of representing frequency distribs. yield asymmetrical curves. By using the log instead of the arithmetic values of the data, the asymmetrical curves become symmetrical. The log curve is described by the frequency constants: geometric mean, geometric standard deviation, log skewness, and log kurtosis. The computation of these constants is as easy as the determination of the corresponding arithmetic constants. The log method of analysis of distribs. includes the use of tables, histograms, probability curves, and frequency formulas, all in log form. The log frequency curve for many statis. distribs. in biol. and medicine is more satisfactory than the arithmetic one. The geometric mean is often more significant than the arithmetic. Similarly the geometric standard deviation is more useful than the arithmetic standard deviation and the C.V. Furthermore, the log frequency formula is, in these cases, more satisfactory than the Pearsonian.

SINGH, B. N., AND CHALAM, G. V. **825**

1937. A quantitative analysis of the weed flora on arable land. Jour. Ecol. [London] 25(1): 213–221, illus.

A total of 95 sq. m. quadrats arranged in 19 5-sq.-m. plots were examined in a field with a history of uniform crop prod. Twelve spp. were listed and the no. of occurrences of each sp. accounted for in every quadrat. The data were compared with Poisson distrib., and the agreement between observed and calculated values tested by χ^2. Overdispersion (patchiness) was great for spp. with high mean frequencies, but for those with low mean frequencies the distrib. was not distinguishable from random dispersion. This led to the concl. that the nature of distrib. of weed spp. on arable land is dependent on the mean density of the spp. and the mode of reproduction. Individuals with high mean density and vegetative methods of propagation are not distributed at random.

SINGH, B. N., AND DAS, K. 826
1938. Distribution of weed species on arable land. Jour. Ecol. [London] 26(2): 455–466.

In a statis. study of the distrib. of individuals of weed spp. made in small plots of arable land left fallow for a short time, it appears from comparison with the terms of a Poisson series that distrib. usually tends to be random (13 out of 21 examples). Determination of the relative variance indicates, however, that all the spp. except 4 show a value which is slightly more than unity, indicating a small degree of aggregation. This is corroborated by the determination of the degree of heterogeneity made on the distrib. of individuals of 1 sp. by employing Ashby's technique of comparing the observed and calculated empty squares in quadrats laid at random. There is good agreement between the results obtained by either relative variance or the empty sq. technique. The former method is more rapid but the latter more precise.—Biol. Abs.

SINGH, B. N., AND DAS, K. 827
1939. Percentage frequency and quadrat size in analytical studies of weed flora. Jour. Ecol. [London] 27(1): 66–77, illus.

While investigating the distrib. of the individuals of weed spp. in small plots of arable land which were left fallow for a short duration, the relations between the % frequency and density and between the quadrat size and mean no. of spp. were studied. The theoretical log relation between % frequency and density holds in the case of the weed spp., but is only approximately true since most of the weed spp. show a small degree of heterogeneity in the distrib. of their individuals. When calculated and observed densities are compared by their standard errors as determined by the formula suggested by Bartlett, it is revealed that although the weed spp. are characterized by a slight degree of heterogeneity, the densities of some spp. may be determined. The difference between the observed and calculated densities is insignificant for those spp. where the agreement with the calculated Poisson series terms is significant. When the relation between the quadrat size and the average no. of spp. found within the quadrat size is studied, a disagreement between the field and calculated data is revealed which, however, improves when the less common spp. are excluded. The disagreement is correlated with the heterogeneity in the distrib. of the individuals of the weed spp.

SNEYERS, R. 828
1955. Sur l'analyse des répartitions statistiques discrètes. [On the analysis of discrete frequency distributions.] Arch. f. Met., Geophys. u. Bioklimatol., Ser. B. [Austria] 7(1): 117–132.

The analysis of discrete frequency distribs. may be reduced to the study of 4 fundamental variables, related to each other in a recurrent manner. The binomial distrib. and derived distribs. are examined and examples given.—Auth. sum.

SPILLER, D. 829
1948. Truncated log-normal and root-normal frequency distributions of insect populations. Nature [London] 162(4118): 530–531, illus.

Because of many zero values there is skew distrib.; e.g., no. of eggs laid by *Anobium puncatum* females, or no. of red scales (*Aonidiella aurantii*) on citrus leaves. Using Gaddum's probit methods, straight lines result from log $n+1$ (to accommodate zero values) plotted against probits for red or black scales; for *Anobium* data a sq.-root transformation is used. If the counting unit is increased (e.g., 20 leaves for scale) until zero values disappear, normal statis. methods may be used, but for data already published, the above method of comparison by linear regression is preferable.

WILLIAMS, C. B. 830
1944. Some applications of the logarithmic series and the index of diversity to ecological problems. Jour. Ecol. [London] 32(1): 1–44, illus.

A log series, 1st suggested in this connection by R. A. Fisher, is appl. to a no. of probs. of the division of individuals into spp. and of spp. into genera. The series is N_1, $(N_1/2)x$, $(N_1/3)x^2$, $(N_1/4)x^3$, . . ., where N_1 is the no. of groups of 1 unit and x a constant less than unity. When several samples are taken from a population containing a no. of spp. the ratio N_1/x is constant and is called the index of diversity. It is found to fit extremely well to a large no. of frequency series drawn from populations of insects, birds, and plants except for a slight tendency for the calculated N_1 to be below the observed. It also fits well the no. of genera with different nos. of spp. in standard classifications of groups of animals and plants. The concept of the index of diversity is appl. to probs. of the no. of spp. of plants on different areas and to the comparison of different floras.

WILLIAMS, C. B. **831**

1947. The logarithmic series and its application to biological problems. Jour Ecol. [London] 34(2): 253–272, illus.

An acct. is given of the math. properties of the log series, so far as they are of interest to biologists. This frequency series, which may be conveniently written αx, $\alpha x^2/2$, $\alpha x^3/3$, $\alpha x^4/4$, . . ., etc., usually represents the no. of groups containing 1, 2, 3, etc., units. Thus in a random sample of insects from a wild population the series fits the no. of spp., represented by 1, 2, 3, etc., individuals. In the series as written above, "α" is a property of the population sampled and is of considerable ecol. interest. It has been called the Index of Diversity. "x" on the other hand is a property of the sample and is a constant, <1, for each sample. Instructions are given for calculating the log series to fit various types of data, and refs. are given to a no. of published biol. appls.

WILLIAMS, C. B. **832**

1950. The application of the logarithmic series to the frequency of occurrence of plant species in quadrats. Jour. Ecol. [London] 38(1): [107]–138, illus.

Previous work on the frequency distrib. of spp. with different nos. of individuals in mixed animal populations has shown that the distrib. conforms fairly closely to a "log series." This present paper is a study of the appl. of the same math. approach to the frequency distrib. of different spp. of plants in quadrat samples. It is shown that this distrib. (whether taken as the no. of spp. found on 1, 2, 3, 4, etc., out of a total no. of quadrats; or as spp. found on 0–20%, 20–40%, . . ., etc., of the quadrats) is dependent on 3 factors: the no. of quadrats, the size of the quadrat, and a measure of the diversity of the assoc. This measure of diversity is 1 of the constants, alpha, in the formula for the log series, or can be measured proportionately by the rate of increase of spp. as the size or no. of quadrats is increased. The size and no. of quadrats can be varied at will by the observer; the real ecol. factor determining the distrib. is therefore the diversity of the population.

See also **787.**

SAMPLING DISTRIBUTIONS

CHAPMAN, R. A. **833**

1938. Applicability of the "z" test to a Poisson distribution. Biometrika [London] 30(1/2): 188–190, illus.

One hundred samples of 16 values were drawn experimentally from a Poisson distrib. with a mean equal to 1. Each sample of 16 was divided into 4 equal subsets. For each sample 2 estimates of the variance of the population were computed, i.e., variance between means of subsets and variance within subsets. The distrib. of the ratio of these 2 variances, or F, was compared with the theoretical distrib. Agreement between actual and theoretical frequency of F, as measured by χ^2, was satisfactory. $P(\chi^2)$ was about 0.5.

COCHRAN, W. G. **834**

1940. Note on an approximate formula for the significance levels of z. Ann. Math. Statis. 9:93–95.

DEMING, W. EDWARDS, AND BIRGE, RAYMOND T. **835**

1934. On the statistical theory of errors. Rev. Mod. Phys. 6(3): 119–161, illus.; also Phys. Rev. 46(11): 1027.

A set of n equally reliable observs. may be viewed as a sample of n variates drawn from an infinite parent population of observs.; hence the interpretation of expt. data obtained in a sci. invest. is a prob. in sampling and should be handled as such. The auth. discuss some of the recent developments in statis. methods as they affect a single set of observs. drawn from a "normal" parent population. These results are put into a form suitable for use in the interpretation of data obtained in the lab. The contents of the paper include a discussion of the sampling distribs. of the error μ in the mean $\bar{x}$ of a set of n observs., their standard deviation s, the "Student" ratio μ/s, and the statis. tests that arise from these distribs. Newly designed charts and tables are shown for convenience in making these tests. R. A. Fisher's notion of "fiducial probability" is applied to the distrib. of s, and a table for the fiducial 5% and 50% points in the probable error of the mean is given. The odds are 19 to 1 that the true probable error in the mean is less than the 5% fiducial probable error; for the 50% probable error the odds are even. Various methods for estimating the probable error are given. Fisher's method of "maximum likelihood" is discussed and illus. analytically and graphically. The methods of Bayes and Laplace for the appl. of "inverse probability" are illus. with Molina and Wilkinson's curves. It is shown that there is no possible way of expressing mathematically a state of complete ignorance of the prior probabilities. The paper

contains illustrative examples, and closes with an introduct. to the estimation of the probable error in the mean of a series of observs., when several series of observs. of equal precision are at hand.—Biol. Abs.

HALDANE, J. B. S. 836
1942. Moments of the distributions of powers and products of normal variates. Biometrika [London] 32(3/4): 226–241.

The 1st 4 moments are calculated for any power of a normally-distributed variate and for the product of any no. of normally-distributed variates (whether correlated or uncorrelated). Results are expressed in terms of the means and coefficients of variation of the original distribs. Since linear measurements on biol. material are frequently nearly normal in their distribs., these results may be applicable to the distribs. of the wts. or vols. of organisms.

HORTON, JEROME S. 837
1941. The sample plot as a method of quantitative analysis of chaparral vegetation in southern California. Ecology 22(4): 457–468.

In order to analyze quantitatively the density of vegetation occurring on a series of small chaparral-covered watersheds, 225 random milacre quadrats were measured. Data were segregated to show vegetative comp. of the assocs. and the several watersheds. In a check of the reliability of sampling, the frequency distribs. of the densities of the various spp. found on the quadrats were not normal curves. Chamise-chaparral was selected as the assoc. to determine the desirability of enlarging the plot size to allow for increased statis. analysis. Eighty of the quadrats occurring in the chamise-chaparral were enlarged to an 8-milacre size. This increased size produced normal frequency curves for the 2 dominants, *Adenostoma fasciculatum* and *Ceanothus crassifolius*. Further study showed that an analysis of the % of open area gave a more sensitive indication of reliability of sampling and could therefore be used in determination of the no. of plots needed to obtain a desired accuracy. As the frequency distrib. of this factor of openness was normal in both the 1-milacre and 8-milacre sized plots, there was little advantage obtained in utilizing the larger plot.

JEFFREYS, HAROLD. 838
1941. Some applications of the method of minimum χ^2. Ann. Eugenics [Cambridge] 11(2): 108–114.

The use of the method of minimum χ^2 for estimation is illus. by numerical appls. to 3 types of probs. where the data are frequencies: (1) a Poisson distrib., (2) 2 negative binomial distribs., (3) a case where no suggested law of chance is available but a certain amount of smoothing is permissible. In the last the method is combined with a method of smoothing that has been found useful in seismological work.

See also **933.**

ESTIMATION AND HYPOTHESIS TESTING

BEAZLEY, RONALD, AND SHIUE, CHERNG-JIANN. 839
1957. Further applications of skewness and central tendency tests with the rectangular distribution as a criterion. Forest Sci. 3(4): 321–328.

Three sets of field data were used to demonstrate the appl. of the skewness and cent. tendency tests previously designed by the auth. These include a forest reproduction survey, a seed source study, and a forest thinning expt. Interpretations in biol. terms for each case are given to develop the meanings of these statis. tests.—Biol. Abs.

BRADLEY, JAMES V. 840
1960. Distribution-free statistical tests. U. S. Air Force Wright Air Devlpmt. Div. Tech. Rpt. 60–661, 378 pp.

As a result of an extensive survey of the literature, a large no. of distrib.-free statis. tests are examined. Tests are grouped together primarily according to general type of math. derivation or type of statis. "inform." used in conducting the test. Each of the more important tests is treated under the headings: Rationale, Null Hypothesis, Assumptions, Treatment of Ties, Efficiency, Appl., Discussion, Tables, and Sources. Derivations are given and math. interrelations among the tests are indicated. Strengths and weaknesses of individual tests, and of distrib.-free tests as a class compared to parametric tests, are discussed.

BRIEGER, F. G. 841
1942. Coeficiente de variacão e índice de varianca. [Coefficient of variation and index of variance.] Bragantia [Brazil] 2(9): 313–331.

The present paper studies the usefulness of 2 relative measures of variation, the well-known C.V. and a new term proposed in this paper and called the index of variance.

These terms are defined by the equations: coefficient of variation $=\sigma\,\% = \frac{\sigma}{\bar{v}} \times 100$; index of variance: $\frac{\sigma}{\sqrt{\bar{v}}}$.

It is shown that, for theoretical reasons, only the index of variance may be expected to be constant. Six different expt. series actually proved this constancy, showing at the same time the variability of the C.V. which proved to be dependent upon the respective mean. The C.V. becomes approximately constant when the respective means are sufficiently distant from the absolute limit zero or other biol. limits. Thus the index of variance may be used to prove the homogeneity of variation in samples with means of different dimensions. Through this it is shown that the index of variance should be constant; it is explained that for biol. reasons we may not always find a good fit between the observed and the expected data. While it seems justified in agr. expts. to accept proportionality between mean yield and area, no such relation exists for the standard error. It can only be said that, generally, the index of variance for large areas is not equal, but bigger than that for smaller ones. The C.V. cannot be used as a general term for comparing the variation in series of different dimensions where we must apply the index of variance. But it still retains its value as a measure of the efficiency of expts.—From auth. sum.

CLOPPER, C. J., AND PEARSON, E. S. **842**

1934. The use of confidence or fiducial limits illustrated in the case of the binomial. Biometrika [London] 26(3/4): 404–413, illus.

If x individuals in a random sample of n possess a certain character we may determine confidence limits, p_1 and p_2, for the proportion p possessing the character in the sampled population, such that in repeated samples the prediction that $p_1 < p < p_2$ is correct in a specified % of the cases. This % is called the confidence coefficient. Charts are given to determine confidence limits and to plan the size of sample necessary to provide a desired degree of accuracy in estimation.—Biol. Abs.

COLE, LAMONT C. **843**

1945. A simple test of the hypothesis that alternative events are equally probable. Ecology 26(2): 202–205.

A table of $P = 2\sum_{0}^{E} \frac{n!}{E!\,(n-E)!} \Big/ 2^n$ is given. This is from the expansion of the binomial $(p+q)^{35}$ to $(p+q)^2$ where $p=q=0.5$.

CORSTEN, L. C. A. **844**

1957. Partition of experimental vectors connected with multinomial distributions. Biometrics 13(4): 451–484.

Methodological paper on the invest. of counts in (possibly nonorthogonal) contingency tables in terms of vectors. On the analogy of the analysis of variance, the partition of a 2×2 table in a level, 2 main effects, and an interaction is introduced. From this partition follows the well-known decomposition of the χ^2-criterion in 3 components which serve to test the mentioned aspects. A similar partition of a 2^3 table in a level, 3 main effects, 3 first-order interactions, and a 2nd-order interaction supplies the decomposition of the χ^2-criterion into 7 components. The hypotheses which can be tested by these components are given in detail; in particular, the hypothesis of independence of the 3 classifications in the level must be acceptable. The decomposition of $m\times n\times$ . . . tables is introduced as well. Lancaster's suggestion for calculating χ^2, in case cells are pooled, is criticized. The usual warning against amalgamating 2^3 tables to 2×2 tables is mostly not justified; rather, judgment of the validity of the null hypothesis of independence is necessary. For each of the cases with 1, 2, or 3 first-order interactions in the level, respectively, new partitions into interactions and a 2nd-order interaction are given. In the case of 3 first-order interactions, Bartlett's definition of 2nd-order interaction is followed. The 4 test criteria for 2nd-order interaction in a 2^3 table are asymptotically equal, unless the no. of admitted 1st-order interactions in the level is too small. The appl. of Bartlett's method on his example is rejected. In connection with an appropriate model another partition and another definition of "no 2nd-order interaction" is proposed.—Biol. Abs.

DAVID, F. N., AND MOORE, P. G. **845**

1954. Notes on contagious distributions in plant populations. Ann. Bot. [London] (n.s.) 18(69): 47–53.

Past experience has shown that the Poisson series is often inadequate as a model for describing plant populations. Various alternative 2-parameter models have been suggested in place of the Poisson series, but they all depend on assumptions which may or may not hold. In this paper a different approach is put forward in that attention is concentrated on the mean no. of plants per quadrat and an index of "clumping" or

"contagiousness." Examples are given as to the use of these concepts to test for differences between the distrib. of a plant in 2 localities or between 2 plants in the same locality.

DAVID, F. N., AND MOORE, P. G. 846
1957. A bivariate test for the clumping of supposedly random individuals. Ann. Bot. [London] (n.s.) 21(82): [315]–320, illus.

A method is proposed for the analysis of plant distribs. from the relative positions of individual plants rather than from the nos. of plants occurring in successive small areas. The method is illus. by ref. to the detailed distrib. in nature of *Solidago rigida* and of plants infected with nettlehead, a virus disease of hops.—Auth. abs.

DUNCAN, DAVID B. 847
1957. Multiple range tests for correlated and heteroscedastic means. Biometrics 13(2): 164–176.

Complete multiple range tests have previously been developed for uncorrelated and homoscedastic means. A method is presented for extending these tests to cases with correlated and/or heteroscedastic means such as ones with unequal replications and adjusted means from analyses of covariance and incomplete block designs. A short-cut skipping method is also presented for applying multiple range tests to a large no. of means. The properties of the proposed tests are discussed briefly and are concluded to be closely approx. to the ones desired.

FRACKER, S. B., AND BRISCHLE, H. A. 848
1944. Measuring the local distribution of *Ribes*. Ecology 25(3): 283–303.

Observations on *Ribes* in 5 locations in Idaho, Wash., and Calif. where these plants are being eradicated on a white pine blister rust control project indicated that they were distributed locally as if what Neyman has called a "contagious" distrib. were superimposed on a random "Poisson" distrib. The auth. term this a "mixed" distrib. In determining which quadrats were occupied by *Ribes*, an 8% systematic sample gave about as accurate inform. concerning 5-acre blocks as a 4% sample did concerning 10-acre blocks. Divergence from the random type of distrib. could be measured satisfactorily either by the method of relative variance or by determining proposed D or d factors giving the relation between the total no. of *Ribes* actually present on the block and the no. that would be expected in a random distrib. judging from the % of quadrats occupied. The relative variance had the disadvantage of increasing with the unit size of sample, while the D or d factors remained more nearly constant on a given area regardless of sample size.—Biol. Abs.

HARTER, H. LEON. 849
1957. Error rates and sample sizes for range tests in multiple comparisons. Biometrics 13(4): 511–536.

The prob. of multiple comparisons has recently aroused a great deal of interest among statisticians. The basic F-test in an analysis of variance determines whether there is a significant difference among a group of means, but it cannot tell which means differ significantly from which others. The latter is often what the investigator really wants to know. Various multiple comparisons tests, including the range tests discussed in this paper, have been proposed. A study is made here of the error rates, α and β, and their relation to sample size, N, for 3 fixed range tests and 3 multiple range tests.—Biol. Abs.

HARTLEY, H. O. 850
1940. Testing the homogeneity of a set of variances. Biometrika [London] 31(3/4): [249]–255.

If standard errors are obtained from k groups of expt. data and if it is desired to obtain a standard error common to all groups, it is often necessary to apply a test for inhomogeneity between the k individual standard errors. For general use in such (and related) cases a statis. test, called the L_1 test, has been developed and has been modified recently with the help of a new statis. denoted by μ. In this note a new math. formula is found from which numerical values of the probability integral of μ can be readily obtained. A scheme to tabulate the 5% and 1% levels of μ is proposed and the accuracy of the new formula is compared with that of approx. formulae hitherto in use.

HOPE-SIMPSON, J. F. 851
1940. On the errors in the ordinary use of subjective frequency estimations in grassland. Jour. Ecol. [London] 28(1): 193–209.

Tests were made to examine the discrepancies between successive subjective estimations, under various conds., of the frequency of plant spp. in grassland. The estimates made in successive trials on the same area were often very different. The main causes of difference, and the types of spp. thereby liable to widely disagreeing estimates, are

(1) the inevitable error of any estimation method—affecting particularly spp. difficult to observe, viz, grasses, other narrow-leaved plants, bryophytes, (2) fluctuation in abundance from yr. to yr.—anns., biens., (3) seasonal change in abundance or aspect—spp. showing a marked periodicity through the season, e.g., conspicuous only in flowering period, (4) individual differences of areas which are parts of a larger supposedly homogeneous area—spp. whose frequency within normal limits does not affect the general appearance of the herbage. The discrepancy of estimations is widest where all these 4 causes are involved together. In comparative field studies, even wide difference in estimates for different areas may be insignificant in spp. of the above types, corresponding to the circumstances. An area was listed and frequencies assigned with special care, taking 2 1/4 hrs. instead of 1 hr. During the extra time spent evaluating frequencies, the no. of spp. in the list was increased by about 1/2 of the orig. no.

KATZ, LEO. **852**

1953. Confidence intervals for the number showing a certain characteristic in a population when sampling is without replacement. Amer. Statis. Assoc. Jour. 48(262): 256–261.

The formulas given are good approxs. for populations containing between 25 and 500 individuals. Tables already published give confidence intervals for populations outside this size range. Several examples are worked out.

MILES, S. R. **853**

1935. A very rapid and easy method of testing the reliability of an average and a discussion of the normal and binomial methods. Amer. Soc. Agron. Jour. 27(1): 21–31, illus.

NEYMAN, J. **854**

1942. Basic ideas and some recent results of the theory of testing statistical hypotheses. Roy. Statis. Soc. Jour. 105(4): 292–322.

The auth. rev. some of the developments connected with testing statis. hypotheses together with several controversies on this phase of statis. Ideas concerning the following are presented: definition of a statis. hypothesis, 2 views of probability, meaning of testing hypotheses, definitions of the 2 kinds of errors arising in making a test, the power function, the power function of a most powerful test, regions and similar regions, tests which are unbiased, tests concerning randomization testing by use of χ^2, tables of power functions, the power function of χ^2, etc. Assumptions underlying the test are given, together with difficulties arising in applying them. This synopsis of the developments involved in testing statis. hypotheses is well written, contains many recent discoveries, and shows the rapid progress made in statis. analyses. The app. discusses the work of R. A. Fisher and Jeffrey.—Biol. Abs.

NEYMAN, J., AND PEARSON, E. S. **855**

1931. On the problem of k samples. Polon. Acad. des Sci. et Lettres, Cl. de Sci. Math. et Nat. Bul. Internatl. Ser. A: 460–481.

PRZYBOROWSKI, J., AND WILENSKI, H. **856**

1940. Homogeneity of results in testing samples from Poisson series. With an application to testing clover seed for dodder. Biometrika [London] 31(3/4): [313]–323, illus.

The prob. considered is that in which x_1 and x_2 are 2 independent random variables distributed in accordance with the Poisson law, and it is desired to test the hypothesis that the expectations m_1 and m_2 are the same. It is shown how a test may be derived which is independent of the value of the unknown common hypothetical expectation but which, owing to the discontinuous nature of the probability distribs., will only provide an upper limit to the significance level, i.e., to the chance of rejecting the hypothesis tested when it is true. The manner of approach of the significance level to its upper limit has, however, been investigated numerically. A table has been provided, containing critical values $k(na)$ required in carrying the test. The power function of the test has also been determined, and tables and charts given which make it possible to determine the chance of detecting differences in expectations m_1 and m_2 of specified magnitudes. Some uses of the test are discussed.

See also **567, 814, 860, 933, 991.**

REGRESSION

AWBERY, J. H. **857**

1934. The determination of a parabolic formula to represent a series of observations. [London] Phys. Soc. Proc. 46(4): 574–582.

When the constants a, b, and c in the formula $y=a+bx+cx^2$ are to be determined

from simultaneous values of x and y, the best-known methods involve the addition of a no. of equations, which are then solved to give the desired constants. A large no. of significant figs. must be retained in the calculation. If 1 constant can be determined separately from the other 2, the arithmetic can be greatly simplified. It is frequently advantageous to determine 1st the constant c, since this is the constant needed to correct mean values to instantaneous values. It can be easily found by the method of divided differences which, in contrast to the more familiar methods, reduces the no. of significant figs. to the minimum permissible. If the observs. are very irregular, the method in its crudest form gives a very poor estimate of c, but a modification is described which adds little to the labor, while considerably improving the accuracy. Numerical examples are given, and the results by the new method compared with those obtained by the methods of least squares and zero sum.—Auth. abs.

BAKER, G. A. 858
1949. An application of linear regression analysis to biometric data. Poultry Sci. 28(2): 293–297.

The prob. discussed is that of finding an estimate of the relation between white and yolk wts. of birds' eggs for all spp. based on partial data for 24 spp. and more adequate data for 8 spp. The general principles considered for determining a "best" fitting line were freehand, least squares, and maximum likelihood. A well-established principle based on assumptions not sufficiently close to reality may give a poor result. If the assumptions are modified towards reality, the results may be vastly improved. Any math. model is only approx., but the principle of least squares based on sufficiently realistic assumptions seems to give acceptable results.

BATEN, WILLIAM DOWELL. 859
1941. How to determine which of two variables is better for predicting a third variable. Amer. Soc. Agron. Jour. 33(8): 695–699.

This article gives the details for applying Hotelling's test for determining which of 2 variables is better for predicting a 3rd when the variables are linearly related. The test answers such questions as the following: Can a steer's wt. be better predicted from his heart girth than from some other body measurement? Can the area of a bean leaflet be better predicted from the length than from the width? Two appls. relating to agr. are presented together with charts showing the geometric meaning of the test. The object of the article is to bring to the attention of res. workers in agr. this important test which can be appl. in many ways.

BLISS, C. I. 860
1958. Periodic regression in biology and climatology. Conn. (State) Agr. Expt. Sta. Bul. 615, 55 pp., illus.

Periodic regression has been applied to cyclic phenonema in which (1) the length of the cycle, such as the yr. or day, is determined independently of the response, (2) observs. are spaced equally through the cycle, and (3) the no. of replicates is constant at each interval. When the response (y) is a symmetrical function of time, it may conform to the sin curve, computed with the equation $Y=a_0+a_1u_1+b_1v_1$, where a_0 is the mean response and a_1 and b_1 are regression coefficients for the orthogonal cos u_1 and sin v_1 respectively, which lead directly to estimates of the amplitude and phase angle of the curve. When the relation is not symmetrical, the sin curve can be extended with similar additional terms for 2, 3, or more cycles in each fundamental period by classical Fourier analysis. For deciding how many terms to retain in a Fourier curve and for determining its error, an analysis of variance is based upon the math. model for replicated regressions. The calculations are illus. numerically with the monthly mean temps. in New Haven over a 14-yr. period, the monthly iodine value in butter fat from 5 creameries in Alberta, and the elect. potential of an elm tree in 8 three-day periods. Both the no. of terms in a periodic regression and the validity of its analysis depend upon a suitable measure of the response. The transformation to logs is appl. to the data on 2 contagious diseases, and to sq. roots for a Poisson count to data on the hr. of birth. An example of seasonal variation in the log-ED_{50} for a biocide or drug from all or none data involves the probit transformation. Diurnal variation in the log heat-exchange of cows in an expt. barn is corrected for aperiodic differences in humidity by covariance. Confidence limits are described for the parameters of the sin curve when each statis. is treated separately and when they are considered jointly. Finer adjustments in periodic regression are examined with the monthly mean temps. in New Haven. These include corrections for differences in the length of the mo., seasonal changes in the variance through the yr., which proved itself to be periodic, tests for the normality of the variation from yr. to yr. within mos., and the bearing of these finer adjustments upon climatol. predictions.—Biol. Abs.

CHISCI, G. C. **861**
1960. L'impiego delle funzioni discriminanti applicate alle misurazioni fogliari per la differenziazione di alcuni ecotipi di erba medica nella stazione ecologica di Lodi. [The use of discriminating functions applied to leaf measurements for differentiating some lucerne ecotypes at the ecological station of Lodi.] Genet. Agr. [Rome] 11(3/4): 243–267, illus. [Eng. sum.]

DENT, BERYL M. **862**
1935. On observations of points connected by a linear relation. [London] Phys. Soc. Proc. 47(1): 92–108, illus.

The prob. of drawing the best straight line through a set of observed points is solved by a method shorter than those previously published. It is essential for the complete solution of the prob. to obtain the most probable value of the ratio of the precision constants of the 2 observed sets of quantities, and a new method is given for finding this ratio. Expressions for the errors in the position and inclination of the line are derived, and a numerical example is added.—Auth. abs.

MANDEL, JOHN. **863**
1957. Fitting a straight line to certain types of cumulative data. Amer. Statis. Assoc. Jour. 52(280): 552–566.

Involves linear data of measurements made at progressive stages of a process where errors are not independent. Ordinary regression methods appl. to wildlife data imply independent errors, often an incorrect assumption.

SCHULTZ, ARNOLD M. **864**
1956. The use of regression in range research. Jour. Range Mangt. 9(1): 41–46, illus.

See also **829, 942, 983.**

VARIANCE ANALYSIS

ASHTON, G. C., RENNIE, J. C., AND ETTER, E. **865**
1958. Interpretation of interaction in the analysis of variance of a factorial experiment. Canad. Jour. Anim. Sci. 38(2): 181–186.

BOURNE, J. B. **866**
1938. The importance and use of appropriate assumed means in collating field experimental results statistically. Trop. Agr. [Trinidad] 15: 247–258.

Where results from several trials are combined and averages vary greatly, it is more advantageous to use different assumed means for each trial than 1 assumed mean, because the labor in calculation is less. This involves some arithmetical manipulation which is described in detail.

BRANDT, A. E. **867**
1933. The analysis of variance in a $2 \times s$ table with disproportionate frequencies. Amer. Statis. Assoc. Jour. 28: 164–173.

According to Bartlett, the auth. does not appear to realize all the complications that absence of orthogonality entails. Thus he assumes that the sums of squares appropriate for testing different effects must necessarily be additive as in an orthogonal expt., and this is not true.

BULLEN, E. R. **868**
1956. The interpretation of field trial results. Indian Jour. Agron. 1(2): 133–140.

CAPÓ, BERNARDO G. **869**
1944. A method of interpreting the results of field trials. Puerto Rico Univ. Jour. Agr. 28(1): 7–21.

The auth. describes a method of interpreting the results of field trials involving comparatively large plots in places where soil fertility varies widely between spots relatively near to one another. The method is applicable when testing a small no. of treatments.

CARLSON, I. T., AND MOLL, R. H. **870**
1959. An analysis of variability in quantitative characters in strains of orchardgrass. Agron. Abs. 1959: 54.

COCHRAN, W. G. **871**
1939. The use of the analysis of variance in enumeration by sampling. Amer. Statis. Assoc. Jour. 34: 492–510.

COCHRAN, W. G. 872
1947. Some consequences when the assumptions for the analysis of variance are not satisfied. Biometrics 3(1): 22–38.

The analysis of variance depends on the assumptions that the treatment and environmental effects are additive and that the expt. errors are independent in the probability sense, have equal variance and are normally distributed. Failure of any assumption will impair to some extent the standard properties on which the widespread utility of the technique depends. Since an experimenter could rarely, if ever, convince himself that all the assumptions were exactly satisfied in his data, the technique must be regarded as approximative rather than exact. From general knowledge of the nature of the data and from a careful scrutiny of the data before analysis, it is believed that cases where the standard analysis will give misleading results or produce a serious loss of inform. can be detected in advance. In general, the factors that are liable to cause the most severe disturbances are extreme skewness, the presence of gross errors, anomalous behavior of certain treatments or parts of the expt., marked departures from the additive relation, and changes in the error variance, either related to the mean or to certain treatments or pts. of the expt. The principal methods for an improved analysis are the omission of certain observs., treatments, or replicates, subdivision of the error variance, and transformation to another scale before analysis. In some cases, as illus. by the numerical examples, the more exact methods require considerable experience in the manipulation of the analysis of variance. Having diagnosed the trouble, the experimenter may frequently find it advisable to obtain the help of the math. statistician.

CORSTEN, L. C. A. 873
1958. General missing plot technique. Wageningen Rijksinst. v. Rassenonderz. van Landbgewassen. Meded. 34: 141–151. [In Dutch with Eng. sum.]

CURNOW, ROBERT N. 874
1959. The analysis of a two phase experiment. Biometrics 15(1): 60–73.

A statis. analysis, proposed by G. A. McIntyre, (Biometrics 11(3): 324–334, 1955), for a rather complicated 2 phase expt. is criticized and a more efficient analysis proposed. In this new analysis the variation is more completely broken down into its component pts. and 2 sets of estimates of treatment effects obtained. Apart from being correlated with each other, these 2 sets of estimates are equivalent to the inter- and intra-block estimates of an incomplete block design. McIntyre's analysis uses the unweighted means of the 2 sets of estimates. The new analysis wts. the 2 sets so as to give estimates with minimum variance. With the particular expt. results discussed by McIntyre the gain in efficiency is small. The difficulties of estimating variance components are discussed.—Auth. abs.

DUTTON, A. M. 875
1952. Statistical analysis of long-term agricultural experiments. (Abstract.) Iowa State Col. Jour. Sci. 26(2): 198.

EISENHART, CHURCHILL. 876
1947. The assumptions underlying the analysis of variance. Biometrics 3(1): [1]–21.

FEDERER, WALTER T. 877
1957. Variance and covariance analyses for unbalanced classifications. Biometrics 13(3): 333–362.

Variance and covariance analyses are classified under 3 categories, viz, Case I, interaction absent; Case II, interaction present and the effects assumed to be fixed effects; and Case III, interaction present and the interaction effects and at least 1 of the main effects of the factors represented in the interactions assumed to be random effects. The statis. procedures for the 3 cases are derived for 2-way and 3-way classifications and are illus. with numerical examples for the 2-way classification with a covariate. The procedures for a q-way classification with b covariates are indicated.—Biol. Abs.

FISHER, R. A. 878
1941. The interpretation of experimental four-fold tables. Science 94: 210–211.

GARBER, R. J., AND MCILVAINE, T. C. 879
1935. Analysis of variance of corn yields obtained in crop production experiments. Amer. Soc. Agron. Jour. 27: 480–485.

GLENDAY, A. C. 880
1955. The mathematical separation of plant and weather effects in field growth studies. Austral. Jour. Agr. Res. 6(6): [813]–822, illus.

The only serious limitations of field growth studies are due to the erratic nature of the

curves caused by short-term weather variations and the less apparent deviations caused by secular changes. The method of constant-fitting is appl., via a suitable math. model and expt. design, to separate growth and weather effects. A detailed acct. of the analysis is given, using a trial conducted as a test of the technique as an example, and the future possibilities of the technique in field growth studies are discussed.—Auth. sum.

GOCH, D. C. 881
1958. Examination of residuals in the analysis of variance. So. African Jour. Sci. 54(3): 67–69.

GREEN, J. U. 882
1949. Herbage sampling errors in grazing trials. Brit. Grassland Soc. Jour. 4(1): 11–16, illus.

HEALY, M. J. R., AND LEECH, F. B. 883
1950. Statistical analysis of results for successive tests on the same organism. Nature [London] 166(4216): 319.

Authors admit that Williams (Nature [London] 166(4216): 319) was not in error. They emphasize that if differences increase during an expt., one needs a linear function of the mean and linear components, with coefficients depending on the variances and covariance of these components. Then the linear function can be calculated for each animal, and significance, etc., can be analyzed from these values.

HOYLE, B. J., AND BAKER, G. A. 884
1959. The analysis of field trials based on the concept of islands of variation. Agron. Abs. 1959: 82.

IYER, T. A. GOVINDA. 885
1957. Quicker methods in the analysis of variance. Madras Agr. Jour. 44(8): 326–336.

An alternate method of analysis of variance is illus. by 4 examples. It involves no use of "Sums of Squares" so is less time-consuming with no loss of efficiency. This method uses certain tables from Pearson's Biometrika Tables for Statisticians, 1954, which are given in an app.

KALTOFEN, H. 886
1958. Über die fehlerschätzung bei feldversuchen einfachster struktur. [The estimation of error in field trials with one replicate.] Ztschr. f. Acker- u. Pflanzenbau [Berlin] 105(2): 145–168. [Eng. sum.]

KELLEHER, THERESE, ROBINSON, H. F., AND COMSTOCK, R. E. 887
1958. Precision of estimates of variance components. Biometrics 14(1): 69–77.

Through study of 4th-degree parameters, estimates of variance of components of variance for grain yield in 5 populations of corn were concluded to be unaffected generally by nonnormality of parent distribs., to the level investigated. From analyses of variance of estimates of components of variance, it was concluded that variability of estimates can be calculated on the assumption of common variances in the parent distribs. if sampling is within yrs. When sampling is among yrs., some attention must be given to the comp. of the individual components which are being estimated.—Biol. Abs.

KRISTENSEN, R. K. 888
1934. Fejlberegning ved markforsøg. Erstatningstal. [Calculation of error in field experiments. Exchange values.] Tidsskr. for Planteavl [Copenhagen] 40(1): 161–168.

This article deals with further work on a new method to determine the mean error of expt. results which possess irregular, 1-sided deviations. This work is based on the fact that successful tests produce smoother curves than less successful ones. When a calculation of the expt. error is based on degree of smoothness of the curves, smoother curves give smaller mean error than irregular curves. When single values on the curve are compared with the mean, differences obtain, and the mean error is calculated according to the formula:

$$M^2=\frac{(d^2)}{n}\cdot 2/3$$

where d is the differences and n the no. of these. The "exchange value" is computed in the following way: If 30 kg. N in $(NH_4)_2SO_4$ gave the same response in yield as 24.1 kg. N in $NaNO_3$, the "exchange value" for $(NH_4)_2SO_4$ is obtained from the proportion

$$\frac{E}{100}=\frac{30}{24.1}\text{ or }E=124.$$

A discussion on use of rectangular plots versus the "checker board system" is also

included; differences obtained from use of the 2 methods are too small to be of practical importance.—Biol. Abs.

LEECH, F. B., AND HEALY, M. J. R. 889
1959. The analysis of experiments on growth rate. Biometrics 15(1): 98–106.

A method is presented for the analysis of expts. in which successive measurements of the same quantity are made on the same organism at equal intervals of time. The specification and estimation of treatment effects are discussed and demonstrated by a numerical example. When a treatment effect can be specified by a curve of degree p passing through the origin, curves of degree p are fitted to the observs. and 2 estimates are obtained of each coefficient of the curve specifying the treatment effect. These can be combined by a method giving minimum variance. Thus when the treatment effect is linear in time, straight lines are fitted to the data and 2 estimates of the linear coefficient specifying the treatment effect are combined with minimum variance to give an improved estimate. Covariance analysis on initial observs. is also discussed.—Biol. Abs.

MADOW, WILLIAM G. 890
1957. Some simple methods of computing parameters in the analysis of variance. Biometrics 13(4): 537–540.

Under general conds., the degrees of freedom of the quadratic forms occurring in the analysis of variance may be computed by taking expected values or by specified substitutions for the variables. Another substitution yields the parameters of Tang's distrib.

MATÉRN, BERTIL. 891
1957. A routine for computing the degrees of freedom in analysis of variance. Biometrics 13(4): 541–543.

The degrees of freedom can be automatically calculated along with the computation of sums of squares, as illus. by an analysis of variance of a factorial expt.

RAJABHOOSHANAM, D. S. 892
1935. Application of modern statistical methods to yield trials. Agr. and Livestock in India 5(2): 145–155.

This is a brief summarization of the statis. methods used in interpretation of the significance of small differences in yields.

ROJAS, B. A. 893
1958. The analyses of groups of similar experiments. Diss. Abs. 19(3): 415.

SALMON, S. C. 894
1938. Generalized standard errors for evaluating bunt experiments with wheat. Amer. Soc. Agron. Jour. 30(8): 647–663, illus.

Six expts. dealing with the resistance of several vars. of winter and spring wheat to many collections of bunt were examined with ref. to the validity of analysis of variance for measuring random variation. Grouping the data without ref. to bunt infection such as is usually done in analysis of variance could lead to serious errors in interpretation. A method of treating such expts. is suggested in which the data are 1st grouped according to % of bunt and standard errors are then calculated for each bunt class. The binomial formula for standard error modified by a constant derived from the expt. data may be used for estimating the standard errors for those classes in which the nos. are very small. Some of the limitations and precautions which should be observed in using these methods are pointed out.

SNEDECOR, GEORGE W. 895
1934. Biological variation vs. errors in measurement. Science 80(2072): 246–247.

In studies of expt. technique, analysis of variance may often be used to estimate the pts. of the expt. error attributable to (a) errors in the actual process of measuring the individual, and (b) variation among the individuals measured. Examples of 2 contrasting situations are given, together with suggestions as to the impr. of the techniques.

SNEDECOR, GEORGE W., AND COX, GERTRUDE M. 896
1935. Disproportionate subclass numbers in tables of multiple classification. Iowa Agr. Expt. Sta. Res. Bul. 180, pp. [235]–272.

A test conducted on actual and theoretical probs. involving disproportionate frequencies testing the actual accuracies of the following methods, expected subclass nos., fitting constants, weighted squares of means, and unweighted means, finds that in reality there is but very little difference in the results by the various methods. Each method is based on a postulate concerning a population. If it is reasonable to suppose that the sample was derived from a population described by 1 of these postulates, then the corresponding method of treatment can be used with greater confidence than otherwise. Usual tests of significance are applicable even when disproportionate frequencies are encountered.

Sváb, J. **897**

1957. Approximating analysis of variance without squaring, with especial regard to statistical analysis of field-trials in block-design. Növénytermelés [Budapest] 6(1): 77–90. [In Hungarian with Eng. sum.]

Sváb, J. **898**

1958. Combined analysis of variance of a series of experiments with partitioning the variation effects into single components; interpretation of interaction. Növénytermelés [Budapest] 7(2): 121–142. [In Hungarian with Eng. sum.]

Tedin, Olof, and Gösta, Julén. **899**

1953. Ett fall, där variansanalysen lämner felaktig uppfattning om den statistiska säkerhelten hos ett försöksresultat. [A case, where the analysis of variance gives an erroneous estimate of the statistical significance of an observed difference.] Sveriges Utsädesför. Tidskr. [Sweden] 63(5): 469–474.

The paper reports a case where a statis. treatment of a trial including different N dressings to timothy leys gives very different results if the old classical method directly based on differences is compared with an analysis of variance. Due to differences in variability and a different correlation between different treatments an erroneous concl. was obtained when the material was treated according to the analysis of variance. The reasons were analyzed and a warning was given that the method is not absolutely infallible.

Wilkinson, G. N. **900**

1958. Estimation of missing values for the analysis of incomplete data. Biometrics 14(2): 257–286.

Equations for missing values can be formed simply by equating each unknown (for a missing value) to its estimated expectation derived from the formally complete data in which the unknowns represent the missing values. The matrix of coefficients of the missing value equations has a simple structure; each coefficient corresponds to a pair of missing values (including identical pairs) and its value is determined by the relation between the pair of missing values in the expt. design. Thus, to facilitate the formation of the equations, a table of relations for the expt. design can be set up, with the corresponding values of coefficients. Note that the inverse of the matrix of coefficients is required in computing correct standard errors. The paper gives a derivation of the basic result, and provides tables of coefficients for some of the standard designs. Solution of the equations by matrix inversion, in particular, is discussed in some detail, and also the solution of singular equations. A concise table for determining missing values in randomized blocks is presented. The procedure of forming and solving equations will generally be simpler than the older method (Yates) of applying the formula for a single missing value iteratively.

Williams, E. J. **901**

1950. Statistical analysis of results for successive tests on the same organism. Nature [London] 166(4216): 319.

The auth. agrees with Leech that it is an error to regard successive tests on the same animal as independent. However, a former analysis by Williams had been misunderstood. In groups of cows treated over 4 periods, the comparison was not of main treatment effects, but interaction of treatment with periods; and with null hypothesis, mean squares for treatment-period interaction, and cow-period interaction would be similar whether or not observs. on the same animal are independent.

Williams, E. J. **902**

1953. A method of analysis for double classification. Austral. Jour. Appl. Sci. 4: 357–370.

Yates, F. **903**

1933. The analysis of replicated experiments when the field results are incomplete. Empire Jour. Expt. Agr. 1(2): [129]–142.

The procedure introduced by Allan and Wishart for supplying a missing value in a table of expt. results, such as the plot yields of a field trial, so that the treatment means form unbiased and efficient estimates of the treatment effects, is here extended to enable any no. of missing values to be replaced, it being shown that the method of derivation adopted previously is equivalent to the simpler method of minimizing the error term in the ordinary analysis of variance.—From auth. sum.

YATES, F. 904
1934. The analysis of multiple classifications with unequal numbers in the different classes. Amer. Statis. Assoc. Jour. 29(185): 51–66.

The methods of estimation and tests of significance of the main effects of a 2-way table differ according as to whether interactions are, or are not, assumed nonexistent. If the assumption is made, the method of fitting constants provides efficient estimates and efficient tests of significance. If it is not made, the subclass means provide efficient estimates, and the method of weighted squares of means provide efficient tests of significance. The method of fitting constants also provides efficient tests of the interactions. The method of weighted squares of means provides efficient tests of the interactions in the special case of a $2\times s$ table, giving a check on the constants. If the class nos. are proportionate only slight modifications are necessary in the methods of analysis appropriate to the case of equal class nos. In the case of a $2\times2\times2\times$ . . . table all estimates and all tests of significance may be made very simply whether interactions are assumed nonexistent or not. Tables with only slight inequalities in the class nos. may be analyzed by an approx. method based on the assumption that the variances of all the subclass means are equal.

YATES, F., AND COCHRAN, W. G. 905
1938. The analysis of groups of experiments. Jour. Agr. Sci. [England] 28: 556–580.

When a set of expts. involving the same or similar treatments is carried out at a no. of places, or in a no. of yrs., the results usually require comprehensive examination and sum. In general, each set of results must be considered on its merits, and it is not possible to lay down rules of procedure that will be applicable in all cases, but there are certain prelim. steps in the analysis which can be dealt with in general terms. These are discussed in the present paper and illus. by actual examples. It is pointed out that the ordinary analysis of variance procedure suitable for dealing with the results of a single expt. may require modification, owing to lack of equality in the errors of the different expts., and owing to nonhomogeneity of the components of the interaction of treatments with places and times.

See also **775, 777, 778, 781, 782, 786, 787.**

COVARIANCE ANALYSIS

BARTLETT, M. S. 906
1935. An examination of the value of covariance in dairy cow nutrition experiments. Jour. Agr. Sci. [England] 25: 238–244.

The results of a winter nutrition expt. on dairy cows were used as a uniformity trial in order to indicate the magnitude of the standard error we may expect if a continuous treatment expt. is designed with a prelim. control period. An initial period of 3 wks. is suggested, and some discussion given on the design and analysis of this type of expt.

BARTLETT, M. S. 907
1938. The approximate recovery of information from replicated field experiments with large blocks. Jour. Agr. Sci. [England] 28: 418–427.

The method suggested by Papadakis of using covariance with the yields of neighboring plots to reduce the error of replicated field expts. is illus. on 2 large-scale cotton expts. In a discussion on the validity and value of the method, it is concluded that for such expts., where the no. of plots per block is large, the method should be approx. valid and sometimes useful.

BOSE, S. S., AND GUPTA, S. C. S. 908
1935. A study in co-variance with fodder crops. 22nd Indian Sci. Cong. Proc. 1935: 347.

Pennisetum purpureum was grown under 6 manurial dressings in 6 randomized blocks at Dacca. The harvest was gathered in 3 installments in Dec. (1932), May, and Sept. (1934). The sampling errors calculated from the analysis of variance in the 3 cases were 6.0%, 4.8%, and 3.8% respectively. The 1st and 2nd cuttings showed a residual correlation +0.63 based on 25 degrees of freedom and this reduced the 2nd yr's. estimate of error from 6.20 lbs. per plot to 4.96 lbs. But 2nd and 3rd cuttings showed very small correlation and thus did not produce any appreciable impr. in the estimate of error.—Auth. abs.

BRADY, J. 909
1935. A biological application of the analysis of co-variance. Roy. Statis. Soc. Jour. Sup. 2: 99–106.

Using data from an expt. on lodging the auth. extends the appl. of covariance in

adjusting for concurrent measurements to adjusting for 2 independent variables. Formulae are presented for the calculation of separate *b* coefficients and for residual sums of squares without use of normal equations. These are simply a summation of the procedure in normal equations. The procedure is extended to an appl. under 2 criteria of classification using the treatment plus error procedure with each criterion of classification and also with the interaction. The treatment is split into components of between regressions and between means.

COCHRAN, WILLIAM G. **910**
1957. Analysis of covariance: Its nature and uses. Biometrics 13(3): 261–281.

The nature and principal uses of the analysis of covariance are discussed, and the standard methods and tests of significance presented.

COONS, IRMA. **911**
1957. The analysis of covariance as a missing plot technique. Biometrics 13(3): 387–405.

Covariance analysis provides a general technique for analyzing data from a statistically designed expt. when 1 or more observs. are missing. The technique may be applied to data from an expt. of any statis. design, and furnishes estimates of the missing observs. and exact tests of significance with relatively little computational effort. This paper describes the appl. of the technique when 1 or several observs. are missing. Specific examples given for fractional factorial and split-plot expts. illustrate the computational procedures involved.—Biol. Abs.

DAY, B., AND FISHER, R. A. **912**
1937. The comparison of variability in populations having unequal means. An example of the analysis of covariance with multiple dependent and independent variates. Ann. Eugenics [Cambridge] 7(4): [333]–348.

By means of analysis of covariance the regression of standard deviation on mean is obtained. It is found that for leaf length of *Plantago maritima*, a unit increase in the mean carries with it an av. increase of .0332 in the standard deviation. Hence, an allowance made by using the C.V. would be about 30 times too large. Complex correlations involving length, breadth, and thickness are then developed to see how the standard deviation (of length, say) is affected by the other mean values. It is found that the simple values, such as that obtained on the other side, may be quite wrong. In any event, the C.V. is not a suitable quantity. Sample: "variability in thickness is favored by a high av. thickness, somewhat favored by low av. length, and practically uninfluenced by av. breadth."

FEDERER, W. T. **913**
1959. Covariance analyses for unbalanced two-way classifications. N. Y. (Cornell) Agr. Expt. Sta. Mem. 360, 60 pp.

GARNER, F. H., GRANTHAM, J., AND SANDERS, H. G. **914**
1934. Covariance in analysing field experimental data. Jour. Agr. Sci. [England] 24: 250–259.

The auth. suggest that the covariance method is of considerable value in correcting for uncontrolled equalities arising early in the expt. and in analyzing the effects of developmental factors on yield. As an example, its appl. to the results of an expt. with beans is described.

LOVE, H. H. **915**
1936. Are uniformity trials useful? Amer. Soc. Agron. Jour. 28(3): 234–245.

The method of covariance analysis as used by Sanders and Fisher was appl. to some results of uniformity trials. Results of other investigators are discussed and the method of analysis given in detail. In some instances the standard error was reduced as a result of removing the effects of regression. Use of uniformity trials is of benefit in suggesting plot lay-out, and analysis of data from other uniformity trials is urged to shed further light on the prob. The refinements of methods suggested by Fisher, Bartlett, and Wishart are useful in such studies.—Biol. Abs.

MAHONEY, CHARLES H., AND BATEN, W. D. **916**
1939. The use of the analysis of covariance and its limitation in the adjustment of yields based on stand irregularities. Jour. Agr. Res. 58: 317–329.

PARKER, E. R. **917**
1942. Adjustment of yields in an experiment with orange trees. Amer. Soc. Hort. Sci. Proc. 41: 23–33.

Application of simple and multiple covariance to the yield data obtained in 3 periods of 4 yrs. each in an extensive fert. expt. with Wash. Navel oranges, laid out on a background of a 6-yr. uniformity trial, indicated that this technique has value for the control

of expt. error. The reduction of error was greater when covariance on prior yields was appl. than when the effects of "yield blocks" based upon the same prior data were eliminated by analysis of variance. However, the area of cross-sect. of the trunks and the vol. of the tree tops at the time the expt. was started had little value when used as independent variables. The use of covariance on yields of check plots and on prior yields resulted in important reductions in error. The yields of the last yr. of the uniformity trial had more effect than the yields of any other yr. in that period, and multiple covariance on the yields of 2 or more prior yrs. gave superior results to simple covariance on sums (or means) of the same prior yrs. The greatest reduction in expt. error, which was equivalent to increasing the no. of replications per treatment from 4 to 7.4, was obtained by multiple covariance on yields of the last yr. of the uniformity trial and the current yields of the check plots. It is concluded that rather perm. variations which are correlated with the yields during the uniformity trial, and variations of a more temporary nature, which are correlated with the yields of check plots, are responsible for an important part of the variability in the expt. yields of this orchard, and that their effects can be eliminated by appl. of the covariance technique.

PECHANEC, JOSEPH F. **918**

1941. Application of analysis of covariance to range research data. U. S. Forest Serv. Intermountain Forest and Range Expt. Sta. Tech. Note 1, 21 pp., illus.

SMITH, H. FAIRFIELD. **919**

1957. Interpretation of adjusted treatment means and regressions in analysis of covariance. Biometrics 13(3): 282–308.

This paper considers 2 of the more important probs. which arise in appls. of covariance analysis: the interpretation of adjusted means, and the comparison of treatment ("external") and error ("internal") regressions.—Biol. Abs.

VAIDYANATHAN, M. **920**

1934. The method of "covariance" applicable to the utilization of the previous crop records for judging the improved precision of experiments. Indian Jour. Agr. Sci. 4(2): 327–342.

The use of inform. based on yields of plots from prelim. uniformity trials in suggesting better plot layouts for permanent expts. is discussed. The method of analysis of results from uniformity trials to obtain increased precision of an expt. as used by Fisher, Sanders, and others, is given in detail. Tables are arranged to show the steps in the analysis and the method is appl. to data from tea yields. The impr. in precision is nearly 16 times what it would otherwise be by analyzing the expt. data alone.—Biol. Abs.

WILKINSON, G. N. **921**

1957. The analysis of covariance with incomplete data. Biometrics 13(3): 363–372.

If a set of data y, with corresponding concomitant data $x_1, x_2, \ldots, x_p$, is incomplete in relation to a given expt. design, both the data y and the concomitant data $x_1, x_2, \ldots, x_p$ should be completed with estimated missing values, each set of missing values being determined in the usual way. The $(p+1)$ sets of equations will have the same matrix of coefficients, so that inversion of this 1 matrix is sufficient to determine all sets of missing values. In the analysis of sums of squares and products for the completed data, the residual line is correct, but the treatments line needs adjustment for a correct test of significance. The necessary adjustment formulae are given. The variance of a treatment comparison (unadjusted) is determined in the usual way (adjustment being made for the missing values), and the additional variance for covariant adjustment of the comparison is given by the standard formula for complete data. Detailed numerical illus. is given.—Biol. Abs.

WISHART, JOHN. **922**

1950. Field trials II: The analysis of covariance. Commonwealth Bur. Plant Breeding and Genet. Tech. Commun. 15, 35 pp.

The objective of this paper is to consider the question of simultaneous consideration of 2 or more observational variables from some plot with a view to presenting methods to take account of soil fertility variations more completely than by mere elimination of block, row, or column differences, or to further elucidate the nature of the facts sought. Methods for determining the regressions, correlations, variances, and their interrelations are developed. These methods are illus. by examples. Significance tests for the different constants are presented.

ZELEN, MARVIN. **923**

1957. The analysis of covariance for incomplete block designs. Biometrics 13(3): 309–332.

The analysis of covariance for the general case of p concomitant variates is outlined

with special ref. to incomplete block designs. Both the intra- and inter-block analyses are considered. An appropriate analysis of covariance is also given when the adjustment for the treatment response depends on the differential block responses. Examples of appl. are included.—Biol. Abs.

See also **860, 877, 889, 930, 991, 999.**

SAMPLING DESIGN

RANDOM SAMPLING DESIGN

BARBACKI, S., AND FISHER, R. A. **924**

1936. A test of the supposed precision of systematic arrangements. Ann. Eugenics [Cambridge] 7: 189–193.

As in the results found by O. Tedin (Jour. Agr. Sci. [England] 21: 191–208), randomized arrangements give more precise results and smaller errors than systematic arrangements. Systematic arrangements consistently underestimate error and fail to furnish a valid test of significance.

BEALL, GEOFFREY. **925**

1940. The technique of randomization in field work. Canad. Ent. 72(3): 45–48.

A method of theoretically perfect randomization is outlined, illus. by tables and figs., for use in any expt. prob. necessitating randomization of samples or plots.

BOURDEAU, PHILIPPE F. **926**

1953. A test of random versus systematic ecological sampling. Ecology 34(3): 499–512.

Data from a full tally of an oak-hickory forest stand of the N. C. Piedmont were used to compare unrestricted and stratified random sampling with systematic sampling on the basis of their respective statis. variances. Over a range of sampling intensities from 2.8% to 33.3% of the total area it was found that random sampling, especially when stratified, is only slightly less accurate than systematic sampling, yet it permits a sound estimate of the error, which cannot be done with systematic sampling. Therefore it is suggested that random sampling should be used whenever reliable quantitative data are needed on stand comp.

COCHRAN, W. G. **927**

1946. Relative accuracy of systematic and stratified random samples for a certain class of populations. Ann. Math. Statis. 17(2): 164–177.

Comparison is made of random, stratified random (1 element per stratum) and systematic samples where serial correlation exists. Stratified random samples are at least as accurate as random samples. The comparison of systematic and random samples depends on the form of the population. No unbiased estimate of error can be made from a single systematic sample, nor from a stratified random sample with only 1 element per stratum.

CONAGIN, A. **928**

1950. Disposicao sistemática dos canteiros. Sua influéncia sôbre a estimativa do êrro experimental. [Systematic arrangement of trial plots. Effect on estimate of experimental error.] Bragantia [Brazil] 10(7): 203–207.

This paper describes the results of superimposing certain types of 5×5 Latin squares on a wheat uniformity trial. The purpose was to investigate the bias in the estimate of error when certain systematic squares (knight's move and diagonal) are chosen and to compare the results under conds. in Brazil with those obtained by Tedin in a similar invest. The following concl. are drawn: (a) when Latin squares are chosen by a random process, as recommended by Fisher, the observed distrib. of the variance ratio of "treatments" compared with error is in agreement with that given by theory; (b) the estimation of error variance is biased when systematic squares are employed. In agreement with Tedin, the auth. finds that the knight's move square furnishes an overestimate, and the diagonal square an underestimate of error variance. Under the conds. of this trial, the systematic squares suffer from the same disadvantages which have been noted elsewhere.—Auth. sum.

COUSENS, J. E. **929**

1958. A study of 155 acres of tropical rain forest by complete enumeration of all large trees. Malayan Forester 21(3): 155–164.

A complete enumeration of all trees over 4 ft. in girth at breast ht. in 155 acres of virgin forest is described. Floristically the area shows considerable variation, but there is little large-scale variation in structure. Symington's Coastal Hill Forest assoc. appears to be clearly defined. It is shown that systematic sampling at an intensity of 10% gives

a maximum error of 12.5%. Unrestricted random and stratified random samples at 20% intensity show somewhat higher maximum errors than systematic sampling. One-chain-wide strips are preferable to wider strips or compact blocks. Recommendations are made for sampling areas of normal compartment size for all spp. and include the adoption of random sampling and measures to insure an adequate no. of strips.—Biol. Abs.

DAWKINS, H. C. 930
1952. Experiments in low percentage enumerations of tropical high-forest. Empire Forestry Rev. 31(2): 131–145.

A series of low % enumerations in S. Mengo, Uganda, was analyzed statistically. It was found that precision, i.e., smallness of sampling errors, depended on density of the population and on the no. of samples available. The actual % of the sample was of little significance compared to its comminution and the density of the observed quantities within it. Sampling errors of less than 20% were obtained on populations of more than 2 stems per acre by a 1% dispersed-plot enumeration of 7.5 sq. miles of highly variable forest. While dispersed-plot enumerations gave more precise estimates, for equal areas sampled, than transect methods, the relative cheapness of the latter made them more efficient except in special cases. When dealing with areas of 5–15 sq. miles, 2-per-1/2-mile stratified random chainwide transects giving 5% coverage are advocated for estimating populations with densities from 1 to 10 stems per acre. For lower densities or smaller areas higher coverage may be necessary, while with increasing density or area, lower % would give tolerable errors. Superimposed dispersed-plot 20% samples of the transects were suitable for estimates of populations exceeding 10 per acre, if more than 1 sq. mile was originally covered. All mangt. relying on enumeration results should be based on the lower fiducial limit and not on the mean of the sample. This value is more easily understood as the Reliable Minimum Estimate, a term here suggested for general use in forest sampling.—From auth. sum.

FORTMANN, H. R. 931
1951. Observations on "selection" of data. Agron. Jour. 43(11): 560–561.

The mean squares for 3 types of samples (N=200) selected at random from a restricted population of 200 variants were determined. The av. mean sq. for samples consisting of means of duplicate determinations was some 21% lower (theoretical expectation=28% lower) than the av. mean sq. for samples consisting of the means of the 2 closest of 3 observs. The results illustrate that, on the av., "selection" of data from multiple determinations of unknown quantities leads to less accurate estimates than "unselected" data.

GREENBERG, B. G. 932
1951. Why randomize? Biometrics 7(4): 309–322.

A set of uniformity data on inocula of *Trichinella* larvae are examined critically for the purpose of comparing the merits of several randomized and systematic expt. designs. Many commonly used systematic designs introduced bias and inflated error estimates. Specific recoms. are made for special cases. Experimental factors which make this prob. important are listed and discussed.

HANSEN, MORRIS H., HURWITZ, WILLIAM N., AND MADOW, WILLIAM G. 933
1953. Sample survey methods and theory. 2 vols. New York: John Wiley and Sons, Inc.

HASEL, A. A. 934
1938. Sampling error in timber surveys. Jour. Agr. Res. 57(10): 713–736, illus.

The heterogeneous nature of variation in board ft. vol. in a 5,760-acre area of pine timber type in northeast. Calif. was shown by use of Fisher's method of analysis of variance. The analyses were based on a 100% inventory. The effects upon sampling error of size, shape, arrangement of plots, and intensity of sampling were determined theoretically and checked against actual results from samples taken according to the specifications set up. The smallest size of plot, 2.5 acres, was a more efficient sampling unit than plots of larger size, and long, narrow plots were more efficient than those approaching the sq. shape. A valid estimate of sampling error was possible only by selecting the sampling units independently and at random. By dividing the area into blocks of uniform size and shape, and selecting equal nos. and at least 2 random sampling units in each, a significant reduction in error variance was obtained as compared to unrestricted random selection. Cruises with plots arranged in a systematic pattern gave somewhat closer estimates of true vol. than did corresponding random cruises, but did not contain the inform. needed for assessing sampling error. A combination of random and systematic cruising was recommended.

JEFFREYS, HAROLD. **935**

1939. Random and systematic arrangements. Biometrika [London] 31(1/2): 1–8.

A distinction is drawn between randomness in the design of expts. and randomness in the sense of mutual irrelevance of the errors. The latter is what is needed for the validity of most statis. methods, and is not necessarily improved by the former. Examples are given from various subjs. The auth. agrees in general with Fisher's recom. to estimate and eliminate known effects as accurately as possible and randomize the rest.

KIRK, L. E. **936**

1929. Field plot technique with potatoes with special reference to the Latin square. Sci. Agr. [Ottawa] 19: 719–729.

Latin-sq. layout gave a 27% lower probable error than systematic arrangement. Increased replication is twice as efficient as larger sized plots.

MAHALANOBIS, P. C. **937**

1944. On large-scale sample surveys. Roy. Soc. [London], Phil. Trans., Ser. B 231(584): 329–451.

The discussion is concerned with sampling on a large scale where the sample units, located at random, are of a definite size (area). Both cost and precision of the result depend on the size (area) and density per unit area of the sample units. The prob. in the planning of large scale sample surveys is to choose the size and the density in such a way that, either: (a) the precision is a maximum for a fixed cost or (b) the cost is a minimum for an assigned precision. The solution is discussed on theoretical consideration for the case where randomization takes place at only 1 stage of sampling (unistage case) and for the case where randomization is carried out at several stages of sampling (multistage case). Application in the unistage case, to estimating acreage under jute in an area covering 60,000 sq. miles in Bengal, is described with numerical data. The margin of error of the sample estimate was about 2%; the cost was only 1/15 that of a complete census made in the same yr. by an official agency.

NEYMAN, JERZY. **938**

1934. On the two different aspects of the representative method: The method of stratified sampling and the method of purposive selection. Roy. Statis. Soc. Jour. 97(4): 558–625, illus.

In planning an invest. of a population by sampling, the samples may be chosen in 2 different ways: (1) at random either from the population as a whole or from each of several strata into which it is divided (stratified sampling). It is often convenient to choose for each sample a group of individuals, e.g., a census district. (2) Groups are chosen so that the weighted mean of some control character, y, known for the whole population and assumed to be linearly correlated with the character x to be investigated, has the same value as in the total population (purposive selection). Bowley's estimate of the mean of x is inconsistent. (In the discussion Bowley pointed out that Neyman had misunderstood his method, which is really consistent). The method of Gini and Galvani is consistent if the regression of x on y is linear not only for the whole population but for each group of districts composed of a fixed no. of individuals. The applicability of this hypothesis can only be tested by an extensive inquiry. On the other hand the method of stratified sampling does not depend on any hypothesis about the stratified population and is therefore preferable except in special cases. If groups are used as elements of sampling they should be as small as possible.—Biol. Abs.

NUMATA, MAKOTA. **939**

1949. The basis of sampling in the statistics of plant communities—studies on the structure of plant communities III. Bot. Mag. [Tokyo] 62(727/738): 35–38. [In Jap. with Eng. sum.]

Sampling methods for studying the statis. of plant communities have hitherto been made by purposive selection of some standard areas or random sampling by the theory of large samples. A 3rd method is suggested, i.e., random sampling by the theory of small samples. By this method it is possible to calculate the homogeneity of a plant community and then decide upon the no. of sampling quadrats to estimate its analytical nature.

PECHANEC, JOSEPH F. **940**

1941. Sampling error in range surveys of sagebrush-grass vegetation. Jour. Forestry 39(1): 52–54.

One major objective of a range survey is to determine the forage cover as a basis on which to estimate grazing capacity. However, it is extremely unlikely that the estimated forage yield of an area will coincide with the actual yield, even if methods of measuring vegetation are without error, and if individual members of survey crews

are mechanical in their precision. If sampling units are drawn correctly, however, an estimate of the magnitude of the difference between the estimated and actual yield and the likelihood of the occurrence of such difference is provided by the unbiased estimate of sampling error. An unbiased or representative estimate of sampling error also provides appropriate inform. for estimating the no. of sampling units (plots) needed to attain arbitrary limits of accuracy in future surveys on similar range areas. —Auth. sum.

PECHANEC, JOSEPH F., AND STEWART, GEORGE. 941
1941. Sagebrush-grass range sampling studies: Variability of native vegetation and sampling error. Amer. Soc. Agron. Jour. 33(12): 1057–1071, illus.

Variability of native sagebrush-grass range vegetation was studied at the U. S. Sheep Expt. Sta. near Dubois, Idaho. The sagebrush-grass type is a heterogeneous plant community, composed of spp. that are highly variable in abundance, and whose frequency distribs. are strongly skewed to the left. Subdivided random sampling, using line-plot sampling units, is as easily used as systematic sampling and increased the inform. secured by 1.31, 0.61 and 1.08 units, respectively, for the 3 major plant spp. over the inform. that might have been secured with strictly random sampling. To provide data reliable enough for studies of plant succession, indicator spp. or poisonous plants, sampling intensity should be determined with full cognizance of the higher variability of secondary spp. No acceptable standard of accuracy can be set for sampling but certain intensive vegetation studies may require sampling sufficiently intense to provide a sampling error of 5% for the major spp. and class totals and 10% for secondary spp.

SAMPFORD, M. R. 942
1962. An introduction to sampling theory with applications to agriculture. 315 pp. Edinburgh and London: Oliver and Boyd.

This book is aimed mainly at those, such as agr. officers, who need to use sampling techniques and wish to know something of the underlying theory, without lengthy math. arguments. A few of the more important results are proved in the App., but generally the auth. relies on illus., as opposed to proof. A wide range of techniques is covered, including random, systematic, cluster and multistage sampling. The use of ratio and regression methods is also discussed. There is a useful glossary and a very necessary list of symbols employed in the text—the wide range of symbols which is required in any reasonably comprehensive book on sampling always makes reading difficult for the nonstatistician. The title of the book is, perhaps, misleading for the emphasis is on the principles and appls. rather than theory. Also, it is doubtful whether the audience for which it is written would regard it as an introduct. The reader who knows little or no statis. might find the many formulas somewhat bewildering, in spite of the ch. on basic statis. concepts. There is, however, a great deal of useful inform. in this book, and in particular there is an excellent ch. devoted to the random siting of sample plots and quadrats, which sets out very clearly the disadvantages of nonrandom methods for siting field samples (such as throwing sticks) which are often adopted because random sampling is said to be inconvenient. This ch. is of real interest to all those concerned with sampling field expts.—Herb. Abs.

SHIUE, CHERNG-JIANN, AND JOHN, HUGO H. 943
1962. A proposed sampling design for extensive forest inventory: Double systematic sampling for regression with multiple random starts. Jour. Forestry 60(9): 607–610, illus.

A sampling design is proposed which involves double sampling for regressions with modified systematic sampling and integrates several sampling methods, regression analysis, and advanced techniques of aerial-photo interpretation. This design permits valid error estimation, increases efficiency, and permits flexibility in sampling intensity.

SMITH, H. FAIRFIELD, AND MYERS, C. H. 944
1934. A biometrical analysis of yield trials with timothy varieties using rod rows. Amer. Soc. Agron. Jour. 26(2): 117–128.

In comparative tests of vars. of timothy by use of broadcast plots and by rod rows, the yields agreed to the extent expected in regard to the expt. errors. The disadvantage of systematic as compared to randomized arrangement is well illustrated. Methods of adjusting varietal yields are discussed. The use of a theoretical or graded check in this case is deemed appropriate. An appl. is made of Fisher's analysis of variance to yields adjusted by relation to the checks. The relation of pts. in the analysis of variance to some of the older statis. used in estimating error is indicated.

TEDIN, O. 945

1931. The influence of systematic plot arrangements upon the estimate of error in field experiments. Jour. Agr. Sci. [England] 21: 191–208.

Effect of systematic plot distrib. upon the estimate of error of a 5×5 field expt. was studied on 91 blocks taken from different uniformity trials. Two different knight's moves, 2 diagonal, and 7 random arrangements were studied. Knight's move arrangements cause an overestimation of error. Diagonal arrangements cause an underestimation of error. In 1 individual expt. it may be desirable to use a systematic arrangement but where expts. are to be repeated frequently the experimenter will find it desirable to choose random arrangements. Ratio of error to total error in uniformity trials: knight's moves—22.77 and 22.83; diagonals—26.24 and 27.94; random—25.25, 20.91, 23.93, 27.45, 25.25, 22.94, 23.16 and 25.69. Author believes that choice of a method of arrangement should consider accuracy of methods, increase in labor, and other factors, as well as the small increased accuracy due to elaborate expt. arrangements and intensive analysis should be considered.

VAN DYNE, GEORGE M. 946

1960. A method for random location of sample units in range investigations. Jour. Range Mangt. 13(3): 152–153, illus.

A system has been devised which allows for random location of study units and provides for rapid relocation of perm. plots, perm. line transects, and permanently tagged individual plants for range studies with only 1 marker post. This technique eliminates the need for gridding an area for accurately locating study units. A system of concentric circles with varying radii and subdivisions by 36° increments allows for delineation of 100 equal units around a single marker post. A general formula for determining the "doughnut shaped" sampling area and the radii of individual concentric circles is as follows:

$$A_t = \pi(r_m^2 - r_o^2)$$

$$r_t = \sqrt{\frac{r_m^2 - r_o^2}{10} + r_{t-1}^2}$$

Where: A_t = area of entire sampling unit
r_m = maximum radius of sampling area
r_o = minimum radius of sampling area
r_t = radius of one of the 10 subdivisions
r_{t-1} = radius of the next smaller subdivision.

YATES, F. 947

1935. Some examples of biased sampling. Ann. Eugenics [Cambridge] 6(2): [202]–213, illus.

The 3 examples described in this paper all agree in showing that when any element of personal selection is exercised by the sampler the results are biased; in all 3 cases a well-designed method of random sampling would have given considerably more accurate results for the same amount of work. The combined evidence of the examples definitely disposes of the claim advanced by some samplers in the case of physical measurements of variable material that they are capable of taking a more representative sample if they are permitted freedom of choice. In studies connected with mankind the problem of sampling is usually rather different. We do not have to determine the mean ht. of a group of men by measuring the ht. of a few picked out from an assembled group. But we do have to make determinations of all kinds on personal characteristics, status, sociol. environment, and genealogy by sampling methods, and here again most serious bias may be introduced by improper selection of the material. In a house-to-house survey, e.g., the temptation to avoid houses which are externally nontypical of the district being surveyed is strong; many other motives of a less worthy nature may also operate, such as the difficulty of collecting the required inform. from certain types of householders, or the mere fact that there is no one there to supply the inform. Perhaps, however, the most glaring examples of bias in human sampling are provided by postal enquiries or questionnaires. Since only those who are interested in the prob. under consideration are likely to trouble to reply, it is clear that such enquiries will be entirely unrepresentative unless very special efforts are made to ensure a complete set of answers. In view of the evidence, therefore, it appears that the only satisfactory method of avoiding bias is for the sampling to be random, whether it be from a wheat field or from a human population. By suitably chosen restrictions and the use of appropriate (possibly complex) sampling units, we can get over the disadvantages on the score of accuracy suffered by purely random samples. In addition, with random sampling we can make the sampling itself provide a really valid estimate of the sampling error with negligible extra labor.

YATES, F. 948

1939. The comparative advantages of systematic and randomized arrangements in the design of agricultural and biological experiments. Biometrika [London] 30(3/4): [440]–466, illus.

The claims advanced in favor of systematic arrangements by Gosset ("Student") and others are examined. The concl. is reached that in cases where Latin sq. designs can be used, and in many cases where randomized blocks have to be employed, the gain in accuracy with systematic arrangements is not likely to be sufficiently great to outweigh the disadvantages to which systematic designs are subj. In particular the available evidence, though not conclusive, indicates that the half-drill strip arrangement, which Gosset particularly favored, is likely to be somewhat less accurate than suitable random arrangements occupying the same plots. On the other hand, systematic arrangements may in certain cases give decidedly greater accuracy than randomized blocks, but in such cases the use of the modern devices of confounding, quasi-factorial designs, or split-plot Latin squares is likely to give a similar gain in accuracy, and is much more satisfactory statistically. As an example the uniformity trial chosen by Barbacki and Fisher to demonstrate the defects of the half-drill strip arrangement is reexamined. Gosset's criticisms of Barbacki and Fisher's work, though at 1st sight convincing, are not as conclusive as he supposed, and this particular trial provides a striking example of just those defects which have always been attributed to the half-drill strip methods by its critics.

YATES, FRANK. 949

1949. Sampling methods for censuses and surveys. 318 pp., illus. New York: Charles Griffin.

In writing a manual to assist in the projected 1950 World Census of Agr. and 1950 World Census of Population, the auth. attempts to cover all the modern developments of sampling theory important in census and survey work. In the orderly devlpmt. of the manual from a discussion of the place of sampling in census work, through requirements and structure of samples, probs. in planning, execution, and analysis of a survey, and estimation of the population values and sampling error, to efficiency, a no. of gaps in current theory had to be filled in. A bibliog. of 373 items classified under 10 headings is included.

See also **366, 952, 955, 965–967, 969, 970, 972, 976, 977, 979, 1065, 1105.**

MULTISTAGE AND DOUBLE SAMPLING

BOSE, C., AND GAYEN, A. K. 950

1946. Note on the expected discrepancy in the estimation (by double sampling) of a variate in terms of a consistent variate when there exists a non-linear regression between the two variates. Sankhyā: Indian Jour. Statis. 8(1): 73–74.

Results obtained by Mrs. C. Bose in a previous paper for double sample where there is a linear relation between a variate y, difficult or expensive to measure, and a correlated variate x, easier or less expensive to measure, are extended to the case where there is a correlation between y and x of the nonlinear type $y=ax^b$.

ECIMOVIC, J. P. 951

1956. Three-stage sampling with varying probabilities of selection. Indian Soc. Agr. Statis. Jour. 8(1/2): 14–44.

KANEKO, Y., AND KOJIMA, K. 952

1957. On the method to estimate the number of seedlings in the nursery. Jap. Forestry Soc. Jour. 39(7): 260–266. [In Jap. with Eng. sum.]

In the estimation of the no. of the seedlings in the nurserybed of 1-yr. seedlings of *Chamaecyparis obtusa*, the degree of accuracy among 4 methods appl. lined up as: Stratified 2-stage sampling (the primary sampling unit was the stratum), stratified 1-stage sampling, random sampling, and cluster sampling. Even with stratified 2-stage sampling, if the primary sampling unit was the cluster, the accuracy of estimation was inferior to the 1 with stratified 1-stage sampling. Number of sampling units for obtaining given degrees of accuracy was shown. The comparison between random sampling and purposive selection is also shown.

PETERSEN, R. G., AND CHAMBLEE, D. S. 953

1955. Optimum size of sample for hand separation of forage crop mixtures into their component species in small plot experiments. Agron. Jour. 47(1): 20–23.

The bot. comp. of 2 expts. uniformly seeded to a mixture of legumes and grasses was

estimated by hand separating subsamples of the fresh forage from the yield-strip sample (2×23 ft.). The optimum size of sample, $s_{opt.}$, was estimated using the following formula:

$$s_{opt.} = \sqrt{\frac{C_r \sigma_s^2}{C_s \sigma_r^2}}$$

in which C_r is the cost assoc. with each plot, C_s is the cost assoc. with each hand separated sample, σ_s^2 is the sample to sample variation, and σ_r^2 is the variation between plots treated alike. With the plot size used in this study, the most efficient size of subsample for estimating bot. comp. by hand separating was found to be approximately 10%.

RAO, J. N. K., AND CHAWLA, H. K. **954**
1956. Efficiency of stratification in subsampling designs for the ratio method of estimation with varying probabilities of selection. Indian Soc. Agr. Statis. Jour. 8(1/2): 91–101.

SCHUMACHER, F. X., AND CHAPMAN, ROY A. **955**
1942. Sampling methods in forestry and range management. Duke Univ. Forestry Bul. 7, 213 pp., illus.

Problems in sampling of forest and field populations, leading to estimates of averages and aggregates, are discussed in case studies. Emphasis is upon striving for maximum inform. so the unknown discrepancy between a population characteristic which is the subj. of inquiry and the sampling estimate thereof may be (1) evaluated unambiguously, and (2) made as small as possible, subj. to the ever-present limitations of time and funds available for the work. The theory and practice of representative sampling, subsampling, and double sampling are treated in some detail.

SUKHATME, P. V. **956**
1950. Efficiency of sub-sampling designs in yield surveys. Indian Soc. Agr. Statis. Jour. 2(2): 212–228.

A general formula appropriate for the estimation of gains in precision due to stratification in a subsampling design from finite population has been developed and illus. on the yield data relating to sample surveys carried out in Delhi Province during 1946–47, 1947–48, and 1948–49. Formulae appropriate for (a) no subsampling and (b) subsampling with a uniform sampling fraction at the 1st stage are shown to be particular cases of the general formula. Based on the same results, an approach has been indicated for calculating the relative efficiency of sampling units of different size and of 1- versus 2-stage sampling and the method illus. on the yield data for Delhi Province.—Auth. sum.

TIWARI, D. K., JACKOBS, J. A., AND CARMER, S. G. **957**
1963. Statistical technique for correcting botanical or floristic estimates in pasture research. Agron. Jour. 55(3): 226–228.

The bias assoc. with visual estimates can be removed if the true values for a few of the samples estimated can be determined. Equations for calculating the regression of the estimates on the actual values are given.

WILM, H. G., COSTELLO, DAVID F., AND KLIPPLE, G. E. **958**
1944. Estimating forage yield by the double-sampling method. Amer. Soc. Agron. Jour. 36(3): 194–203.

Two double-sampling methods, using line-transects and forage wt. estimates for the large samples and actual wts. of clipped forage for the small samples, were tested to ascertain their relative efficiency in estimating the amount of forage present on expt. areas in Colo. Double sampling with the line-transect method provided about 28% more inform. than could have been obtained by clipping only, during the same period of field time. About 11% more inform. was obtained when time expended in both field and office was considered. When wt. estimates were used in double sampling, 37% more inform. was obtained than would have been provided by straight clipping during an equivalent amount of field time. Considering both field work and office compilation the gain in inform. dropped to about 14%. With the intensive sampling used in this study both methods provided substantial savings in field time and some economy in total time expended. The study indicated, however, that clipping of all plots might be as efficient as any short-cut method in large-scale extensive surveys where time consumed in field travel is a major factor.—From auth. sum.

See also **219, 227, 933, 942, 943, 949.**

BATEN, WILLIAM D., AND AREND, JOHN L. 959
1954. A laboratory study of various systematic sampling methods applicable to forest-regeneration surveys. Mich. Acad. Sci., Arts and Letters, Papers (1953) 39: 113–123, illus.

The paper reports on the reliability of estimates obtained from applying 25 systematic sampling methods that might be used in forest-reproduction surveys to 1 artificially created seed pattern of known distrib. Since it is almost impossible to count and map all tree seedlings on a forest tract in order to have a known quantity and distrib. as a basis for appraising the reliability of different methods and intensities of sampling, an artificial distrib. was created in the lab. for study. The tests revealed that when only 1% of the area is sampled, only 1/2 of the estimates of the total no. may be within 50% of the actual no. Estimates of the no. of seedlings should be based on sampling more than 4% of the area, for with a smaller sample no particular sampling design or sample-plot arrangement can be expected to provide reliable estimates of quantity. Fairly dependable estimates of the % of plots stocked with 1 or more seedlings appear to be possible when as little as 2% of the area is sampled. Offsetting a continuous series of 5 or 10 plots diagonally across the sample population may be a sampling method to consider in forest reproduction surveys.—Biol. Abs.

CAIN, STANLEY A., FRIESNER, RAY C., AND PATZGER, JOHN E. 960
1930. A comparison of strip and quadrat analyses of the woody plants on a central Indiana river bluff. Butler Univ. Bot. Studies 1: 157–171.

A floristic study. Quadrats gave more spp. and a frequency spectrum.

CRAIG, A. T. 961
1939. On the mathematics of the representative method of sampling. Ann. Math. Statis. 10: 26–34.

FISSER, H. G., AND VAN DYNE, GEORGE M. 962
1960. A mechanical device for repeatable range measurements. Jour. Range Mangt. 13(1): 40–42, illus.

A device is described which will mechanically locate short line-intercept transects, permitting accurate reading and rereading of transects with a minimum of human decision in line placement. The device consists of a horizontal 1-in. aluminum rod about 6 ft. long, in which a 5-ft. length of calibrated steel tape is embedded. The rod is adjustable for ht. and supported at each end by a tripod. A movable sleeve slides along the rod and carries an extension arm with a pointer which marks out the transect line at ground level. Steel stakes are driven through holes in the tripod legs to mark the position of the device for future measurements.

HAIG, I. T. 963
1929. Accuracy of quadrat sampling in studying forest reproduction on cut-over areas. Ecology 10(4): 374–381, illus.

The purpose of this paper has been to discuss the accuracy of quadrat sampling as appl. to reproduction studies in the west. white pine type, and to discuss methods by which this accuracy can be measured. In general, the methods used in this study consisted in counting reproduction on milacre (6.6 ft. sq.) quadrats distributed at 1/2- or 1-chain (33 and 66 ft.) intervals along parallel strips 2.5 to 10 chains apart. This quadrat-at-interval system, giving a sample of from .1% to .8% of total area, was found to give satisfactory values for both frequency index (% of area stocked) and av. no. of seedlings per acre. In checking the values for av. no. of seedlings per acre, a method is suggested by which the J-shaped frequency distribs., probably common in similar ecol. and silvical studies, can be converted into more nearly normal distribs. and so strengthened as to permit the appl. of the probable error concept with a reasonable degree of safety. Indications are given that in sampling by the quadrat-at-interval method it is essential to have the parallel strips well distributed over the area, and that when only a limited sample can be taken the tendency should be to lengthen the interval between quadrats rather than the distance between strips.—Auth. sum.

HASEL, A. A. 964
1942. Sampling error of cruises in the California pine region. Jour. Forestry 40(3): 211–217, illus.

The timber on 31 20-acre blocks was inventoried in small units. Stands containing heavy vols. generally require less sampling than lighter stands for the same degree of accuracy. Curves of variance provide a basis for estimates of sampling accuracy in systematic cruises. The size of the area to which cruise estimates apply has a marked effect upon sampling error.

HUMMEL, S. C. 965
1952. An experiment on the sampling of early thinning. Forestry [London] 25(1): 19–31.

Several subjective and objective methods of sampling the av. vol. per tree in the 1st and 2nd thinnings were tested in stands of Sitka spruce, Norway spruce, Scotch pine, Corsican pine, Douglas-fir, and European larch. Altogether 7,000 trees were measured. The subjective methods, consisting of visual estimates and a measurement of representative groups of trees, tended to give biased results. The objective methods tested were random groups, systematic sampling by trees, and systematic sampling by rows. Systematic sampling by rows appeared to be the most satisfactory since it combined a reasonable degree of precision with simplicity in execution.

HUTCHINSON, A. H., AND KNAPP, F. M. 966
1947. Random sampling, planned sampling, and selective sampling as applied to forest ecology and silviculture. Roy. Soc. Canada, Proc. and Trans., (3rd Ser.) Sect. 5 (1946) 40: 77–79.

An ecol. survey of the Univ. of Brit. Columbia Forest Reserve is in progress, under the Brit. Columbia Industrial and Sci. Res. Council. Selection of sample plots on a basis of ecol. contours has been adopted. Lines paralleling and running at right angles to contours are chosen. Contours may be the margin of the forest bordering a logged area, the topog. slope, or the light, humidity, or temp. contours. In this way the factors of distrib. of seedlings may be evaluated.—Auth. abs.

JOHNSON, FLOYD ALFRED. 967
1943. A statistical study of sampling methods for tree nursery inventories. Jour. Forestry 41(9): 674–679.

Tree counts were made on systematic, random, and stratified-random sampling units in drill-sown, broadcast, and transplant nursery beds. Samples consisted of 1-, 2-, and 3-ft. lengths of single rows, and of 1/2-, 1-, 1-1/2-, 2-, and 3-ft. bed lengths across beds 52 in. wide. Completely random samples were less accurate than stratified-random samples. Where no estimate of sampling error was required, systematic sampling was superior to stratified-random sampling of seedbeds; in transplant beds the 2 methods were equally accurate. The relation of sampling efficiency to size of sampling unit varied with spp. and class of stock, but the smaller units were usually best. The statis. relation between intensity and accuracy of sampling in forest nurseries is discussed.—Biol. Abs.

JONES, A. E. 968
1948. Systematic sampling of continuous parameter populations. Biometrika [London] 34(3/4): 283–290; and Kendall, M. G. Continuation of Dr. Jones's paper. Biometrika [London] 35(3/4): 291–296.

The prob. of estimating the mean value of a random variable along a continuous strip of finite length is considered for the case in which the autocorrelations decay exponentially. It is shown that, if the serial correlation is appreciable or if the sample is large, the best systematic arrangement is a measurement at the centers of equally spaced intervals. The 2nd paper points out that this result is valid only in the case considered and that for other autocorrelation schemes, this arrangement might be very bad. In the case of sinusoidal autocorrelation, it is actually the worst possible.

NEYMAN, J., AND PEARSON, E. S. 969
1938. Note on some points in "Student's" paper on "Comparison between balanced and random arrangements of field plots." Biometrika [London] 29(3/4): [380]–388, illus.

This paper gives some fuller explanation of certain points in "Student's" paper which, it was known, he had intended to revise.

OSBORNE, JAMES G. 970
1942. Sampling errors of systematic and random surveys of cover-type areas. Amer. Statis. Assoc. Jour. 37(218): 256–264, illus.

To estimate the comp. of an area by cover-type classes, sampling is usually systematic, the national forest-survey procedure being 1 line in 10 miles of width. By superimposing on a map 20 lines per mile, randomly placed, 3 types of sampling were tried: completely random, stratified random, and a systematic type consisting of lines 1 mile apart. The estimates of the mean area in cultivated land were practically the same in the 3 types of sampling, but the stratified random surveys were only 1/2 to 1/4 as efficient as systematic surveys of the same intensity. The nature of the variation found in populations in place is such that the variate measured may be considered as a continuous function of position and the prob. of sampling reduces, sensibly, to 1 of curve fitting. A polynomial of 6th degree was fitted to the variate, no. of chains of

cultivated land, and formulas developed for estimating the error of predicting the mean of another survey. If data taken in the systematic manner investigated are used with random sampling formulas, biased estimates of the sampling errors result; but from estimates of the correlation of measured and unmeasured lines dependable estimates of the sampling errors of this kind of systematic samples are obtained.—Biol. Abs.

PEARSON, E. S. 971
1937. Some aspects of the problem of randomization. Biometrika [London] 29(1/2): 53–64.

PEARSON, E. S. 972
1938. Some aspects of the problem of randomization. II. An illustration of "Student's" inquiry into the effect of "balancing" in agricultural experiments. Biometrika [London] 30(1/2): 159–179, illus.

This paper discusses in some detail 1 aspect of the problem dealt with in "Student's" (W. S. Gosset's) last paper. The point in question was that in agr. expts. "balanced" arrangements would have the following advantage over "random" arrangements: While being less likely to detect the presence of small differences, they would seem to be somewhat more likely to detect the larger and therefore more important differences. The auth. of the paper expresses the position in algebraic form, relating it to certain theoretical work of Neyman and Pearson concerning the "power" of the test of a statis. hypothesis. He also makes further use of A. W. Hudson's uniformity trial data, quoted by "Student."

RAO, J. N. K. 973
1958. Partially systematic line-plot surveys. Indian Forester 84(7): 424–427.

REPPERT, JACK N., REED, MERTON J., AND ZUSMAN, PINHAS. 974
1962. An allocation plan for range unit sampling. Jour. Range Mangt. 15(4): 190–193, illus.

In grazing mangt. studies at the San Joaquin Expt. Range in Calif., the total no. of range sampling units that could be afforded were allocated in the most efficient manner to serve study objectives and travel conds. A formula is described which determined the allocation within limits of cost and study objectives. It is based on site proportions, variability in herbage prod., and av. site prod. capability. A method of "once over" field placement of sampling units is described as well as appropriate analysis procedures. —Biol. Abs.

RIPLEY, THOMAS H., JOHNSON, FRANK M., AND THOMAS, WILLIAM P. 975
1960. A useful device for sampling understory woody vegetation. Jour. Range Mangt. 13(5): 262–263, illus.

A 4-1/2-ft. rod equipped with a ring bubble level and a retractable spike serves in establishing vertical ref. lines for sampling understory vegetation in the browsing zone. When used with permanently located line transects, this piece of equip. relocates sampling planes essentially without error.

SALMON, S. C. 976
1953. Random versus systematic arrangement of field plots. Agron. Jour. 45(10): 459–462.

A critical rev. of and a reinterpretation of the literature plus additional data by the auth. leads to concl. that random arrangements of field plots often result in substantial increases in the real error and in such cases cannot be justified. Such arrangements may be desirable for theoretical statis. studies using data from field expts. and in certain practical expts. to protect the investigator against charges of or suspicion of bias. In many expts., mostly seeded or harvested by hand, plots may be arranged randomly or systematically according to the taste or preference of the experimenter if randomization does not introduce important sources of error.

SALMON, S. C. 977
1955. Random versus systematic arrangements in non-Latin square field experiments. Agron. Jour. 47(7): 289–294.

"Random" and "good" systematic arrangements were compared with respect to "treatment" and error variances for 113 separate and distinct hypothetical expts. superimposed on uniformity data for 27 different locations and 14 different crops in the U.S.A. and Canada. The study involved 7,155 plot yields and 5,238 individual plots of land. "Treatment" variances for the systematic arrangements averaged 80% of those from random arrangements; about 1/4 more replications would be required with random arrangements to assure the same degree of accuracy of mean yields as would be expected from "good" systematic arrangements.

STRICKLER, GERALD S. 978
1961. A grid method for obtaining loop readings on small plots. Jour. Range Mangt. 14(5): 261–263, illus.

The apparatus described provides for exact duplication of sampling sites. A rigid T-frame, supported on the ground, is moved at regular intervals along a measuring tape and loop positions are located from notches in the cross-member. In trials on 8 grass plots an av. of 93.2% duplication was obtained. The apparatus is suitable for use in sparse cover of low shrubs and in grassland.

"STUDENT." [GOSSET, W. S.] 979
1938. Comparison between balanced and random arrangements of field plots. Biometrika 29(3/4): [363]–379.

This paper is concerned with the statis. basis underlying the interpretation of results obtained in agr. experimentation. In "Student's" view, the advantages of randomly assigning to plots the treatments or varieties under consideration are usually offset by an increased error, as compared with a balanced assignment. In this view he had been vigorously opposed by R. A. Fisher, and the 1st object of the paper is to set out as clearly as possible in what this difference consists. After clearing away certain misrepresentations concerning the half-drill strip method of comparing 2 vars., "Student" illustrates some of his points on a new type of balanced lay-out which he describes as a chess-board with fringes. Finally he shows how, when real treatment or variety differences exist, the balanced lay-out, while it will not detect small differences, is somewhat more likely to detect large differences than a random lay-out. He considers that in this sense the former procedure is more, not less valid than the latter. These ideas are illus. on some statis. analyses carried out by Mr. A. W. Hudson on uniformity trial data, details of which are given in an App.—Biol. Abs.

See also **366, 372, 924, 926, 927, 929, 932–936, 941–945, 948, 949, 952, 955, 1114.**

DESIGN OF EXPERIMENTS

GENERAL

BAILEY, G. L., BROSTER, W. H., AND BURT, A. W. A. 980
1958. Experiments on the nutrition of the dairy heifer. II. Experimental methods in short-term experiments. Jour. Agr. Sci. [England] 50(1): [1]–7.

Data from 24 short-term trials on the nutrition of dairy heifers have been used in a study of the effects of mangt., method of estimation of live-wt. gain, length of expt. period, covariance analysis and the use of monozygous twins upon expt. error. The value of rigid adherence to a routine and allowing ample time for the animals to settle down before the trial have been demonstrated. Error standard deviations were assoc. with length of expt. period, those for 42-day periods being about half those per 21-day periods, but were not appreciably correlated with initial live wt. No advantage could be demonstrated for the use of monozygous twins, or covariance analysis with initial wt. or rate of gain, indicating that genetic effects contributed little to the error in expts. lasting 3–6 wks. There was no significant difference between errors in live-wt. gains calculated from the regression of live wt. on time, from single initial and final wts., or from 2 initial and final live wts., indicating that deviations from linear regression are not solely in the nature of random day to day fluctuations in live wts.—Auth. sum.

BAKER, G. A., AND ROESSLER, E. B. 981
1957. Implications of a uniformity trial with small plots of wheat. Hilgardia 27(5): 183–188.

A field trial with small plots of wheat, which can be regarded as a uniformity trial, is presented. This trial was examined in a manner similar to that used on other field trials, with very contrasting results. Results of randomization trials in other studies have differed markedly from the conventional published analysis-of-variance tests based on the *F* tables. However, this trial, although judged by experienced investigators because of weed infestation, soil variation, and stand variation, seems to correspond very closely in many important respects to the model and to resulting tests given in the textbooks.—Biol. Abs.

BEHRENS, W. H. 982
1956. Feldversuchsanordnungen mit verbessertem ausgleich der bodenunterschiede. [The arrangement of field experiments with improved compensation for soil variations.] Ztschr. f. Landw. Vers.- u. Untersuchw. [Berlin] 2(3): 176–193, illus.

Belz, Maurice H. 983
1957. Common errors in obtaining and evaluating experimental data. Phys. in Med. and Biol. [London] 2(1): 3–16.

The paper rev. the contrib. which statis. and statisticians can make to the design of expts. and the analysis of expt. results in biol. and medicine. An acct. is given of the principles of factorial expts., in which, with maximum economy of experimentation, inform. may be obtained on the main effects of a no. of individual factors as well as their interactions in an expt. system. The planning of expts. from the point of view of the no. of observations necessary to obtain the required inform. is discussed, particular ref. being made to the advantages and disadvantages of the sequential method of planning. Common errors and misunderstandings in the study of regression and correlation and the use of significance testing are described and discussed.—Auth. sum.

Black, J. N. 984
1961. Border and orientation effects and their elimination in experimental swards of subterranean clover (*Trifolium subterraneum* L.). Austral. Jour. Agr. Res. 12(2): 203–211, illus.

Two expts. were carried out in swards of subterranean clover, of the var. Bacchus Marsh, to determine the width of the border required firstly at the edge of swards and secondly between harvest areas. Peripheral growth was restricted by (a) root panels, (b) leaf panels, and (c) root and leaf panels; a 4th treatment with no lateral restrictions was also used. The results showed that in a sward growing without restrictions, a border at the edge of only 2 in. was required before homogeneous dry wts. were reached. This border effect could be eliminated by using leaf- or leaf-and-root restricting panels, but not by root panels alone. The data for borders between harvest areas were more difficult to interpret, but growing swards without panels while allowing for a 3 in. border, both at the periphery and between defoliated areas, is recommended as the simplest procedure. From a consideration of marginal growth under the different peripheral restriction regimes, it was concluded that water and nutrients were nonlimiting, but that sward growth was limited by the amount of light energy intercepted.—Biol. Abs.

Bradley, R. A., and Schumann, D. E. W. 985
1957. The comparison of the sensitivities of similar experiments: Applications. Biometrics 13(4): 496–510.

Brandt, A. E. 986
1937. Factorial design. Amer. Soc. Agron. Jour. 29: 658–668.

This paper shows how, in factorial expts., single degrees of freedom are appl. to single treatments and interactions. The χ^2 test for homogeneity of variances before pooling into 1 error term is illus. A factorial design in 2 expts. is discussed and an appl. of a split-plot design to 1 of them is described.

Calzada Benza, J. 987
1957. El error experimental y la precision en los experimentos. Lima, Peru, Estac. Expt. Agr. de La Molina, Bol. 67, 33 pp. [Eng. sum.]

Capó, Bernardo G. 988
1944. A new method of performing field trials. Puerto Rico Univ. Jour. Agr. 28(1): 22–34.

A new method of performing expts. with small nos. of treatments is described. The auth. applies the method to the interpretation of a fert. expt.

Christidis, Basil G. 989
1935. Intervarietal competition in yield trials with cotton. Jour. Agr. Sci. [England] 25: 231–238.

Competition may cause a definite bias in estimating the comparative yielding value of cotton vars. It appears advisable that field trials should be arranged so competition effects between different vars. will be eliminated.

Cochran, W. G. 990
1937. Catalogue of uniformity trial data. Roy. Statis. Soc. Jour. Sup. 4(2): 233–253.

Catalogue shows where uniformity trial data has been collected, whether published, and if not, where filed. Entries are classified by crops; only 1 entry is given for pasturage.

Cochran, William G., and Cox, Gertrude M. 991
1957. Experimental designs. Ed. 2, 611 pp., illus. New York: John Wiley and Sons, Inc.

The 2nd ed. of this well recognized text on expt. design brings the subj. more up to date. It incorporates new material on fractional replication in factorial expts. Factorial

methods are discussed in which the response to the levels of the factors is represented by some math. function. Methods for obtaining the levels at which the factors must be set in order to obtain maximum response are introduced. New incomplete block designs are presented together with refs. to many more that are now available. Newer methods for analyzing discrete data for completely randomized and randomized block designs are considered. Other probs., less exhaustively discussed, are those of sequential experimentation, new significance tests, errors in recovery of inter-block inform., etc. The text follows the general arrangement of the 1st ed. The subj. matter is divided into 17 ch., a selected bibliog., list of auth. refs., index and tables of *t* and *F*. The 1st. ch. deal with methods for increasing the accuracy of expts.; notes on statis. analysis; designs of randomized, randomized block and Latin sq. arrangements; factorial expts.; confounding; factorial expts. in fractional replication; main effects confounded; split plot designs and confounded quasi-Latin squares. Later ch. consider methods for study of response surfaces; incomplete block designs; lattice designs; balanced and partially balanced incomplete block designs; lattice squares and incomplete Latin squares; analysis of results of a series of expts.; and random permutations of 9 and 16 nos. The 2nd ed. promises to be every bit as important as the first in furthering knowledge of expt. design.—Biol. Abs.

CRAMPTON, E. W. **992**
1942. The design of animal husbandry experiments. Jour. Anim. Sci. 1(4): 263–276.

This is chiefly a general discussion of the appl. of factorial design to certain types of animal husbandry expts. Statistical analysis of data is undertaken partly to more accurately and conveniently describe a mass of otherwise unintelligible figs. This may be as important as its objective of establishing significance of the results found. Factorial design violates the principle of varying but 1 thing at a time in experimentation. This principle does not permit of as comprehensive an interpretation of the results as is possible with modern trial-design and subsequent statis. analysis. Loss of precision through studying with the same group of animals several experimentally imposed conds. is less than has often been supposed, and may be negligible. The appl. of factorial design is illus. by pig-feeding trials at Macdonald Col.—Biol. Abs.

CROWTHER, E. M. **993**
1936. The technique of modern field experiments. Roy. Agr. Soc. England Jour. 97: 54–80.

DANIEL, HARLEY A., COX, MAURICE B., TUCKER, BILLY B., AND VIETS, FRANK G., JR. **994**
1957. Design of plots conforming to the land for evaluating moisture conservation practices. Soil. Sci. Soc. Amer. Proc. 21(3): 347–350.

DEMBICZAK, C. M., EATON, H. D., BEALL, G., AND LUCAS, H. L. **995**
1957. Design and conduct of calf nutrition studies. I. One- vs. two- and three-day growth measurements. Jour. Dairy Sci. 40(9): 1133–1151.

DORPH-PETERSEN, K. **996**
1949. Parcelfordeling i markforsøg. [Plot arrangement in field experiments.] Tidsskr. for Planteavl [Copenhagen] 52(1): 111–175.

Investigations on the effect of plot arrangement on expt. error, involving the use of uniformity trials, mainly of Dan. origin, showed that in a Latin sq. field expt., Fisher's restriction greatly reduces the expt. error. The different plot arrangements in field expts. of that type give somewhat different values for "*F*," but the variation in "*F*" is not greater than may be due to coincidence. The error of a difference between 2 treatments indicates that in many expts. the yields of different treatments are not independent of each other. The difference in yield between adjacent plots treated differently is smaller than between nonadjacent ones. Among the types of arrangements used in expts. with long, narrow plots in a single range investigated in this paper, the type with the same arrangement of plots repeated in blocks showed the smallest error. A few types of large expts. suited to the Latin sq. method were examined.

DUNLOP, GEORGE. **997**
1933. Methods of experimentation in animal nutrition. Jour. Agr. Sci. [England] 23(4): 580–614.

The unsatisfactory nature of methods adopted in feeding expts. at animal nutrition res. inst. is due to neglect of the worker to control variable factors, other than those being investigated, which affect growth rate. It is proved that age, sex (females and castrated males), cond., and previous growth rate have no effect on rate of live-wt. increase of swine in the Cambridge Univ. herd, and the basis on which animals are allotted to groups to ensure homogeneity is fallacious. Merits and drawbacks of different methods in animal feeding expts. are discussed. A new method involving individual rationing, random distrib. of animals for statis. analysis of results, and eliminating variability due

to controllable factors which must remain uncontrolled in other methods is described and its precision, accuracy, and sensitivity is 16 times greater than the group-feeding method. A table showing the precision of methods at various centers demonstrates that the precision of any given method is approx. the same at all centers. A standard technique for feeding expts. is described, suitable for adoption elsewhere.—Auth. sum.

EATON, H. D., GOSSLEE, D. G., AND LUCAS, H. L., JR. **998**
1959. Effect of duration of experiment on experimental errors in calf nutrition growth studies. Jour. Dairy Sci. 42(8): 1398–1400.

FINNEY, D. J. **999**
1957. Stratification, balance and covariance. Biometrics 13(3): 373–386.

Experimenters sometimes impose on the animals allocated to different treatments the cond. that treatment means in respect of some prelim. measurement, believed to be correlated with the measurement that is to be used in assessment of results, shall be approx. equal. Such balance may be used in completely randomized or randomized block designs. The expected variance of treatment means for these designs and for the corresponding randomized designs are compared. Three major criticisms of the balanced designs emerge; difficulty of objective allocation, temptation to omit the necessary covariance analysis, and smallness of any gain in precision. The disadvantages seem far to outweigh the advantages, and such designs should not be used unless special circumstances dictate their advisability. The possibility of using Latin sq. and allied design as alternatives to the type of balance discussed is briefly mentioned. When there is anything to be gained by balance, these designs avoid the theoretical objections and will usually have almost equal merits.—From auth. sum.

FISHER, R. A. **1000**
1935. The independence of experimental evidence in agricultural research. Third Internatl. Cong. Soil Sci. Trans. 2: 112–119.

The paper discusses the logical meaning of "control" as used in experimentation; and, in quantitative expts., the need, if the expt. is to be self-sufficient, of its supplying the means of making a valid estimate of the errors, to which the results are subj. This may be achieved only by randomization. The purpose of randomization is not to diminish the expt. error, but to afford a valid estimate of it. It is, however, consistent with all the different means and devices by which the expt. error may be diminished. The idea of increasing the precision at the expense of abandoning randomization is always illusory. —Biol. Abs.

FORESTER, H. C. **1001**
1937. Design of agronomic experiments for plots differentiated in fertility by past experiments. Iowa Agr. Expt. Sta. Res. Bul. 226, 29 pp.

GARBER, R. J., AND HOOVER, M. M. **1002**
1930. Persistence of soil differences with respect to productivity. Amer. Soc. Agron. Jour. 22: 883–890.

"Natural differences in productivity of plots persisted over a period of 5 yrs., even though these plots were subjected to different treatments."

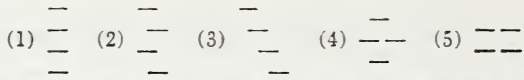
GEIDEL, H. **1003**
1957. Zum ausgleich von bodenunterschieden bei blockanlagen. [Balancing out soil differences in block layouts.] Ztschr. f. Acker- u. Pflanzenbau [Berlin] 103(1): 71–82.

GOULDEN, C. H. **1004**
1931. Modern methods of field experimentation. Sci. Agr. [Ottawa] 11: 681–701.

The paper is a statis. study which presents the methods of conducting field expts. evolved at Rothamsted.

KALAMKAR, R. J. **1005**
1932. A study in sampling technique with wheat. Jour. Agr. Sci. [England] 22: 783–797.

Yield analyses are given from a uniformity trial where wheat from a plot 40.6 by 60 links, comprised of 80 rows, was harvested in row half-m. lengths. Analysis of the data indicated significantly higher yields on border plots and on end sections of the rows. After eliminating the border rows and end half-m. of each row, there were 1,092 yields left upon which to test yield sampling methods. Sampling units of 4 half-m. lengths arranged in 5 different ways were used as follows:



In every case except with method (1), the sampling error between samples was greater than within. Effect of competition between rows is offered as an explanation for the superiority of method (1). A slight advantage is gained by the subdivision of the area to be sampled. Eighteen units arranged as in (1) gave a sampling error of 5% on 1/40-acre plots.

KINCAID, C. M., LITTON, GEORGE W., AND HUNT, R .E. **1006**
1945. Some factors that influence the production of steers from pasture. Jour. Anim. Sci. 4(2): 164–173.

A 2×3×4 factorial design was used to measure the effect of age, winter feeding level, and summer grazing rate on the gain in wt. and carcass grade of steers fattened on pasture. No significant difference in gain occurred between yearling and 2-yr.-old steers, but the latter were significantly fatter, the carcass grades being "good" and "high good," respectively. Each lb. of wt. gained in the winter feeding period reduced summer gains by 0.58 lb. and increased ann. gains by 0.42 lb. Increasing the amount of pasturage from 1 1/3 to 3 2/3 acres per steer increased gains by 19.6 lbs. for each added acre. No advantage resulted from withholding animals from pt. of the pasture until July. In a discussion of the factorial design for expts. with large animals it is suggested that this design offers possibilities for efficient use of expt. material without appreciable loss in precision. The animals used in this trial gave inform. on 3 factors and also the interactions between them which was only 3% less precise than if they had been used to study 1 factor alone.

LUCAS, H. L. **1007**
1956. Switchback trials for more than two treatments. Jour. Dairy Sci. 39(2): 146–154.

To take better advantage of the high sensitivity of switch-back or double-reversal trials commonly used to compare 2 treatments and which have been extended to permit the comparison of 3 or more treatments, certain convenient and useful features have been added. Designs are given for 3, 4, 5, 6, 7, and 9 treatments. The statis. analysis is outlined symbolically and is illus. numerically with uniformity data. Missing value formulas are given.—Auth. sum.

LUCAS, H. L. **1008**
1959. Experimental designs and analyses for feeding efficiency trials with dairy cattle. *In* Nutritional and economic aspects of feed utilization by dairy cows, pp. 177–192. Hoglund, C. R., ed. Ames: Iowa State Col. Press.

LYNCH, P. B. **1009**
1960. Conduct of field experiments. New Zeal. Dept. Agr. Bul. 399, 155 pp., illus.

Some basic concepts and general rules to follow in conducting field expts. are outlined, together with statis. considerations, details of field technique, and preparation of the data for pub. In the apps. there is inform. on amounts of seed or fert. to drill, calculation of fert. and seed wts., conversion factors for use with a fert. wt. table, ferts. and herbicides used in the trials.—Herb. Abs.

LYND, J. Q., GRAYBILL, F., AND TOTUSEK, R. **1010**
1956. Factors affecting results of grazing trials with yearling steers. Agron. Jour. 48(8): 352–355, illus.

Evaluation of factors affecting steer performance used in pasture expts. are presented for 3 uniform herds. Coefficients of variation increased through the wintering period and decreased through the following grazing periods. There was no relation between initial wt. and total gain. No significant correlation was indicated between winter gain and corresponding pasture gains. Keratitis, wart virus and internal parasite egg count of fecal samples were not related to gains of treated steers.—Auth abs.

LYND, J. Q., GRAYBILL, F., AND TOTUSEK, R. **1011**
1957. Grazing trial evaluations using paired pastures with yearling steers. Agron. Jour. 49(9): 488–492.

The results are given of studies during 3 yrs. on Bermuda grass [*Cynodon dactylon*]/ legume pastures, established on different soil types. Each pasture was split into 2 halves. Yearling hereford steers were selected for uniformity during the winter previous to the grazing trials. Those steers which had the least deviation from the mean wt. and winter-live-wt. gain of the herd were designated as "tester" steers. These steers were paired on the basis of size and winter-live-wt. gain and 1 steer from each pair grazed 1 half and the

other steer grazed the other half of the same split pasture. The "tester" steers remained, each on their own half-pastures, for the whole grazing season. Stocking rates were adjusted to utilize the full estimated stocking capacity of the pastures by introducing so-called "grazer" steers. These were introduced as required during the early pt. of the season and removed again as pasture prod. declined. Pasture prod., expressed as live-wt. gain of tester plus grazer steers, was affected more by soil type than by manurial treatment or method of appl. Live-weight gains per head of grazer and tester steers were similar. Gains of tester steers were relatively uniform between the halves of split pastures and between different pastures in given yrs. The combined, pooled variation between paired steers for all pastures during the 3 trial yrs. was 17.86, with a C.V. of 12.3%. It was thought that the use of paired pastures was of value for the statis. evaluation of pasture prod. where variations between animals grazing different pastures, or different halves of the same pastures, were minimized. The use of paired tester steers reduced the variation between animals. The effectiveness of the procedures described is dependent on: (a) the use of uniform animals; (b) the use of a prelim. wintering period in order to evaluate individual animal performance; and (c) effective continuous judgment of proper stocking rates throughout the grazing season.—Herb. Abs.

MAHALANOBIS, P. C. **1012**
1933. The use of the method of paired differences for estimating the significance of field trials. Indian Jour. Agr. Sci. 3(2): 349–359.

The use of the method is justified only in special cases as is shown by a discussion of the principles involved. The method assumes no systematic differences or changes in fertility between different plots. Although in adjacent plots soil heterogeneity might be disregarded, it is seldom entirely absent and, therefore, the use of paired differences is seldom justified.—Biol. Abs.

MASON, D. D. **1013**
1958. Field experiments. (Summary.) Amer. Statis. Assoc. Jour. 53(282): 585.

MERCER, W. V., AND HALL, A. D. **1014**
1911. Experimental error in field trials. Jour. Agr. Sci. [England] 4: 107–132.

MEYER, J. H., LOFGREEN, C. P., AND GARRETT, W. N. **1015**
1960. A proposed method for removing sources of error in beef cattle feeding experiments. Jour. Anim. Sci. 19(4): 1123–1131.

MOTT, G. O. **1016**
1960. Grazing pressure and the measurement of pasture production. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 606–611, illus. [In Eng. with Eng., Fr., and Ger. sum.]

The failure to adjust stocking rate to provide equal grazing pressures on all treatments and replications of a grazing trial may bias performance per animal and per acre. The effects of under- or overgrazing of plots are discussed.

MULLER, K.-H. **1017**
1956. Exakte auswertungsverfahren des kontrollierten anbauvergleiches. [An accurate method of carrying out controlled comparative cultivation trials.] Ztschr. f. Landw. Vers.- u. Untersuchw. [Berlin] 2(3): 153–161.

The layout and statis. analysis of the method suggested are described.

OKUNO, T. **1018**
1958. On the design and analysis of field experiments. II. Tokyo Natl. Inst. Agr. Sci. Bul., Ser. A 6: 81–146. [In Jap. with Eng. sum.]

PIGDEN, W. J., AND GREENSHIELDS, J. E. R. **1019**
1960. Interaction of design, sward and management on yield and utilization of herbage in Canadian grazing trials. Eighth Internatl. Grassland Cong., Reading, Proc. 1960: 594–597. [In Eng. with Eng., Fr., and Ger. sum.]

Grazing trials with yearling beef steers were carried out at 5 locations in Canada. Replicated plots, continuously grazed to a ht. of about 4 in., were compared with rotationally grazed plots. Interactions between wt. gain and DM consumption were found between locations and between treatments within locations. Dry matter consumed per lb. of live-wt. gain ranged from 12.4 to 4.2 lbs.

RAMPTON, H. H. **1020**
1959. Sampling methods for measuring seed yield and seed quality of orchardgrass (*Dactylis glomerata* L.) as determined by uniformity trials. Agron. Abs. 1959: 87.

RIEWE, MARVIN E. 1021

1961. Use of the relationship of stocking rate to gain of cattle in an experimental design for grazing trials. Agron. Jour. 53(5): 309–313, illus.

A rev. of a no. of stocking-rate studies showed a tendency for a negative correlation between stocking rate and live-wt. gain per head. A nonreplicated design for grazing expts. in which 3 or more stocking rates per pasture treatment are used is proposed, allowing the determination, by means of covariance analysis, of expt. error and stocking rate×treatment interaction.

RIGNEY, J. A., MILES, S. R., AND ANDREWS, W. B. 1022

1948. The choice of suitable experimental units and experimental designs. Natl. Joint Comt. Fert. Appl. Proc. (1947) 23: 228–234.

The following factors are considered briefly: shape of plots, guard areas, no. of replications, locations and seasons, and expt. design.

RUBIN, THEODORE. 1023

1956. Experiments wherein experimental and control groups vary in time and number. Diss. Abs. 16(2): 321.

SNEDECOR, GEORGE W., AND CULBERTSON, C. C. 1024

1933. An improved design for experiments with groups of animals whose outcome may be estimated. Amer. Soc. Anim. Prod. Proc. (1932) 25: 25–28.

The animals were arrayed according to outcome, then divided into an equal no. of rows and columns so that (a) the best animals were in the 1st row, the next best in the 2nd, etc., and (b) the best animal in each row was at the left and so on to the poorest at the right. One animal in each row was chosen for each lot with this restriction: no 2 members of the same column might be in the same lot. R. A. Fisher's Latin sq. analysis of variance was used. With 100 swine the standard error was 11% of the av. daily gain.

SUMMERBY, R. 1025

1934. The value of preliminary uniformity trials in increasing the precision of field experiments. Macdonald Col., McGill Univ. Tech. Bul. 15, 64 pp.

VERVELDE, G. J. 1026

1960. Enkele gedachten over de kosten van proefvelden. [Some thoughts on the cost of experimental plots.] Landbouwk. Tijdschr. [Wageningen] 72(20): 830–837.

The cost of agr. experimentation is reviewed from technical and statis. standpoints. It was considered that costs incurred in preparation and layout of expts. in order to facilitate statis. treatment are always justified. A tendency was noted for res. workers and res. inst. to give preference to the less expensive type of trial.—Herb. Abs.

WELLMAN, R. H., THURSTON, H. W., JR., AND WHALEY, F. R. 1027

1948. A method for correcting for geographic variation in field experiments. Boyce Thompson Inst. Contribs. 15(3): 153–163.

A method for minimizing the geog. variation found in field expts. and examples are given. Geographic variation is defined as any organized variation which affects the data such as soil type, soil profile, moisture, or weed population variation. This method makes possible more precise comparisons than are possible on uncorrected data, the method does not impose limitations on no. of treatments or replicates, and has been found to minimize geog. variation better than existing methods.

WERMKE, M. 1028

1963. [Mathematical and statistical considerations in the design and evaluation of experiments on pasture land.] Ztschr. f. Acker- u. Pflanzenbau [Berlin] 117(1): 32–54. [In Ger. with Eng. sum.]

From field trials, it is suggested that: group-grazing expts. are preferable to period-grazing expts.; the grazing rotation should harmonize with the growth pattern of the pasture; the design and evaluation should be at least bifactorial, with 1 factor the rotational period or the no. of grazings; the group should contain more than 5 animals, which should be as heterogeneous as possible except for age.

WHEELER, J. L. 1029

1960. Field experiments on systems of management for mesophytic pastures. Austral. C.S.I.R.O. Div. Plant Indus., Div. Rpt. 20, 51 pp.

Experimental comparisons of pasture mangt. systems in which animal prod. measurements have been recorded are reviewed. Few definite concl. can be drawn. Forms of rotational grazing *per se* have not, in objectively conducted expts., proved appreciably more productive than continuous grazing. Strip-grazing systems are slightly more productive on an acreage basis than rotational systems at the same stocking rate. When

more stock are carried on the former, resulting acre yields are approx. in the ratio of the stocking rates. A no. of expts. have compared soiling (mechanical pasturing) and also hay-silage feeding with grazing systems. Generally prod. per head is lower but prod. per acre higher than with strip- or rotational-grazing although expts. have almost invariably supported a greater no. of stock on areas cut for silage than on the grazed areas. The concl. are discussed and the relevant principles of pasture prod. and util. considered. Possible limitations in the expt. techniques that have been used are noted and points which should be given attention in future experimentation in this and related fields are listed.

WHEELER, J. L. **1030**
1962. Within-paddock variation in the fertility of a virgin soil. Austral. C.S.I.R.O. Div. Plant Indus., Field Sta. Rec. 1(1): 13–19.

When oats were sown in a 32-acre paddock, previously under native pasture, the yields from the most productive plots were more than 6 times that from the poorest plot. The significance of these results with expts. on uncultivated soils is discussed.

WIENER, W. T., AND BROADFOOT, R. **1031**
1925. The effect of fallow borders on the variability of plot yields. Sci. Agr. [Ottawa] 5: 310–312.

The outside drill rows in plots of Mindum wheat, each 8×72.6 ft., yielded 26.52% more than the 12 central rows, but the effect of the fallow borders did not extend inward beyond the outside rows.—Bot. Abs.

WILSON, EDWIN B. **1032**
1941. The controlled experiment and the four-fold table. Science 93: 557–560.

WISHART, JOHN. **1033**
1938. Field experiments of factorial design. Jour. Agr. Sci. [England] 28: 299–306.

In factorial-type field expts., the increasing use of individual degrees of freedom necessitates examination of some dangers in their use. The customary procedure computes the mean sq. for treatments as a whole, which if tested in terms of the error component determines the significance of treatment effects as a group. Frequently, individual degrees of freedom are written out and tested even when treatments as a whole are indicated to be without effect. Such a procedure may lead to unnecessary explanations of significant individual degrees of freedom attributable to chance. The auth. proposes a χ^2 test to determine whether any of the individual single degrees of freedom may be significant.

YATES, F. **1034**
1933. The formation of Latin squares for use in field experiments. Empire Jour. Expt. Agr. 1(3): 235–244.

The conds. which must be fulfilled in selecting Latin-sq. arrangements for agr. field trials, if an unbiased estimate of error is to be obtained, are discussed. Examples of squares up to size 12×12 are given, from which expt. arrangements may be derived by simple processes of permutation. All squares up to size 6×6 have been enumerated elsewhere, and the totalities of these squares are presented here in compact form.—Auth. sum.

YATES, F. **1035**
1933. The principles of orthogonality and confounding in replicated experiments. Jour. Agr. Sci. [England] 23(1): 108–145.

The term "orthogonal" designates effects that can be directly evaluated without entanglement with others. Except where nonorthogonality is purposefully introduced as in confounding, orthogonality should be designed in the expt. Cases of nonorthogonality introduce complex computation by fitting constants using the least squares method and complicate interpretation of results because of the failure of treatment effects to remain isolated. The principle of confounding, deliberately introducing nonorthogonality into expts. by confounding 1 of higher order interactions with block differences, is fully discussed. This design is for giving greater accuracy on the unconfounded comparisons at the expense of the confounded. By partial confounding, accuracy may be gained throughout the expt.

See also **46, 589.**

NUMBER OF SAMPLING UNITS AND EFFICIENCY

BORDEN, R. J. **1036**
1943. Replication: The safeguard for uncontrolled variation. Hawaii. Planters, Rec. 47(3): 135–153.

In field work, sufficient replications must be included to take care of the possible varia-

tions that may occur. Variations which may occur in soil, crop comp., plant growth, plant comp., and yields are discussed.—Biol. Abs.

CHILTON, NEAL W., AND FERTIG, JOHN W. **1037**
1953. The estimation of sample size in experiments. I. Using comparisons of averages. Jour. Dent. Res. 32(4): 530–540.

To estimate the size of samples necessary for assertion of statis. significance, the investigator must know what contemplated result is considered important, and possess a certain amount of prelim. data. Illustrations are presented using prelim. data in which comparisons of arithmetic averages, for both independent and correlated samples, are studied. By the use of formulas based upon the *t*-curve and normal curve probability values, and upon the use of a table from the statis. literature, methods are presented for estimating the size of samples necessary for a difference in averages to be found at different significance levels and powers of the test.

CHILTON, NEAL W., AND FERTIG, JOHN W. **1038**
1953. The estimation of sample size in experiments. II. Using comparisons of proportions. Jour. Dent. Res. 32(5): 606–612.

Formulae are presented for estimating the size of samples necessary for statis. significance to be asserted at different levels of significance and powers of the test, for comparison of a sample proportion with a universe proportion, and for comparison of 2 sample proportions. A table is presented which will enable the reader to rapidly determine the size of the samples necessary for significance to be asserted at 1% level of significance with 99% power, or at 5% level of significance with 95% power. If the reader assumes the smaller true proportion he can read the estimated sample sizes once he knows how much larger the other true proportion is to be. Illustrations from the dental res. literature are presented.

DAVIS, DAVID E., AND ZIPPIN, CALVIN. **1039**
1954. Planning wildlife experiments involving percentages. Jour. Wildlife Mangt. 18(2): 170–178.

Charts are presented which help the planning of expts. by indicating the approx. no. of animals required in each sample to establish a difference in percentages as significant at the 5% (probability of Type 1 error) level. The charts are constructed for 2 levels of Type 2 error (failure to ascribe significance to a real difference). Discussion of the 2 types of error, applicability of the respective charts, and several examples are also given.

GHENT, A. W. **1040**
1963. Studies of regeneration in forest stands devastated by the spruce budworm. III. Problems of sampling precision and seedling distribution. Forest Sci. 9(3): 295–310, illus.

The precision of estimates of *Abies balsamea* (L.) Mill. populations is adequately described by the rectangular hyperbola that relates standard error and sample size in elementary statis. theory. With sample size held constant, standard error is found to be a power function of density, of the form $Y \cdot X^{s} = b$. Inspection of standard error vs. sample size hyperbolas at selected population densities demonstrates that the sampling effort required to attain a given level of precision varies inversely with density. The roles of competitive and noncompetitive influences upon seedling distribs. are considered. A new method of applying the binomial to the assessment of contagion demonstrates that areas of both very high and very low seedling densities are contagiously distributed, while areas of intermed. density are more randomly dispersed. Studies of the influence of observational scale upon the apparent distrib. of *A. balsamea* seedlings show this to be independent of quadrat size over the range from 0.25 to 2.25 milacres. The apparent distrib. changes dramatically, however, with changes in the total area over which the quadrats are spread. Disagreement with the Poisson distrib., rather than agreement with the negative binomial or other variance-dependent distrib., is found to be the more reliable criterion of contagion. Unlike *A. balsamea*, *Pinus strobus* L. seedling distribs. do show a change in apparent distrib. with increasing quadrat size, and illustrates the convergence of the negative binomial to the Poisson distrib. as mean and variance approach equality.

GOULDEN, C. H. **1041**
1937. Efficiency in field trials of pseudo-factorial and incomplete randomized block methods. Canad. Jour. Res. 15: 231–241.

HOLMES, M. C. **1042**
1935. Sampling analysis and sample size. Franklin Inst. Jour. 219(4): 483–486.

An equation is derived which gives the no. of increments per sample (n) required in terms of 3 factors; the allowed limits of tolerance (x) expressed as a fraction of the

mean; the desired degree of assurance that such limits will not be exceeded (γ), expressed as a probability; and the inherent variability of the material being sampled (S), measured by the C.V. The relation is given by the inequality

$$n \geqq \frac{S^2}{x^2} [erf^{-1}(\gamma)]^2,$$

the last member of which may be obtained from error function tables. Normality is assumed in the derivation, but evidence is presented which shows that the equation gives good results even for certain extreme departures from normality.—Biol. Abs.

KEULS, M. **1043**

1960. The power of the *F*-criterion in the analysis of the variance in randomized block designs; nomograms for the choice of the number of repetitions. Biométrie-Praximétrie [Brussels] 1(3/4): 65–80. [In Fr. with Eng. sum.]

KEULS, M. **1044**

1960. The power of the *F*-criterion in the analysis of variance of randomized block designs; nomograms for determining the number of repetitions. Gembloux Inst. Agron. de l'État Bul., Sér. Extraordinaire 1: 256–271. [Eng. sum.]

KHANNA, K. L., NIGAM, L. N., AND BANDYOPADHYAY, K. S. **1045**

1950. Studies in sampling technique. II. Estimation of *Pyrilla* incidence in sugarcane. Indian Acad. Sci. Proc. Sect. B 31(1): 34–45, illus.

Two plots, each measuring 60×60 ft., infested with *Pyrilla* were completely enumerated to find the minimum sample size for the estimation of incidence at a desired level of precision. Of the 2 plots, plot I had a denser crop and slightly more infestation than plot II, but the variation of incidence in plot II has been of a slightly higher order than in plot I. Four characters have been simultaneously used to define incidence and the sample sizes have been worked out in terms of the percentages of the total 3 ft. units available in the plots. The sample sizes are such as would furnish the estimates within an error of 7%.—Auth. sum.

KNOWLES, R. P. **1046**

1952. The use of lattice designs for testing forage crops. Sci. Agr. [Ottawa] 32(11): 614–617.

Plot arrangement and relative efficiencies are tabulated for 27 lattice tests of peren. forage crops for hay prod. Average gains in precision were 51%, 44%, and 39%, respectively, for crested wheatgrass (*Agropyron cristatum*), bromegrass (*Bromus inermis*), and alfalfa over comparable randomized block analyses. Good gains in efficiency were noted for tests of 16 strains but not for tests of 9 strains. Six test plots harvested for seed showed an av. efficiency gain of 17%.

KOEK, W. A., WAL, P. VAN DER, AND WEERDEN, E. J. VAN. **1047**

1962. [Some observations on the number of experimental animals required in feeding trials.] Landbouwk. Tijdschr. [Wageningen] 74(2): 57–69. [In Dutch]

LIVERMORE, J. R., AND NEELY, WINSTON. **1048**

1933. The determination of the number of samples necessary to measure differences with varying degrees of precision. Amer. Soc. Agron. Jour. 25(9): 573–577.

Tables are presented by means of which, if the probable error of a single observation is known, one may predict with a reasonable degree of accuracy the no. of plots or other units necessary to measure a known difference with any desired degree of precision. Examples illustrating certain uses of the tables are presented in detail. The use of these tables is predicated on the assumption that the deviations in the particular expt. conform to the normal curve of error.—Biol. Abs.

MA, R. H., AND HARRINGTON, J. B. **1049**

1948. The standard errors of different designs of field experiments at the University of Saskatchewan. Sci. Agr. [Ottawa] 28(10): 461–474.

During the 22-yr. period, 1925–46, 523 field plot expts. of various types of design were conducted. The standard errors per plot in % were obtained for the different expts. and a study made to ascertain the av. value of the standard deviation for each type of design used for the different crops; the relative efficiency of these designs for field testing; and the probable no. of replicates required in the planning of future expts. The results offer an overwhelming case in favor of the use of lattice designs under conds. such as obtained in the tests considered. Latin squares proved efficient but the limitation of this design to very few vars. made it unsatisfactory for testing large nos. of vars. The randomized blocks were definitely inferior to the lattice designs. The semi-Latin squares

not only averaged high in % standard error per plot but also had the added disadvantage of bias in the estimation of error. The lattices were superior to the split-plot Latin squares and to the split-plot randomized blocks. The split-plot type of design proved closest to lattices in one respect, viz, varietal comparisons within groups. However, comparisons between groups which constitute the majority of the comparisons between pairs of vars. were low in precision.

NUMATA, MAKOTO. **1050**

1950. The investigation of vegetation by means of sampling method.—Studies on the structure of plant communities. V. Bot. Mag. [Tokyo] 63: 149–154. [In Jap. with Eng. sum.]

The significance of the difference between several sampling methods is indicated by analysis of variance. The relative no. of sampling units required for a given degree of accuracy according to sampling methods is calculated from the av. comparable variance.

PAN, CHIEN-LIANG. **1051**

1935. Uniformity trials with rice. Amer. Soc. Agron. Jour. 27: 279–285.

The efficiency index was calculated by dividing the variance of a single-rowed plot by the product of the variance of a multiple-rowed plot times the no. of rows included in this plot and expressing the result in %, i.e.,

Plot	Variance	Efficiency
1-row	35.049	100.00
2-row	16.066	109.08
3-row	14.084	82.95
4-row	12.286	71.32

POPE, O. A. **1052**

1936. Efficiency of single and double restrictions in randomized field trials with cotton when treated by the analysis of variance. Ark. Agr. Expt. Sta. Bul. 326, 28 pp.

The efficiency of restricted arrangements varied between tests of the same size at different locations, as well as between tests of different sizes. All sizes and arrangements used were capable of significantly increasing the accuracy of interpretation. In general, greater efficiency of restricted arrangements was found in tests located on perm. expt. blocks arranged in an orderly manner. Decreases in efficiency were roughly proportional, inversely, to the amount of care used in selecting the expt. area. Even with the most careful selection of the expt. area, a sufficient increase in accuracy usually results from restricted arrangements to warrant the general use of the method in field expts.

REID, ELBERT H., KOVNER, JACOB L., AND MARTIN, S. CLARK. **1053**

1963. A proposed method of determining cattle numbers in range experiments. Jour. Range Mangt. 16(4): 184–187, illus.

A formula is given relating stocking rate with % util. of the herbage and ann. prod. of ann. and peren. grasses. An example is given of its appl. to 7-yr. data at the Santa Rita Expt. Range, Ariz.

SEELBINDER, B. M. **1054**

1953. On Stein's two-stage sampling scheme. Ann. Math. Statis. 24(4): 640–649.

This refers to prelim. sampling for variance to decide the no. needed in the total sample. This will depend on the significance level (α), and the allowable discrepancy (d) in estimating the mean. The N (preliminary sample size) to minimize total work has been based on the incomplete gamma function; an approx. using the normal distrib. is developed. Tables are presented for choice of N_1 for various values of α and d taken in terms of standard deviation. An example from Cochran's data is presented, and 5 refs. are cited.

SINGH, D. **1055**

1956. On efficiency of cluster sampling. Indian Soc. Agr. Statis. Jour. 8(1/2): 45–55.

SMITH, JUSTIN G. **1056**

1962. An appraisal of the loop transect method for estimating root crown area changes. Jour. Range Mangt. 15(2): 72–78, illus.

A large no. of transects were required to obtain an acceptable level of accuracy when comparing changes in root crown area occasioned by (hand) removal of plants from the sward at random.

SOUTHCOTT, W. H., ROE, R., AND TURNER, HELEN NEWTON. **1057**

1962. Grazing management of native pastures in the New England region of New South Wales. II. The effect of size of flock on pasture and sheep production with special reference to internal parasites and grazing behaviour. Austral. Jour. Agr. Res. 13(5): 880–893, illus.

Yields and behavior of Merino sheep were studied with flocks of 2–30 animals grazing a pasture dominated by *Bothriochloa ambigua* at 1 sheep/acre. Flock size did not affect yields or bot. comp. of the pasture. Live-weight and wool yields were lower for the flock of 2 sheep than for flocks of 4–30 sheep, and less time was spent grazing and more time idling. It is concluded that the minimum flock size for pasture prod. expts. should be 4 sheep.—Herb. Abs.

SWINEFORD, FRANCES. **1058**

1946. Graphical and tabular aids for determining sample size when planning experiments which involve comparisons of percentages. Psychometrika 11(1): 43–49.

Charts are presented which eliminate any computation where the 2 groups involved are to be equal. A table is included for the case where 1 group will be 1 to 3 times the size of the other. The charts are also useful for determining whether obtained differences are statistically significant at the 5% or the 1% level.

TORRIE, J. H., SHANDS, H. L., AND LEITH, B. D. **1059**

1943. Efficiency studies of types of design with small grain yield trials. Amer. Soc. Agron. Jour. 35(8): 645–661, illus.

Data of grain yields from wheat, oats, and barley rod-row and 1/60-acre plot expts. were collected by the Dept. of Agron. at the Univ. Hill Farms, Madison, Wis., during 1937–42. Also included are data for 1938–41 from the rod-row nurseries at the Hancock and Marshfield branch expt. stas. The precision of the lattice design, with and without recovery of interblock inform., as compared to the randomized complete block was determined for 22 small grain trials. The av. of all tests gave an increase of 9% in precision with recovery of interblock inform. and a loss of 8% when interblock inform. was ignored. Four quadrats harvested from 1/60- or 1/80-acre field plots provided, for the most pt., reliable estimates of the yield of the entire plot. The precision of the quadrats as measured by the C.V. is essentially the same as that of the field plots. A good agreement was found for most of the vars. tested when grain yields from rod-row plots were compared with those from field plots and quadrats. Calculations based on the 19 field-plot trials showed that increasing the no. of replications would be more effective than increasing the no. of quadrats per plot as a means of increasing precision. The av. precision factors calculated for different nos. of quadrats and replicates were essentially the same for the different cereals, especially for oats, spring wheat, and winter wheat.

YATES, F., AND ZACOPANAY, I. **1060**

1935. The estimation of the efficiency of sampling, with special reference to sampling for yield in cereal experiments. Jour. Agr. Sci. [England] 25: 545–577.

A prelimin. discussion of the interpretation of the analysis of variance as applied to sampling results is given, and an expression is found for the loss of inform. arising out of sampling applicable to all types of sampling carried out on replicated expts. The method of determining the optimal % of sampling is described. Gain due to subdivision of the plots for sampling is shown to be advantageous.

See also **151, 598, 641, 724, 745, 933, 934, 939–941, 949, 953, 964, 983, 991, 1022, 1065, 1090, 1101, 1106, 1113.**

SIZE AND SHAPE OF SAMPLING UNIT

ANSARI, M. A. A., AND SANT, G. K. **1061**

1943. A study of soil heterogeneity in relation to size and shape of plots in wheat field at Raya (Muttra District). Indian Jour. Agr. Sci. 13(6): 652–658, illus.

Standard errors indicate that a plot of 270–360 sq. ft. is optimal for wheat var. trials. Long plots had no advantage over broad plots of the same area. The Papadakis method of adjustment for fertility indices increased the accuracy of measurement of differences.

ARCHBALD, D. **1062**

1950. The effect of quadrat size and quadrat method on apparent plant dispersion. (Abstract.) Ecol. Soc. Amer. Bul. 31: 52.

BARTLETT, M. S. **1063**

1948. Determination of plant densities. Nature [London] 162(4120): 621.

The auth. reaffirms that the most efficient size of quadrat is with about 20% absence (product of quadrat size and plant density about 1.6; there is reasonable efficiency from 0.7 to 3).

BONAZZI, A. **1064**

1933. Errors in field experimentation with ratoon cane. Asoc. de Téc. Azucareros Cuba, Proc. 7: 32–40.

The practical value of expt. results depends on 2 fundamental factors: (1) the reliability of the absolute value of the mean of an appropriate series of repetitions, and, (2) the variability of the individual values obtained in this series, i.e., the form of frequency curve which represents their values, expressed in terms of standard deviation $\pm \sigma$ or of probable error $\pm e$. It is clear that the mean of 50 measurements made with a measuring rod which, due to an error in manufacture, measures only 90 cm. instead of 100, will be 1.111 times greater than the true distance existing between 2 points, even though the individual deviation from the mean value of a series of measurements, made with this same rod, be very small. With this concept in mind, and as a final concl. to the present study, it may be stated that: due to obvious econ. limitations that do not permit numerous replications of large plots, experimentation with ratoons of sugar cane may be made with plots of 600 sq. m. (combination $a \times 6$ in a row) since this size and shape unites a high index of probability to a minimum systematic error realizable with a limited no. of replications.—Auth. sum.

BORMANN, F. H. **1065**

1953. The statistical efficiency of sample plot size and shape in forest ecology. Ecology 34(3): [474]–487, illus.

Statistical variance was used to determine the most favorable size and shape of plot to sample randomly an oak-hickory forest in the N.C. Piedmont, as well as to determine the no. of plots necessary to obtain a sample of a given precision. It was found that long narrow plots (4×140 m. and 10×140 m.) crossing any observed contours and soil or vegetational banding are most efficient, especially in the sampling of sporadic spp. The size of the sample can be reduced without much loss of precision if segments no longer than the width of the plots are omitted systematically. In this manner a sample covering 7% of the total area of the stand gives an estimate of the total basal area that will be within about 10% of the mean. The use of random sampling is advocated for several reasons.

BOSE, R. D. **1066**

1935. Some soil-heterogeneity trials at Pusa and the size and shape of experimental plots. Indian Jour. Agr. Sci. 5(5): 579–608.

CHRISTIDIS, BASIL G. **1067**

1931. The importance of the shape of plots in field experimentation. Jour. Agr. Sci. [England] 21: 14–37.

In agr. expts. it seems that significant results cannot be secured by only using appropriate statis. methods; uniformity amongst the individual plots is more essential than anything else. Some theoretical considerations suggest that the shape of the plots constitutes an important means of controlling soil heterogeneity. In accordance with these: (a) in no case can sq. plots be more uniform than long and narrow ones, (b) the smaller the value w/l [width over length] the more uniform the expt. plots, and (c) since uniformity depends (apart from w/l) on the value of the angle a, in some exceptional cases (soil fertility varying gradually and evenly, and angle a approaching 90°) the advantage of the long plots may be less than would be anticipated. This, however, is most unlikely on acct. of the complexity of the variation in soil conds. and the possibility of easily avoiding such a critical value of the angle a. In order to test the validity of the assumption made regarding the effect of the shape of the plots, the numerical data of several uniformity trials have been considered. A close agreement was found between expectation and actual results, in the great majority of cases the evidence being remarkably significant in favor of the long plots. In only 3 cases were the results inconclusive, this apparently being accounted for by the way in which the original plots were formed, causing an inequality in area amongst them. In the light of these invests., in order to reduce the effect of soil heterogeneity, the plots used should be as long and narrow as possible. This, of course, within the limits set by different practical considerations, amongst which convenience, competition (when acting), and the accurate measurement of the width appear to be the most important.—Auth. sum.

CHRISTIDIS, BASIL G. 1068

1939. Variability of plots of various shapes as affected by plot orientation. Empire Jour. Expt. Agr. 7(28): 330–342, illus.

Long and narrow plots were generally more effective than squares in controlling soil heterogeneity. To find out if this is true irrespective of the orientation of the plot an expt. was made in which 5 shapes were compared in 4 different orientations. In no case were long and narrow plots more variable than squares, the difference in their variability depending entirely on the ratio w/l (width over length) of the respective plots. Loesell's data considered in this respect provided additional evidence in favor of long plots.—Biol. Abs.

CLAPHAM, A. R. 1069

1932. The form of the observational unit in quantitative ecology. Jour. Ecol. [London] 20(1): 192–197.

From subdividing a sq. 4 m. on a side into 256 squares 1/4 m. on a side, in a closely grazed turf, auth. concludes that the variance (standard deviation squared) among sq. m. quadrats is about twice that among (1/4×16) strips of the same size. He suggests that the m. quadrat be replaced by a strip 4 m. by 1/4 m. on the side.

DAVIES, J. GRIFFITHS. 1070

1931. The experimental error of the yield from small plots of "natural" pasture. Austral. Council Sci. and Indus. Res., Bul. 48, 22 pp.

Three-eighths of an acre of typical "natural pasture" was divided into 760 plots, 5×10 links in size, herbage air dried. Eighteen different combinations of plots were made to determine the best size and shape of plot to use in sampling pastures for yield. Standard error of a unit plot (50 sq. links) was 34.28% of the mean yield of the plot, considerably higher than that of field crops. Optimal plot size appears to be long and narrow, 5×90 links. In natural pastures there is a minimal plot size to use below which the distrib. of yield is nonnormal and the standard deviation is not reliable. The minimal plot size giving a normal distrib. of yield is 150 sq. links, 5×30 links. Bot. comp. greatly affects yield.

DOWN, E. E. 1071

1942. Plot technic studies with small grains. Amer. Soc. Agron. Jour. 34(5): 472–481.

Studies were made with fall-sown wheat and spring-sown barley for 5 seasons to determine the width of plot necessary to overcome the influence of competition between contiguous nursery plots. Ten replications of competitive plots were alternated for 2 rates of seeding and for 2 vars. for both grains, using plots 1, 3, 5, or 7 rows wide. The effect of competition did not extend beyond the outside border rows of a plot to a statistically measurable amount; a 5-row plot for wheat and a 3-row plot for barley with the border rows discarded at harvest are satisfactory for nursery invests. A minimum of 3 replications for wheat and 7 for barley was necessary (for the plot widths mentioned) to reduce the standard error of the mean to 5% of the mean.

EHRENPFORDT, V. 1072

1961. Plot size in statistical research projects, where plots must be ploughed separately. Ztschr. f. Landwirt. Vers.- u. Untersuchw. [Berlin] 7(2): 100–108. [In Ger. with Eng. sum.]

FRENCH, M. H. 1073

1956. Minimum size of experimental plots for the assessment of pasture yield. East African Agr. and Forestry Res. Organ. Rpt. 1956 [n.d.], pp. 82–83.

Trials at Muguga over a no. of yrs., in which very large nos. of plots were sampled, indicate that the minimum plot size to give a 10% C.V. in DM herbage yields varies enormously according to luxuriance of growth. The minimum plot size is estimated to range from 16 to 755 sq. yds. for the same grass sp. It is suggested that in arid and semiarid areas, the minimum plot size should be 600 sq. yds.—Herb. Abs.

FRENCH, M. H. 1074

1960. Errores asociados con el uso de pequeñas parcelas de prueba en la evaluación de rendimiento de pastos. [Errors resulting from the use of small test plots in the evaluation of pasture yield.] Agron. Trop. [Maracay] 10(2): 71–76. [Eng. sum.]

In temperate areas herbage yields are estimated by cutting small test plots. The results from trials in E. Africa and Venezuela showed that such small plots are inadequate in the tropics for the forage spp. studied. The data given show the % errors and the coefficients of variation obtained by using 10–12 plots of 0.87, 6, 10, 12.48, 24, and 40 sq. m. for estimating herbage yields in tropical pastures.—Herb. Abs.

FRENCH, M. H. **1075**

1961. Problems associated with cutting and weighing techniques for measuring tropical herbage productivities. Turrialba [Costa Rica] 11(1): 4–11, illus. [Sp. sum.]

The prob. of using data and techniques developed in temperate areas for measuring herbage productivity in the tropics is discussed. Particular attention is given to possible errors when weighing cut forage. Trials carried out in E. Africa are used for pointing out serious errors which can arise in the tropics from the use of small plots which would give good results in temperate zones. Plots of 1×6 yds. are compared with those of 12×54 yds. It is concluded that before beginning studies of herbage productivity in tropical regions, invests. should be carried out to determine suitable plot size.—Herb. Abs.

GEIDEL, H. **1076**

1958. Zur variabilität der einzelpflance. [The variability of the individual plant.] Ztschr. f. Acker- u. Pflanzenbau [Berlin] 106(1): 49–57.

The magnitude of the variability of plant attributes is studied statistically and used to determine the optimum size of sampling unit of a crop plant.

HANSON, HERBERT C. **1077**

1934. A comparison of methods of botanical analysis of the native prairie in western North Dakota. Jour. Agr. Res. 49(9): 815–842, illus.

The methods tested were area-list, count-list, wt.-list, frequency-abundance, and the point method. A study was also made of various sizes and shapes of sample areas and plots. The use of sample areas located in plots was recommended in place of sample areas not in plots. The minimum desirable size was found to be 2×3 rods containing 24 sample areas, each sample area being 0.1 m. sq. It is concluded that reliable quantitative results may be secured when listing is done on sample areas arranged in plots, both in sufficient nos. for systematic treatment. Valuable supplementary inform. will be furnished by use of the point and frequency-abundance methods since with them it is possible to cover large areas quickly. For extensive studies and where time and assistance are limited, the point and frequency-abundance methods, supplemented by perm. quadrats, are recommended.—Biol. Abs.

HANSON, H. C., AND LOVE, L. D. **1078**

1930. Size of list quadrat for use in determining effects of different systems of grazing upon *Agropyron smithii* mixed prairie. Jour. Agr. Res. 41: 549–560, illus.

HATHEWAY, W. H., AND WILLIAMS, E. J. **1079**

1958. Efficient estimation of the relationship between plot size and the variability of crop yields. Biometrics 14(2): 207–222.

An improved method of estimating the coefficient in Fairfield Smith's empirical relation between plot size and variability is described and illus. on data from an agr. field trial. The coefficient is determined from a weighted regression in which the weighting takes into account the correlations and unequal variances of the variance estimates.

HOLLOWAY, J. T., AND WENDELKEN, W. J. **1080**

1957. Some unusual problems in sample plot design. New Zeal. Jour. Forestry 7(4): 77–83, illus.

Sample plots are being established along selected sampling lines throughout the high-mountain protection forests of New Zeal., to measure changes in the vegetation, particularly those consequent on the presence of introduced animals and affecting the soil-conserv. and water-regulation values of the forests. The present cond. of the forests must be recorded as thoroughly and accurately as possible, but physical factors, examples of which are given, impose severe limitations on plot design. The design adopted, a 1/10-acre cruciform belt transect with internal circular milacre subplots, is a compromise. Items recorded on each plot are listed briefly.—Biol. Abs.

HUDSON, H. G. **1081**

1939. Population studies with wheat. I. Sampling. Jour. Agr. Sci. [England] 29(1): 76–110, illus.

The design and field techniques of 2 large-scale expts., laid down to investigate the probs. of sampling and "propinquity," are described in detail. These expts. were designed so that plant no., stem no., ear no., straw wt., and grain wt. for 7,200 lengths of 6 in. of drill row, together with the position of each observ., might be obtained. The lowest sampling error, expressed as a % of the mean, is obtained by using the smallest sampling unit, but the large no. of sampling units of this size that would have to be

taken make it impracticable. Optimum sampling unit consists of 6 in. of drill row taken as 3 in. in 2 adjacent rows. As size of sampling unit is more important than shape in determining its accuracy, little was lost by using sampling units of 18 in. in 5 adjacent rows. The observs. of grain wt. require a sample about twice as large as that required for other observs. The larger the plot the lower the sampling % necessary to obtain any given accuracy. Subdividing plot and taking equal nos. of sampling units from each subdivision greatly increase the accuracy of sampling. The actual percentages necessary to insure accuracy under various plot sizes and degrees of subdivision are given.

HUTCHINSON, J. B., AND PANSE, V. G. 1082
1935. Studies in the technique of field experiments. I. Size, shape and arrangement of plots in cotton trials. Indian Jour. Agr. Sci. 5: 523–538.

HYDER, D. N., CONRAD, C. E., TUELLER, PAUL T., AND OTHERS. 1083
1963. Frequency sampling in sagebrush-bunchgrass vegetation. Ecology 44(4): 740–746, illus. (Calvin, Lyle D., Poulton, C. E., and Sneva, Forrest A., joint auth.)

Appropriate quadrat sizes and efficient allocations of sampling units were determined for frequency sampling of the *Artemisia arbuscula/Festuca idahoensis* assoc. in southeast. Oreg. The theoretical considerations pertinent to these determinations were reviewed. A quadrat 6 to 10 in. sq. is appropriate for frequency sampling of the common spp., and an allocation of 10 to 20 quadrats per transect attained optimum efficiency. A sample of 15 transects, each including 10 9-in. quadrats, was convenient, appropriate, and efficient. This allocation of sampling units is recommended for subsequent frequency sampling of this assoc.

ILVESSALO, VRJÖ. 1084
1921. Vegetationsstatistische untersuchungen über die waldtypen. [Statistical investigations on the vegetation of forest types.] Acta Forest. Fenn. [Helsinki] 20: 1–73, illus.

The invests. in question pertaining to forest types were made in the south. half of Finland in even-aged, regular, and clean forest stands. They show that the no. of higher plant spp. to a sample plot is different in different forest types (presupposing the stand to be of the same age and equally dense throughout); and from the poorest to the best types it rises distinctly and regularly. It is shown, principally by graphs and with the assistance of correlation calculations and mean av. values, that in studying the no. of plant spp. in any chosen plant-community (at least in forests) a few plots will not suffice, even though they be large (1/8–1/4 ha.). The richer the community is in spp. and the more luxuriant its growth the larger the no. of plots necessary for its analysis. Satisfactory results are not obtainable from small plots of a few sq. m. Elongated sample plots have proved more satisfactory than sq. ones, but for heterogeneous types, rich in spp., broad strips are most satisfactory.—Bot. Abs.

IMMER, F. R., AND RALEIGH, S. M. 1085
1933. Further studies of size and shape of plot in relation to field experiments with sugar beets. Jour. Agr. Res. 47(8): 591–598, illus.

The standard errors in % of the mean decreased with increasing size of plots. When the entire plot was harvested, the efficiency in use of the land decreased as plot size increased. When a single border row was removed on each side of the plot, the 4-row width was decidedly the most efficient. The regression of yield of all plants in a plot on total no. of beets was essentially linear. Stands of the various plots varied from 50 to 100%.

JOHNSON, FLOYD A., AND HIXON, HOMER J. 1086
1952. The most efficient size and shape of plot to use for cruising in old-growth Douglas-fir timber. Jour. Forestry 50(1): 17–20.

A 66×198-ft. rectangular plot was found to be the most efficient of the 12 kinds of plot that were tested.

JUSTESEN, S. H. 1087
1932. Influence of size and shape of plots on the precision of field experiments with potatoes. Jour. Agr. Sci. [England] 22: 365–372.

A uniformity trial with potatoes was used for investigating the effect of size and shape of plots on the precision of field expts. Up to a certain limit the standard deviation in % of the mean decreases when the size of plots is increased; further increase of plot size increases the errors as a lesser part of the soil variation can be removed. When the area to be used is fixed, smaller plots are more efficient than larger, owing to the greater no. of replications in the former case. Long and narrow plots are

more efficient than shorter and wider ones of the same size. In field expts. with potatoes, fairly large plots should be used, at least 2 rows wide and preferably long and narrow strips.

KALAMKAR, R. J. **1088**
1932. Experimental error and the field-plot technique with potatoes. Jour. Agr. Sci. [England] 22: 373–383.

An invest. using data from a uniformity trial with potatoes confirms the findings of Justesen that the standard error in % of the mean decreased slightly with the increase in plot width up to a certain point. Increased size of the plot resulted in a decrease in efficiency which points to increased replication with plots of smaller size. Long narrow plots are more efficient than shorter wide plots.

KOCH, E. J., AND RIGNEY, J. A. **1089**
1951. A method of estimating optimum plot size from experimental data. Agron. Jour. 43(1): 17–21.

LEONARD, H. **1090**
1932. Ueber die genauigkeit und zuverlässigkeit der quantitativbotanischen untersuchung bei wiesenversuchen. [The accuracy and reliability of the quantitative botanical analysis in grassland trials.] Arch. f. Pflanzenbau [Berlin] 8: 650–682.

As the size of the trial plots and the no. of samples were increased, the no. of spp. present in the samples also increased, at first considerably, then more slightly. The accuracy of the results of sample taking on plots with heterogeneous stands was numerically very slight, and it was naturally still less the more heterogeneous the stand. Elongated, narrow plots generally gave more accurate results than quadrat-shaped plots of equal or even larger area. As the size of the plots increased, error became at first less, but only up to a certain point, after which error began to increase again, because as the area was extended so did the difference in plant stand tend to increase. Even if samples from definitely limited areas lead to more accurate results than single or av. samples, from the practical point of view the 2 latter are to be preferred. With the increase in the no. of trial plots, accuracy increased at first considerably, later to a less extent. Reduction of error by increasing the no. of samples taken was very slow. The increased effort involved is by no means in scientifically and economically justifiable ratio to the result. For this reason a relatively high degree of inaccuracy must often be allowed in comparatively small proportions of a sp. In ascertaining the proportion of individual sp., one has to reckon with comparatively large errors. These are the less, the more uniform and large the proportion of the particular sp. in the sward. The reliability values showed in general the same tendency as the accuracy values. In spite of the greater unreliability of the results obtained from "single samples" and "av. samples," as compared with samples from limited, definite sample areas, the probability is that the former are more "just."—Transl. from auth. sum.

MCCLELLAND, C. K. **1091**
1926. Some determinations of plat variability. Amer. Soc. Agron. Jour. 18(9): 819–823.

MACDONALD, D., FIELDING, W. L., AND RUSTON, D. F. **1092**
1939. Experimental methods with cotton. I. The design of plots for variety trials. Jour. Agr. Sci. [England] 29: 35–47.

MAHALANOBIS, P. C. **1093**
1946. Use of small-size plots in sample surveys for crop yields. Nature [London] 158: 798–799.

A discussion is presented of the various ways in which sample size and shape of sample plot may prejudice accurate estimations of yields.

MARANI, A. **1094**
1963. Estimation of optimum plot size using Smith's procedure. Agron. Jour. 55: 503.

MILLER, JOHN D., AND KOCH, E. JAMES. **1095**
1962. A plot technique study with birdsfoot trefoil. Agron. Jour. 54(2): 95–97.

The effects of row spacing, border vars. (having different habits of growth), and plot size on the yields of birdsfoot trefoil were studied over 2 yrs. The method used to evaluate optimum econ. plot size is also applicable to other crops.

OVESNOV, A. M. **1096**

1937. [On the size of the sample square in the study of phytocoenoses on continental grasslands.] Uchen. Zap. Perm. Gos. Univ. 2(4): 137–143. [Eng. sum.]

Of the 8 sizes tested on 19 phytocoenoses, the round plot of 50 sq. m. proved to be most significant; it registered 85% of spp. composing a phytocoenosis, including all the typical spp. With a larger size of plot, the no. of spp. increased, but mainly at the expense of less important spp. In comparative studies of phytocoenoses, the size of the sample plots must be uniform.—Herb. Abs.

PANSE, V. G. **1097**

1946. Plot size in yield surveys on cotton. Cur. Sci. [India] 15(8): 218–219.

Small plots, 1/200 acre and less, give biased estimates of the yield of the whole field.

PECHANEC, JOSEPH F., AND STEWART, GEORGE. **1098**

1940. Sagebrush-grass range sampling studies: Size and structure of sampling unit. Amer. Soc. Agron. Jour. 32(9): 669–682, illus.

Herbage yield data of arrowleaf balsamroot (*Balsamorhiza sagittata*) and tapertip hawksbeard (*Crepis acuminata*), collected on 640 5×5-ft. plots located in the sagebrush-grass vegetation type at the U.S. Sheep Expt. Sta., Dubois, Idaho, were used in testing the efficiency of various sampling-unit sizes and shapes and in exploring the influence of subdivision of sampling upon accuracy of the sample. Principles of sampling previously evolved in agronomic research held for native vegetation, viz, smaller sampling units tended to be more efficient per unit area than larger units, and long narrow units more efficient than sq. or round units. In selection of a sampling unit for use, an effective balance must be established between statis. efficiency and such practical factors as time involved and accuracy of observ. By trial a complex type unit, designated as the line-plot, and subdivision of the area in sampling were found to hold much promise for use with native vegetation. Subdivided random sampling, using line-plot units whose subunits were approx. 50 sq. ft. in area, was recommended for trial in sampling similar sagebrush-grass range areas.

PENFOUND, WILLIAM T. **1099**

1948. An analysis of an elm-ash floodplain community near Norman, Oklahoma. Okla. Acad. Sci. Proc. 28: 59–60.

Concerns a 4th-level-floodplain elm-ash forest. The site, relatively wet and with little herbaceous cover, was once occupied by a cottonwood-willow forest. Quadrats 13.2 ft. on a side seem to be of proper size to "delineate frequency, no., cover, and basal area." It was believed that at least 50 quadrats of the size employed are necessary for the analysis.

PIELOU, E. C. **1100**

1957. The effect of quadrat size on the estimation of the parameters of Neyman's and Thomas's distributions. Jour. Ecol. [London] 45(1): [31]–47, illus.

Models of Neyman's Type A and Thomas's distribs., with the clusters occupying appreciable areas, were constructed and sampled with quadrats of various sizes. Results show that these distribs. are indistinguishable by quadrat sampling and that the size of quadrat used greatly affects the form of observed frequency distribs. obtained. All the derived statis., which should give an estimate of no. of points per cluster, were too low. The highest and most nearly correct estimates of this parameter were obtained by sampling a population with quadrats of several sizes and calculating the regression of log % absence on density. The constant term in the regression equation gives some idea of the degree of diffuseness of the clusters constituting the population.

RAMPTON, H. H., AND PETERSEN, ROGER G. **1101**

1962. Relative efficiency of plot sizes and numbers of replications as indicated by yields of orchardgrass seed in a uniformity test. Agron. Jour. 54(3): 247–249, illus.

Increasing replications or increasing plot size permitted detection of smaller differences in yield of orchardgrass (*Dactylis glomerata*) seed. Shape of plot had little effect on yield variance. Accuracy of yield estimates changed most rapidly with change in replications. Hence, on a given area, most accurate yield estimates would result with plots of minimum size and increased replications. Plot cost:land cost relations showed that as land cost increased, optimum plot size decreased. Optimum plot size for close-drills was about half that for 3-ft. rows.

REID, DAVID. 1102

1951. A quantitative method for determining palatability of pasture plants. Brit. Grassland Soc. Jour. 6(4): 187–195.

Methods used to date in the study of the relative palatability of herbage plants are reviewed, and a method described for determining palatability on a quantitative basis. A study of the relative palatability of 15 strains of grasses is described, and the advantages and disadvantages indicated. Despite large sampling errors, the results obtained in the present trial indicate, that with refinement, it could be a valuable method for studying palatability. Refinement would involve slightly larger plots than those used so that more precise sampling could be effected. Further replication may also be desirable, as part of the discrepancy between blocks is ascribable to differences between groups of animals.

ROBINSON, H. F., RIGNEY, J. A., AND HARVEY, P. H. 1103

1948. Investigations in plot technique with peanuts. N.C. Agr. Expt. Sta. Tech. Bul. 86, 19 pp., illus.

Two yrs.' uniformity data were used to estimate the most efficient size and shape of plot and to evaluate certain incomplete block designs. The basic data were taken on 12-1/2-ft. single-row units. The C.V. decreased with increasing plot size, and the long narrow plots were more effective than the short wide ones. Increasing the no. of plots per block from 6 to 16 did not increase the error perceptibly. The technique suggested by H. Fairfield Smith for determining optimum plot size was also used. The expression for the variance of a treatment mean (on a per-unit basis), $V_{(x)}=\frac{V}{rx^b}$, was transformed to a log scale to give the regression form $\log V_{(x)}=\log V-\log r-b\log x$. The coefficient b was estimated from the data to av. 0.57 for the 2 yrs. and is used as an indication of soil heterogeneity. A cost function was set up and minimized to give the optimum plot size for any degree of soil heterogeneity and any distrib. of cost. When the proportion of cost that is related to plot size is low, small plots are most efficient regardless of soil uniformity. As this cost increases, larger plots become the most economical, especially on less uniform soils. A balanced lattice gave very little gain in precision with 16 entries and small plots. The gains tended to increase as the no. of entries and plot size increased. Triple lattices were only slightly less efficient than the balanced lattice, but simple lattices lost up to 15% of the gains when the balanced lattice had a relative precision of 200. Lattice squares were slightly more efficient than balanced lattices, since columns accounted for some of the residual error.

SCHMITT, L., AND BRAUER, A. 1104

1958. Untersuchungen über die gegenseitigen randbeeinflussungen verschieden gedüngter teilstücke bei langjährigen feld- und wiesendüngungsversuchen. [Reciprocal edge effects between differently manured plots in long-term arable and grassland experiments.] Landw. Forsch. [Germany] 11(1): 10–22, illus. [Eng. and Fr. sum.]

Edge effects were investigated in plots of arable land and grassland which had undergone manurial trials for 54 and 40 yrs., respectively. P_2O_5, K_2O, and pH were determined. As a consequence of soil cultivation, mutual edge effects occurred in the arable expt., often extending into the plots by 75 cm. or more. Only slight effects, undergone manurial trials for 54 and 40 yrs., respectively. P_2O_5, K_2O, and pH were separated by shallow furrows 10 to 12 cm. wide. Consequently, plots in arable long-term expts. should be large enough to include discard strips 1 m. wide at the edges of the treated area. For grassland expts. no such guard strips are needed, provided that the plots are separated clearly by furrows, and herbage samples are not taken from their very extreme edges.—Herb. Abs.

SHIMADA, Y. 1105

1958. [Statistical studies on the design of yield survey and field experiment in natural grassland. Part 1. Estimation of yield, especially with reference to size and shape, and replication of field experimental plot in natural *Miscanthus* grassland.] Tohoku Univ. Sci. Rpts., Ser. D 9(2): 117–130, illus.

The area studied was a natural grassland in Miyagi Prefecture in which *Miscanthus sinensis* 180 cm. high was dominant and belonged to the frequency class 5. The object was to study prod. of *M. sinensis*. A rectangular area 16 m.×64 m. was divided into 1,024 sq.-m. quadrats. Production (fresh wt.) was expressed in 5 classes each of 1,000 g. per sq. m. and the results were charted. By combining sq.-m. quadrats, blocks of different shapes and sizes were formed, from 1×1, 1×2, etc., to 8×8 sq.-m., their no. ranging from 128 for 1×1 sq. m. to 2 for 8×8 sq. m. The larger the sampling unit,

the smaller was the C.V., but shape of block had no effect. On this land, which had a slope of 15.8°, stratified sampling with horizontal strata gave results which were 10–50% more accurate than purely random sampling. For measuring prod. of *Miscanthus* grasslands, plots of 8×8 sq. m. with 8 replications are recommended.—Herb. Abs.

SHIMADA, Y. 1106

1959. Statistical studies on the design of yield survey and field experiment in natural grassland. Part 3. Estimation of yield, especially with reference to size and shape, and replication of field experimental plot in natural *Zoysia* grassland. Tohoku Univ. Sci. Rpts., Ser. D 10(2): 87–107, illus.

In a *Zoysia*-type grassland at 300–450 m. altitude, the expt. error was investigated in estimations of the yield of a field of *Z. japonica* and other herbage and in the yield from small sample plots. Since the proportion of *Z. japonica* in the total herbage was approximately constant, separation of spp. for *Zoysia* alone was not necessary. In small sq.-m. plots the error was lower in oblong than in sq. plots. The number of replications was studied in plots of 0.5 m.×0.5 m.; in these, the expt. error diminished rapidly as the no. of replications increased up to 16, after which the decrease in error was very slight.

SIAO, FU. 1107

1935. Uniformity trials with cotton. Amer. Soc. Agron. Jour. 27: 974–979.

Increase in size of plot reduces expt. error, but larger plots are lower in efficiency than smaller ones. Increased replication is much more efficient than increased plot size. An increase in size of plot in the direction of least assoc. is most efficient. Because of high seasonal variation, no definite no. of replications could be recommended. Experimental error is larger in an unfavorable than in a favorable season.

SINGH, B. N., AND CHALAM, G. V. 1108

1936. Unit of quantitative study of weed flora on arable lands. Amer. Soc. Agron. Jour. 28: 556–561.

A 5×5-m. plot which was divided into 625 small squares was laid out on a flat that had been fallowed 1 winter. Small squares were combined into 5×5 quadrats and 1×25 strips. Variances were calculated with the following results: (1) A higher variance for strips when density was high: (2) a higher variance for quadrats when density was low, agreeing with Clapham's findings. They give no explanation of (1) other than to refer to "edge effects" and to a "uniform environment of arable land where random distrib. is minimized."

SMITH, H. FAIRFIELD. 1109

1938. An empirical law describing heterogeneity in the yields of agricultural crops. Jour. Agr. Sci. [England] 28: 1–23.

Using data from a blank expt. with wheat, it was found that the regression of the logs of the variances for plots of different areas on the logs of their areas was approx. linear. A graphical rev. of variances indicates that most uniformity trials conform to such a law. It is shown that the above law can be generalized (so as to apply to any size of field) by applying a certain adjustment to the regression coefficient b' to give a modified coefficient b applicable to an "infinite" field. From this generalized relation there has been deduced an expression to indicate av. relative efficiencies to be expected for randomized block expts. with varying nos. of plots per block in a field for which the coefficient b is known. A formula which may be used to estimate the most efficient size of plot for any given expt. has also been deduced. The cost of using plots of other than the most efficient size is indicated graphically.

SPECHT, R. L., AND RAYSON, PATRICIA. 1110

1957. Dark Island heath (Ninety-Mile Plain, South Australia). I. Definition of the ecosystem. Austral. Jour. Bot. 5(1): [52]–85, illus.

The heath vegetation and its environment are described. The study has shown that the flora is one adapted to flourish on soils of very low fertility and that the growth rhythm of the flora is markedly out of phase with the present ann. climatic cycle, which is typically mediterranean. It was found to be necessary to examine at least 4 random 25-sq. yd. quadrats for a satisfactory study of the larger spp.; a subquadrat of 22 sq. ft. within each large quadrat enabled the smaller spp. to be examined critically.—Herb. Abs.

SUKHATME, P. V. 1111

1947. Use of small-size plots in yield surveys. Nature [London] 160(4068): 542.

The auth. reaffirms, contra Mahalanobis, the advantage of large plots (1/80 acre) for estimating yield. The largest factor of bias is the choice of including or excluding border plants; random selection of plot can be adequately controlled.

SUMMERBY, R. **1112**

1925. A study of sizes of plats, numbers of replications and the frequency and methods of using check plats, in relation to accuracy in field experiments. Amer. Soc. Agron. Jour. 17: 140–150.

Small plots were more accurate than large plots. There is a steady and rapid increase in accuracy as the no. of replications is increased. There was no consistency of the effect of more or less frequent checks no matter what system of checking was used.

TORRIE, J. H., SCHMIDT, D. R., AND TENPAS, G. H. **1113**

1963. Estimates of optimum plot size and shape and replicate number for forage yield of alfalfa-bromegrass mixtures. Agron. Jour. 55(3): 258–260.

Two uniformity trials were conducted to obtain inform. on plot sizes and shapes, block shapes, nos. of replicates, cost relations and incomplete block designs as affecting efficiency of sampling alfalfa/bromegrass for forage yield. Increasing plot length was generally more effective in reducing variation than increasing plot width. Differences among block shapes had little effect on within-block variation. The most efficient plot size was 4.5×10 ft. (basic unit), and the optimum plot size was calculated to be 1.26 basic units (presumably 4.5×12.6 ft.). Greater efficiency and less variation in the relative costs of plots of different sizes were observed for lattice as compared with randomized complete block designs.

TSAI, H., AND CHOW, C. Y. **1114**

1943. Studies on plot technique in wheat. Chinese Jour. Sci. Agr. 1(2): 93–118. [In Chin. with Eng. sum.]

Analysis of the expt. results gave the following conclusions: For any given plot size, long, narrow strips give greater precision than short, wide ones; replication under 6 may decrease the expt. errors as much as expected; with systematic arrangements the deviations from math. expectation are greater than those derived from random arrangement, but this method of interpreting results will not lead to a serious error and facilitates the mechanical operation of taking records; the pseudo-factorial and incomplete randomized block methods are more efficient for testing a large no. of vars.

VAN DYNE, GEORGE M., VOGEL, W. G., AND FISSER, H. G. **1115**

1963. Influence of small plot size and shape on range herbage production estimates. Ecology 44(4): 746–759, illus.

Different sizes and shapes of plots were evaluated for measuring herbage prod. on southwest. Mont. foothill bunchgrass ranges. Plots were restricted to those which could be conveniently located in cage exclosures. Statistical analyses were made of spp. or plant-group yield, total herbage yield, clipping time, and no. and frequency of spp. Yield estimates derived from different sizes and shapes of plots on these foothill grasslands varied. In general, less variable data per unit area were found with circular than with rectangular, sq., or strip plots. Larger plots gave more uniform estimates than smaller plots. A circular, 2 sq.-ft. plot, and a 1×4-ft. plot, respectively, were the most efficient for estimating herbage prod. of 2 bunchgrass ranges based on minimizing yield variance and clipping time. The distrib. of the spp. influenced yield estimates. Scattered shrubs or aggregated clusters of large bunchgrass clumps caused an abnormally high variation in yield from plot to plot, indicating that different spp. or groups of spp. require different shapes, sizes, and nos. of plots for equally efficient estimates. Smaller plants, which occurred at a greater density, required fewer or smaller plots to obtain the same efficiency of estimate as compared to the aggregated clusters of large plants. Plot shape appeared to have no influence on the no. of spp. encountered. Percentage frequency was not different for 1- and 2-sq.-ft. plots, but was different for 2-, 4-, and 6-sq.-ft. plots. Differences in plot yields for different shape plots of a given area may possibly be explained by the ratio of plot perimeter to area. More subjective decisions must be made in harvesting individual plants or plant parts as the ratio of the perimeter to the area becomes larger. Workers harvesting range vegetation probably tend to take more vegetation than is necessary when a subjective decision must be made. In general, the estimates of yield increased as the ratio of plot perimeter to area increased. There was a heterogeneity of variance among different rectangular plot sizes for forbs and for bunchgrasses on grazed sites and for all shrubs and half-shrubs on ungrazed sites. The effects of grazing and of mean yield are discussed in relation to heterogeneity of variance. Since common statis. tests are not completely valid if the assumption of homogeneity of variance cannot be accepted, such a relation is of obvious importance.

WIEBE, GUSTAV A. **1116**

1935. Variation and correlation in grain yield among 1,500 wheat nursery plots. Jour. Agr. Res. 50(4): 331–357.

Federation C.I. No. 4734 was grown in a uniformity trial. The ultimate plots were

rows 1 ft. apart and 15 ft. long. Total variation tended to increase when more and more land was added, provided the size and shape of the ultimate unit remained the same. When, however, more and more land was added by increasing the size of the ultimate plot (the no. remaining the same), total variation tended to decrease. When the entire expt. area was used in each study of variation with increasing row lengths, the variation decreased and was a function of n, the no. of ultimate plots combined, and r, their intraclass correlation. The correlation of the yields of adjacent rows was high and decreased in a nearly linear relation until the rows were 48 ft. apart; beyond this distance statistically significant correlations could not be established. The intraclass correlation coefficient increased as the size of the combination plot, compounded by contiguous assoc., decreased, provided the shape remained constant. When the size of the combination plot remained the same, the coefficient increased as the shape of plot approached a sq. The variation of the ultimate plots (rows) within combination plots, compounded by contiguous assoc., decreased when the shape was constant but the size decreased, and also when the size was constant, but the shape approached a sq. The variation within combination plots, compounded by noncontiguous assoc., approached the total variation. The nearness of approach depends on the intraclass correlation. The variation between combination plots, compounded by contiguous assoc., increased when their shape was constant but their size decreased, and also when their size was constant but their shape approached a sq. The variation between combination plots, compounded by noncontiguous assoc., decreased as the no. of ultimate plots grouped became larger, the reduction being nearly proportional to $\sqrt{n}$, the no. of plots grouped. A greater reduction in variation between combination plots was secured when an equal no. of replicates were distributed noncontiguously than when they were distributed contiguously. The actual and theoretical curves for the variation agree exactly when the latter is calculated as a function of both n and r. Less bias was secured in the estimate of the expt. error when the replicates were distributed completely at random as contrasted with systematic distribs. When the vars. of each replication were arranged according to the principle of maximum contiguity, the expt. error was reduced. Two systems, involving the principle of maximum contiguity, are suggested as plot arrangements for nursery practice. In 1 system the vars. or hybrids to be tested are divided into groups of 5 (1 of the group is always a check or standard var.) and replicated the desired no. of times. The arrangement within the group is random for the several replications. In the other system they are arranged in the same sequence in the replications with every 5th var. a check. The expt. error is calculated by analysis of variance for each group of 5 when their no. is not too large. Where there are many groups, the av. error from several groups of 5 may be appl. throughout all the groups of 5. When the vars. or hybrids are planted in sequence as in the 2nd system, the error may be used as a "moving error" and is appl. to any contiguous group of 5 vars. or hybrids. The "moving error" permits any var. or hybrid to be compared with the check or standard var. on either side.—Biol. Abs.

WIEGERT, RICHARD G. **1117**

1962. The selection of an optimum quadrat size for sampling the standing crop of grasses and forbs. Ecology 43(1): 125–129, illus.

The optimum quadrat size is that yielding the smallest confidence limits of the mean for a given cost. A general method for determining this optimum was developed from data on the plant biomass of an old field in southeast. Mich. The method emphasizes the following: (1) Sample initially with nested quadrats to measure variance changes and calculate the cost of each quadrat size. The largest quadrat should be commensurate with the vegetation type and probable dispersion pattern. (2) Graph relative variance of the mean against quadrat size to show the presence of clumping, to evaluate changing correlation, and to determine the mean clump size. (3) Minimize the product, relative variance of the mean times relative cost, in order to calculate the optimum size of quadrat. (4) Consider the possibilities of bias of the mean and inflation of the confidence limits of the mean due to very small quadrats or to few of them in a sample. The optimum sizes determined in this study were as follows: Forbs and total green material, 0.187 sq. m.; grass, 0.047 sq. m.; and dead material, 0.063 sq. m. The optimum changed with vegetation type because of differences in dispersion patterns of the plant biomass.

WIENER, W. T., AND BROADFOOT, R. **1118**

1925. The amount of variability which may be expected to occur in a determination of comparative yields in small grain. Sci. Agr. [Ottawa] 5: 305–309.

This is a preliminary rpt. on a series of field plot tests commenced at Winnipeg in 1924. Under variable soil conds. systematic distrib. of a no. of plots of each var. is necessary to insure a reasonable degree of precision. The yields of 94 1/100-acre plots of Mindum wheat were compared when taken singly and when grouped to form plots of 1/50-, 1/25-, and 1/10-acre each. Under the conds. of the expt., the 1/100-acre

plot replicated 3–4 times gave the best results. The removal of the 2 border rows on either side and to a depth of 12 in. on the ends is sufficient to overcome the effect of fallow borders.

See also **151, 734, 888, 929, 933, 934, 949, 956, 967, 991, 1005, 1022.**

ABBREVIATIONS FOR TITLES OF PUBLICATIONS

Acta Agr. Fenn. [Helsinki]	Suomen Maataloustieteellinen Seuran. Julkaisuja. Acta Agralia Fennica. Helsinki, Finland.
Acta Agr. Scand. [Stockholm] Sup.	Acta Agriculturae Scandinavica. Supplementum. Stockholm, Sweden.
Acta Bot. Néerlandica	Acta Botanica Néerlandica. Amsterdam, Netherlands.
Acta Forest. Fenn. [Helsinki]	Acta Forestalia Fennica. Helsinki, Finland.
Agr. and Livestock in India	Agriculture and Livestock in India. Delhi, India.
Agr. Engin.	Agricultural Engineering. St. Joseph, Mich.
Agr. Prog. [Cambridge]	Agricultural Progress. Cambridge, England.
Agrártudomány [Budapest]	Agrártudomány. Budapest, Hungary.
Agricultura [Lisbon]	Agricultura. Lisbon, Portugal.
Agricultura [Madrid]	Agricultura. Madrid, Spain.
Agron. Abs.	Agronomy Abstracts. American Society of Agronomy. Madison, Wis.
Agron. Jour.	Agronomy Journal. Madison, Wis.
Agron. Trop. [Maracay]	Agronomia Tropical. Maracay, Venezuela.
Agron. Trop. [Paris]	Agronomie Tropicale. Paris, France.
Akad. Nauk SSSR Bot. Inst. Trudy	Akademiya Nauk SSSR. Botanicheskii Institut. Trudy. Moscow, U.S.S.R.
Amer. Jour. Bot.	American Journal of Botany. Lancaster, Pa.
Amer. Jour. Pub. Health	American Journal of Public Health. New York, N.Y.
Amer. Midland Nat.	American Midland Naturalist. Notre Dame, Ind.
Amer. Soc. Agron. Jour.	American Society of Agronomy. Journal. Geneva, N.Y.
Amer. Soc. Anim. Prod. Proc.	American Society of Animal Production. Record of Proceedings of Annual Meeting.
Amer. Soc. Hort. Sci. Proc.	American Society for Horticultural Science. Proceedings. College Park, Md.
Amer. Statis. Assoc. Jour.	American Statistical Association. Journal. Menasha, Wis.
Anim. Behaviour [London]	Animal Behaviour. London, England.
Anim. Prod. [Edinburgh]	Animal Production. Edinburgh, Scotland.
Ann. Agron. [Paris]	Annales Agronomiques. Paris, France.
Ann. Appl. Biol. [London]	Annals of Applied Biology. London, England.
Ann. Biochem. and Expt. Med. [Calcutta]	Annals of Biochemistry and Experimental Medicine. Calcutta, India.
Ann. Bot. [London]	Annals of Botany. London, England.
Ann. della Sper. Agr. [Rome]	Annali della Sperimentazione Agraria. Rome, Italy.
Ann. Eugenics [Cambridge]	Annals of Eugenics. Cambridge, England.
Ann. Math. Statis.	Annals of Mathematical Statistics. East Lansing, Mich.
Arch. f. Met., Geophys. u. Bioklimatol., Ser. B [Austria]	Archiv für Meteorologie, Geophysik und Bioklimatoligie. Series B. Wien, Austria.
Arch. f. Pflanzenbau [Berlin]	Archiv für Pflanzenbau. Berlin and Leipzig, Germany.

Ark. Agr. Expt. Sta. Bul.	Arkansas. Agricultural Experiment Station. Bulletin. Fayetteville, Ark.
Asoc. de Téc. Azucareros Cuba, Proc.	Asociación de Técnicos Azucareros de Cuba. Proceedings. Habana, Cuba.
Austral. Council Sci. and Indus. Res., Bul.	Australia. Council for Scientific and Industrial Research. Bulletin. Melbourne, Australia.
Austral. C.S.I.R.O. Div. Plant Indus.,	Australia. Commonwealth Scientific and Industrial Research Organization. Division of Plant Industry. Canberra, Australia.
Div. Rpt.	Divisional Report.
Field Sta. Rec.	Field Station Record.
Austral. Inst. Agr. Sci. Jour.	Australian Institute of Agricultural Science. Journal. Sydney, N.S. Wales, Australia.
Austral. Jour. Agr. Res.	Australian Journal of Agricultural Research. Melbourne, Australia.
Austral. Jour. Appl. Sci.	Australian Journal of Applied Science. Melbourne, Australia.
Austral. Jour. Bot.	Australian Journal of Botany. East Melbourne, Australia.
Austral. Jour. Expt. Agr. and Anim. Husb.	Australian Journal of Experimental Agriculture and Animal Husbandry. Melbourne, Australia.
Austral. Jour. Sci.	Australian Journal of Science. Sydney, Australia.
Austral. Jour. Sci. Res. Ser. B	Australian Journal of Scientific Research. Series B, Biological Science. Melbourne, Australia.
Austral. Soc. Anim. Prod. Proc.	Australian Society of Animal Production. Proceedings. Melbourne, Australia.
Barcelona R. Acad. de Cièn. y Artes, Mem.	Reale Academia de Ciències y Artes de Barcelona. Memorias. Barcelona, Spain.
Bayer. Landw. Jahrb. [Munich]	Bayerisches Landwirtschaftliches Jahrbuch. Munich, Germany.
Biol. Abs.	Biological Abstracts. Philadelphia, Pa.
Biometrics	Biometrics. Washington, D.C.
Biometrics Bul.	American Statistical Association. Biometrics Section. Biometrics Bulletin. Washington, D.C.
Biométrie-Praximétrie [Brussels]	Biométrie-Praximétrie. Brussels, Belgium.
Biometrika [London]	Biometrika. London, England.
Bodenkultur [Vienna] Ser. A	Bodenkultur. Series A. Vienna, Austria.
Bot. Abs.	Botanical Abstracts. Baltimore, Md.
Bot. Mag. [Tokyo]	Botanical Magazine. Tokyo, Japan.
Bot. Notiser [Sweden]	Botaniska Notiser. Lund, Sweden.
Bot. Rev.	Botanical Review. Lancaster, Pa.
Bot Tidsskr. [Copenhagen]	Bot Tidsskrift. Copenhagen, Denmark.
Bot. Zhur. [Moscow]	Botanicheskii Zhurnal. Moscow, U.S.S.R.
Boyce Thompson Inst. Contribs.	Boyce Thompson Institute. Contributions. Yonkers, N.Y.
Bragantia [Brazil]	Bragantia. Campinas, Brazil.
Brit. Grassland Soc. Jour.	British Grassland Society. Journal. Belfast, Northern Ireland.
Butler Univ. Bot. Studies	Butler University. Botanical Studies. Indianapolis, Ind.
Calif. Fish and Game	California Fish and Game. San Francisco, Calif.
Cambridge Phil. Soc. Biol. Rev.	Cambridge Philosophical Society. Biological Reviews. London, England.
Canad. Ent.	Canadian Entomologist. Guelph, Ontario, Canada.

Canad. Jour. Anim. Sci.	Canadian Journal of Animal Science. Ottawa, Ontario, Canada.
Canad. Jour. Plant Sci.	Canadian Journal of Plant Science. Ottawa, Ontario, Canada.
Canad. Jour. Res. Sect. C, Bot. Sci.	Canadian Journal of Research. Section C, Botanical Sciences. Ottawa, Ontario, Canada.
Canad. Soc. Anim. Prod. Proc.	Canadian Society of Animal Production. Proceedings of the General Annual Meetings. Edmonton, Alberta, Canada.
Canada Cent. Expt. Farm, Prog. Rpt.	Canada. Central Experimental Farm. Progress Report. Ottawa, Canada.
Ceylon Jour. Sci. Sect. A, Bot.	Ceylon Journal of Science. Section A. Botany. Colombo, Ceylon.
Chinese Jour. Sci. Agr.	Chinese Journal of Scientific Agriculture. Chungking, China.
Chron. Bot.	Chronica Botanica. Waltham, Mass. and Leiden, The Netherlands.
Colo. Dept. Game and Fish Tech. Bul.	Colorado. Department of Game and Fish. Technical Bulletin. Lakewood, Colo.
Commonwealth Bur. Pastures and Field Crops Bul.	Commonwealth Bureau of Pastures and Field Crops. Bulletin. Hurley, England.
Commonwealth Bur. Plant Breeding and Genet. Tech. Commun.	Commonwealth Bureau of Plant Breeding and Genetics. Technical Communication. Cambridge, England.
Cong. Internatl. de Bot. Raps. et Commun., Deuxiéme Sér.	Congrès International de Botanique. Rapports et Communications. Deuxiéme Série. Paris, France.
Conn. (State) Agr. Expt. Sta. Bul.	Connecticut. Agricultural Experiment Station. Bulletin. New Haven, Conn.
Consult. Comt. Devlpmt. Spectrographic Work [Edinburgh] Bul.	Consultative Committee for Development of Spectrographic Work. Bulletin. Edinburgh, Scotland.
Cur. Sci. [India]	Current Science. Bangalore, India.
[Czechoslovakia] Min. Zeměděl. Sborn.	Czechoslovakia. Ministerstva Zemědělství. Sbornik Výzkumných Ústavú Zemědělských. Prague, Czechoslovakia.
Diss. Abs.	Dissertation Abstracts. Ann Arbor, Mich.
Duke Univ. Forestry Bul.	Duke University. School of Forestry. Bulletin. Durham, N.C.
East African Agr. and Forestry Res. Organ. Rpt.	East African Agriculture and Forestry Research Organisation. Report. Kikuyu, Kenya.
East African Agr. Jour.	East African Agricultural Journal. Kenya, Tanganyika, Uganda and Zanzibar. Nairobi, Kenya Colony.
Ecol. Monog.	Ecological Monographs. Durham, N.C.
Ecol. Soc. Amer. Bul.	Ecological Society of America. Bulletin. East Lansing, Mich.
Ecology	Ecology. Brooklyn, N.Y.
Ekologia Polska, Ser. A	Ekologia Polska, Seria A. Warsaw, Poland.
Empire Forestry Rev.	Empire Forestry Review. London, England.
Empire Jour. Expt. Agr.	Empire Journal of Experimental Agriculture. London, England.
Ent. Soc. Amer. Ann.	Entomological Society of America. Annals. Columbus, Ohio.
European Grassland Conf., Paris, Sum.	European Grassland Conference. Summary, General Conclusions and Recommendations and Technical Papers. Paris, France.

Excerpta Bot. [Stuttgart], Sect. B	Excerpta Botanica. Sectio B, Sociologica. Stuttgart, Germany.
Fiziol. Rast. [Moscow]	Fiziologiia Rastenii. Moscow, U.S.S.R.
Forestry [London]	Forestry. London, England.
Forestry Abs.	Forestry Abstracts. Oxford, England.
Forestry Chron. [Canada]	Forestry Chronicle. Knowlton, Quebec, Canada.
Forest Sci.	Forest Science. Washington, D.C.
Forstwiss. Centbl. [Berlin]	Forstwissenschaftliches Centralblatt. Berlin, Germany.
France Serv. de la Carte Phytogéog. Bul., Sér. B	France. Service de la Carte Phytogéographique. Bulletin. Série B. Paris, France.
Franklin Inst. Jour.	Franklin Institute. Journal. Philadelphia, Pa.
Ga. Expt. Stas. Tech. Bul.	Georgia. Experiment Stations. Technical Bulletin. Athens, Ga.
Gembloux Inst. Agron. de l'État Bul.	Gembloux Institut Agronomique de l'État. Bulletin. Gembloux, Belgium.
Gembloux Inst. Agron. de l'État Bul., Sér. Extraordinaire	Gembloux Institut Agronomique de l'État. Bulletin. Série Extraordinaire. Gembloux, Belgium.
Genet. Agr. [Rome]	Genetica Agraria. Rome, Italy.
Ghent Landbouwhogesch. en de Opzoekinssta. Meded.	Ghent. Landbouwhogeschool en de Opzoekinsstation. Mededelingen. Ghent, Belgium.
Grünland [Hannover]	Grünland. Hannover, Germany.
Hammenhög Gullåkers Växtförädlingsanst. Meddel.	Hammenhög. Gullåkers Växtförädlingsanstalt. Meddelande. Hammenhog, Sweden.
Harper Adams Agr. Col. Tech. Bul.	Harper Adams Agricultural College. Technical Bulletin. Newport, England.
Hawaii. Planters' Rec.	Hawaiian Planters' Record. Honolulu, Hawaii.
Herb. Abs.	Herbage Abstracts. Farnham Royal, England.
Hilgardia	Hilgardia. Berkeley, Calif.
Human Biol.	Human Biology. Detroit, Mich.
Hurley Grassland Res. Inst. Expts. Prog.	Hurley. Grassland Research Institute. Experiments in Progress. Hurley, England.
Ill. Agr. Expt. Sta. Bul.	Illinois. Agricultural Experiment Station. Bulletin. Urbana, Ill.
Ill. Biol. Monog.	Illinois Biological Monographs. Urbana, Ill.
Imp. Bur. Pastures and Forage Crops,	Imperial Bureau of Pastures and Forage Crops. Cambridge, England.
Bul.	Bulletin.
Herbage Rev.	Herbage Reviews.
Imp. Bur. Plant Genet., Herbage Plants	Imperial Bureau of Plant Genetics. Herbage Plants. Aberystwyth, Wales.
Bul.	Bulletin.
Herbage Rev.	Herbage Reviews.
Ind. Acad. Sci. Proc.	Indiana Academy of Science. Proceedings. Indianapolis, Ind.
Indian Acad. Sci. Proc. Sect. B	Indian Academy of Sciences. Proceedings. Section B. Bangalore, India.
Indian Council Agr. Res. Statis. Newslet.	Indian Council of Agricultural Research. Statistical Newsletter. New Delhi, India.
Indian Forester	Indian Forester. Lahore, India.

Indian Jour. Agr. Sci.	Indian Journal of Agricultural Science. New Delhi, India.
Indian Jour. Agron.	Indian Journal of Agronomy. New Delhi, India.
Indian Jour. Vet. Sci. and Anim. Husb.	Indian Journal of Veterinary Science and Animal Husbandry. Calcutta, India.
Indian Sci. Cong. Proc.	Indian Science Congress. Proceedings. Calcutta, India.
Indian Soc. Agr. Statis. Jour.	Indian Society of Agricultural Statistics. Journal. New Delhi, India.
Inst. Internatl. de Statis. Bul. [Hague]	Institut International de Statistique. Bulletin. Hague, Netherlands.
Inst. Natl. pour l'Étude Agron. Congo Sér. Sci.	Institut National pour l'Étude Agronomique du Congo. Série Scientifique. Brussels, Belgium.
Internatl. Bot. Cong.	International Botanical Congress. (Various places.)
Proc.	Proceedings.
Recent Advn. Bot.	Recent Advances in Botany.
Internatl. Cong. Soil Sci. Trans.	International Congress of Soil Science. Transactions. (Various places.)
Internatl. Grassland Cong.	International Grassland Congress. (Various places.)
Proc.	Proceedings.
Rpt.	Report.
Invest. Pesquera [Barcelona]	Investigacion Pesquera. Barcelona, Spain.
Iowa Agr. and Home Econ. Expt. Sta.	Iowa. Agricultural and Home Economics Experiment Station. Ames, Iowa.
Iowa Agr. Expt. Sta. Res. Bul.	Iowa. Agricultural Experiment Station. Research Bulletin. Ames, Iowa.
Iowa State Col. Jour. Sci.	Iowa State College of Agriculture and Mechanic Arts. Journal of Science; a Quarterly of Research. Ames, Iowa.
Jap. Forestry Soc. Jour.	Japanese Forestry Society. Journal. Tokyo, Japan.
Jap. Jour. Bot.	Japanese Journal of Botany. Tokyo, Japan.
Jap. Jour. Ecol.	Japanese Journal of Ecology. Sendai, Japan.
Jap. Jour. Zootech. Sci.	Japanese Journal of Zootechnical Science. Tokyo, Japan.
Jour. Agr. Res.	Journal of Agricultural Research. Defunct journal formerly published by the U.S. Department of Agriculture, with the cooperation of the Association of Land-Grant Colleges. Washington, D.C.
Jour. Agr. Sci. [England]	Journal of Agricultural Science. London, England.
Jour. Anim. Sci.	Journal of Animal Science. Menasha, Wis.
Jour. Dairy Sci.	Journal of Dairy Science. Lancaster, Pa.
Jour. Dent. Res.	Journal of Dental Research. New York, N.Y.
Jour. Ecol. [London]	Journal of Ecology. London, England.
Jour. Econ. Ent.	Journal of Economic Entomology. Amherst, Mass.
Jour. Forestry	Journal of Forestry. Washington, D.C.
Jour. Range Mangt.	Journal of Range Management. Baltimore, Md.
Jour. Sci. and Indus. Res. [Delhi]	Journal of Scientific and Industrial Research. Delhi, India.
Jour. Soil and Water Conserv.	Journal of Soil and Water Conservation. Baltimore, Md.
Jour. Wildlife Mangt.	Journal of Wildlife Management. Menasha, Wis.

K. Vetensk. Akad. Nobelinst. Meddel. [Uppsala]	Kungl. Vetenskapsakademiens Nobelinstitut. Meddelanden. Uppsala, Sweden.
Kans. Acad. Sci. Trans.	Kansas Academy of Science. Transactions. Topeka, Kans.
Ky. Agr. Expt. Sta. Bul.	Kentucky. Agricultural Experiment Station. Bulletin. Lexington, Ky.
Kyushu Univ., Faculty Sci. Mem. Ser. E	Kyushu University. Faculty of Science. Memoirs. Series E. Fukuoka, Japan.
Landbouwk. Tijdschr. [Wageningen]	Landbouwkundig. Tijdschrift. Wageningen, Netherlands.
Landbouwvoorlichting [Hague]	Netherlands. Rijkslandbouwvoorlichtingsdienst. Landbouwvoorlichting. Hague, Netherlands.
Landw. Forsch. [Germany]	Landwirtschaftliche Forschung. Darmstadt, Germany.
Landw. Jahrb. der Schweiz [Bern]	Landwirtschaftliches Jahrbuch der Schweiz. Bern, Switzerland.
Leningrad Univ. Vest., Ser. Biol.	Leningrad. Universitet. Vestnik. Seriya Biologii. Leningrad, U.S.S.R.
Lima, Peru, Estac. Expt. Agr. de La Molina, Bol.	Lima. Estacion Experimental Agricola de La Molina. Boletin. Lima, Peru.
Linn. Soc. London, Proc.	Linnean Society of London. Proceedings. London, England.
Linn. Soc. N.S. Wales, Proc.	Linnean Society of New South Wales. Proceedings. Sydney, Australia.
[London] Phys. Soc. Proc.	Physical Society. Proceedings. London, England.
Macdonald Col., McGill Univ. Tech. Bul.	Macdonald College, McGill University. Technical Bulletin. Quebec, Canada.
Madras Agr. Jour.	Madras Agricultural Journal. Coimbatore, So. India.
Maine Univ. Forestry Dept. Tech. Note	Maine. University. Forestry Department. Technical Note. Orono, Maine.
Malayan Forester	Malayan Forester. Kuala Lumpur, Malaya.
Mich. Acad. Sci., Arts and Letters, Papers	Michigan Academy of Science, Arts and Letters. Papers. Ann Arbor, Mich.
Mich. Agr. Expt. Sta. Quart. Bul.	Michigan. Agricultural Experiment Station. Quarterly Bulletin. Lansing, Mich.
Mich. Univ. Lab. Vert. Biol. Contribs.	Michigan. University. Laboratory of Vertebrate Biology. Contributions. Ann Arbor, Mich.
Minas Gerais Univ. Esc. de Vet. Arq.	Minas Gerais. Universidade. Escola de Veterinaria. Arquivos. Belo Horizonte, Brazil.
Mont. Acad. Sci. Proc.	Montana Academy of Sciences. Proceedings. Helena, Mont.
Mont. Agr. Expt. Sta. Mim. Cir.	Montana. Agricultural Experiment Station. Mimeograph Circular. Bozeman, Mont.
Montes [Madrid]	Montes. Madrid, Spain.
N.C. Agr. Expt. Sta. Tech. Bul.	North Carolina. Agricultural Experiment Station. Technical Bulletin. Raleigh, N.C.
N.Y. (Cornell) Agr. Expt. Sta. Mem.	New York. (Cornell) Agricultural Experiment Station. Memoir. Ithaca, N.Y.
Natl. Acad. Sci.- Natl. Res. Council Pub.	National Academy of Sciences. National Research Council. Publication. Washington, D.C.

Natl. Joint Comt. Fert. Appl. Proc.	National Joint Committee on Fertilizer Application. Proceedings, Annual Meeting. Washington, D.C.
Nature [London]	Nature. London, England.
Naturf. Gesell. in Bern, Mitt.	Naturforschende Gesellschaft in Bern. Mitteilungen. Bern, Switzerland.
Netherlands Jour. Agr. Sci.	Netherlands Journal of Agricultural Science. Wageningen, Netherlands.
Nev. Agr. Expt. Sta., Bul.	Nevada. Agricultural Experiment Station. Bulletin. Reno, Nev.
New Phytol. [London]	New Phytologist. London, England.
New Zeal. Dept. Agr. Bul.	New Zealand. Department of Agriculture. Bulletin. Wellington, New Zealand.
New Zeal. Jour. Agr.	New Zealand Journal of Agriculture. Wellington, New Zealand.
New Zeal. Jour. Agr. Res.	New Zealand Journal of Agricultural Research. Wellington, New Zealand.
New Zeal. Jour. Forestry	New Zealand Journal of Forestry. Christchurch, New Zealand.
New Zeal. Jour. Sci. and Technol.	New Zealand Journal of Science and Technology. Christchurch, New Zealand.
Sect. A	Section A. Agricultural Section.
Sect. B	Section B. General Research Section.
Nord. Jordbrugsforsk. [Helsinki]	Nordisk Jordbrugsforskning. Helsinki, Finland.
Nord. Jordbrugsforsk. [Stockholm] Sup.	Nordisk Jordbrugsforskning. Supplement. Stockholm, Sweden.
Norges Landbrhogskole. Meld. [Oslo]	Norges Landbrukshogskole. Meldinger. Oslo, Norway.
North Amer. Wildlife Conf. Trans.	North American Wildlife Conference. Transactions. Washington, D.C.
North. Ireland Min. Agr. Res. and Expt. Rec.	Northern Ireland. Ministry of Agriculture. Research and Experimental Record. Belfast, Northern Ireland.
Northwest Sci.	Northwest Science. Cheney, Wash.
Növénytermelés [Budapest]	Növénytermelés. Budapest, Hungary.
Nutr. Soc. Proc. [Cambridge]	Nutrition Society. Proceedings. Cambridge, England.
NYT Mag. [Oslo]	NYT Magazin for Naturvidenskaberne. Oslo, Norway.
Ohio Jour. Sci.	Ohio Journal of Science. Columbus, Ohio.
Oikos [Copenhagen]	Oikos, Acta Ecologica Scandinavica. Copenhagen, Denmark.
Okla. Acad. Sci. Proc.	Oklahoma Academy of Science. Proceedings. Enid, Okla.
Onderstepoort Jour. Vet. Sci. and Anim. Indus.	Onderstepoort Journal of Veterinary Science and Animal Industry. Pretoria, South Africa.
Osaka Univ., Inst. Polytech. Jour. Ser. D	Osaka. University. Institute of Polytechnics. Journal. Series D, Biology. Osaka, Japan.
Pa. Agr. Expt. Sta. Bul.	Pennsylvania. Agricultural Experiment Station. Bulletin. University Park, Pa.
Pacific Sci. [Honolulu]	Pacific Science. Honolulu, Hawaii.
Pflanzenbau [Leipzig]	Pflanzenbau; Monatsschrift für den Gesamten Acker- und Pflanzenbar und das Pflanzenbauliche Versuchswesen. Leipzig, Germany. (Title varies.)
Phys. In Med. and Biol. [London]	Physics in Medicine and Biology. London, England.
Phys. Rev.	Physical Review. Lancaster, Pa.
Physiol. and Ecol. [Japan]	Physiology and Ecology. Kyoto, Japan.
Plant and Soil [Hague]	Plant and Soil. Hague, Netherlands.

Plant Physiol.	Plant Physiology. Lancaster, Pa.
Polon. Acad. des Sci. et Lettres, Cl. de Sci. Math. et Nat. Bul. Internatl.	Polonaise Académie des Sciences et Lettres. Classe de Sciences Mathématiques et Naturelles. Bulletin International. Cracovie.
Portug. Acta Biol. Sér. B	Portugaliae Acta Biologica. Série B. Lisbon, Portugal.
Poultry Sci.	Poultry Science. Menasha, Wis.
Psychometrika	Psychometrika. Colorado Springs, Colo.
Puerto Rico Univ. Jour. Agr.	Puerto Rico. University. Journal of Agriculture. Rio Piedras, Puerto Rico.
Referat. Zhur., Biol. [Moscow]	Referativnyĭ Zhurnal. Biologiĭa. Moscow, U.S.S.R.
Rev. d'Élevage et de Méd. Vét. des Pays Trop. [Paris]	Revue d'Élevage et de Médecine Vétérinaire des Pays Tropicaux. Paris, France.
Rev. Mod. Phys.	Reviews of Modern Physics. New York, N.Y.
Rio de Janeiro, Jard. Bot. Arq.	Rio de Janeiro. Jardim Botânico. Arquivos. Rio de Janeiro, Brazil.
Rocz. Nauk Rolnicz. i Leśnych (Polish Agr. and Forest Ann.)	Roczniki Nauk Rolniczych i Leśnych. Poznań, Poland.
Roy. Agr. Soc. England Jour.	Royal Agricultural Society of England. Journal. London, England.
Roy. Soc. Canada, Proc. and Trans., Sect. 5	Royal Society of Canada. Proceedings and Transactions. Ottawa, Toronto, and London.
Roy. Soc. [London], Phil. Trans., Ser. B	Royal Society. Philosophical Transactions. Series B, Biological Sciences. London, England.
Roy. Soc. So. Africa, Cape Town, Trans.	Royal Society of South Africa. Transactions. Cape Town, South Africa.
Roy. Statis. Soc.	Royal Statistical Society. London, England.
Jour.	Journal.
——Sup.	——Supplement.
Sankhyā: Indian Jour. Statis.	Sankhyā; the Indian Journal of Statistics. Calcutta, India.
Sci. Agr. [Ottawa]	Scientific Agriculture. La Revue Agronomique Canadienne. Ottawa, Ontario, Canada.
Science	Science. Lancaster, Pa.
Skand. Aktuarietidskr. [Uppsala]	Skandinavisk Aktuarietidskrift. Uppsala, Sweden.
So. African Jour. Agr. Sci.	South African Journal of Agricultural Science. Pretoria, South Africa.
So. African Jour. Sci.	South African Journal of Science. Johannesburg, South Africa.
Soc. Amer. Foresters Proc.	Society of American Foresters. Proceedings. Washington, D.C.
Soc. Bot. de France Bul.	Société Botanique de France. Bulletin. Paris, France.
Soc. Bot. de Genève Bul.	Société Botanique de Genève. Bulletin. Geneva, Switzerland.
Soc. Brasil. de Agron. Bol. [Rio de Janeiro]	Sociedade Brasileira de Agronomia. Boletim. Rio de Janeiro, Brazil.
Soc. Vaud. des Sci. Nat. Bul. [Switz.]	Société Vaudoise des Sciences Naturelles. Bulletin. Lausanne, Switzerland.
Soil Sci.	Soil Science. Baltimore, Md.
Soil Sci. Soc. Amer. Proc.	Soil Science Society of America. Proceedings. Geneva, N.Y.
South. Pasture and Forage Crops Impr. Conf. Rpt.	Southern Pasture and Forage Crops Improvement Conference. Report. Stillwater, Okla.

Sovet. Bot. [Moskva]	Sovetskaîa Botanika. Moskva and Leningrad, U.S.S.R.
Stockholm Statens Skogsforskningsinst. Meddel.	Stockholm. Statens Skogsforskningsinstitut. Meddelanden. Stockholm, Sweden.
Svenska Mosskulturför. Tidskr. [Sweden]	Svenska Mosskulturförening. Tidskrift. Jönköping, Sweden.
Svenska Skogsvårdsför. Tidskr. [Stockholm]	Svenska Skogsvårdsföreningens. Tidskrift. Stockholm, Sweden.
Sveriges Utsädesför. Tidskr. [Sweden]	Sveriges Utsädesförening. Tidskrift. Svalöf, Sweden.
Taipei Natl. Taiwan Univ. Col. Agr. Mem.	Taipei. National Taiwan University. College of Agriculture. Memoirs. Taipei, Formosa.
Tex. Agr. Expt. Sta. Prog. Rpt.	Texas. Agricultural Experiment Station. Progress Report. College Station, Texas.
Tidsskr. för Planteavl [Copenhagen]	Tidsskrift för Planteavl. Copenhagen, Denmark.
Tohoku Univ. Sci. Rpts., Ser. D	Tohoku University. Science Reports. Series D, Agriculture. Sendai, Japan.
Tokyo Natl. Inst. Agr. Sci. Bul., Ser. A	Tokyo. National Institute of Agricultural Sciences. Bulletin. Series A (Physics and Statistics). Tokyo, Japan.
Tokyo Univ. Forests Bul.	Tokyo University Forests. Bulletin. Tokyo, Japan.
Torrey Bot. Club Bul.	Torrey Botanical Club. Bulletin. Menasha, Wis.
Trop. Agr. [Ceylon]	Tropical Agriculturist. Peradeniya, Ceylon.
Trop. Agr. [Trinidad]	Tropical Agriculture. St. Augustine, Trinidad.
Turrialba [Costa Rica]	Turrialba. Turrialba, Costa Rica.
U.S. Air Force Wright Air Devlpmt. Div. Tech. Rpt.	U.S. Air Force. Wright Air Development Division. Technical Report. Wright-Patterson Air Force Base, Ohio.
U.S. Atomic Energy Comn. Off. Tech. Inform.	U.S. Atomic Energy Commission. Office of Technical Information. Oak Ridge, Tenn.
U.S. Dept. Agr.	U.S. Department of Agriculture. Washington, D.C.
Cir.	Circular.
Misc. Pub.	Miscellaneous Publication.
Tech. Bul.	Technical Bulletin.
U.S. Forest Serv. Intermountain Forest and Range Expt. Sta. Tech. Note	U.S. Forest Service. Intermountain Forest and Range Experiment Station. Technical Note. Ogden, Utah.
U.S. Forest Serv. Pacific Northwest Forest and Range Expt. Sta. Res. Note	U.S. Forest Service. Pacific Northwest Forest and Range Experiment Station. Research Note. Portland, Oreg.
U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper	U.S. Forest Service. Southern Forest Experiment Station. Occasional Paper. New Orleans, La.
U.S. Forest Serv. Southeast. Forest Expt. Sta.	U.S. Forest Service. Southeastern Forest Experiment Station. Asheville, N.C.
U.S. Forest Serv. Southwest. Forest and Range Expt. Sta. Res. Rpt.	U.S. Forest Service. Southwestern Forest and Range Experiment Station. Research Report. Tucson, Ariz.
Uchen. Zap. Perm. Gos. Univ.	Uchenȳe Zapiski Permskogo Gosudarstvennogo Universiteta im. M. Gor'kogo. Perm, U.S.S.R.
Uppsala Lantbrhögsk. Ann.	Uppsala. Lantbrukshögskolan. Annaler. Uppsala, Sweden.

Uppsala Lantbrhögsk. och Statens Lantbrförsok. Statens Jördbrförsok., Meddel.	Uppsala. Lantbrukshögskolan och Statens Lantbruksförsök. Statens Jördbruksförsök. Meddelande. Stockholm, Sweden.
Utah Agr. Expt. Sta. Bul.	Utah. Agricultural Experiment Station. Bulletin. Logan, Utah.
Valtion Maatalouskoet. Julkaisu. [Helsinki]	Finland. Maatalouden Koetoiminnan Keskusvaliokunta. Valtion Maatalouskoetoiminnan Julkaisuja. Helsinki, Finland.
Vegetatio [Hague]	Vegetatio. Hague, Netherlands.
Verslag. van Landbouwk. Onderzoek. der Rijkslandbouwproefsta. [Hague]	Verslagen van Landbouwkundige Onderzoekingen der Rijkslandbouwproefstation. 's Gravenhage, Netherlands.
Vetensk. och Prakt. Undersökn. i Lappland [Stockholm]	Vetenskapliga och Praktiska Undersökningar i Lappland. Stockholm, Sweden.
Victoria Dept. Agr. Jour.	Victoria. Department of Agriculture. Journal. Melbourne, Australia.
Vsesoyuzn. Akad. Sel'sk.-Khoz. Nauk Dok. [Moscow]	Vsesoyuznaya Akademiya Sel'skokhozyaistvennykh Nauk. Doklady. Moscow, U.S.S.R.
Wageningen Cent. v. Landbpub. and Landbdoc. Verslag. van Landbouwk. Onderzoek.	Wageningen. Centrum voor Landbouwpublikaties and Landbouwdocumentatie. Verslagen van Landbouwkundige Onderzoekingen. Wageningen, Netherlands.
Wageningen Inst. v. Biol. en Scheik. Onderz. van Landbgewassen.	Wageningen. Instituut voor Biologisch en Scheikundig Onderzoek van Landbouwgewassen. Wageningen, Netherlands.
Jaarb.	Jaarboek.
Jaarv.	Jaarverslag.
Meded.	Mededelingen.
Wageningen Rijksinst. v. Rassenonderz. van Landbgewassen. Meded.	Wageningen. Rijksinstituut voor Rassenonderzoek van Landbouwgewassen. Mededelingen. Wageningen, Netherlands.
Wash. Acad. Sci. Jour.	Washington Academy of Sciences. Journal. Baltimore, Md.
Wash. Agr. Expt. Sta. Bul.	Washington. Agricultural Experiment Station. Bulletin. Pullman, Wash.
Welsh Plant Breeding Sta., Aberystwyth,	Welsh Plant Breeding Station. Aberystwyth, Wales.
Bul., Ser. H	Bulletin. Series H.
Rpt.	Report.
Ztschr. f. Acker- u. Pflanzenbau [Berlin]	Zeitschrift für Acker- und Pflanzenbau. Berlin and Hamburg, Germany.
Ztschr. f. Landw. Vers.- u. Untersuchw. [Berlin]	Zeitschrift für Landwirtschaftliches Versuchs- und Untersuchungswesen. Berlin, Germany.

SINGLE WORD ABBREVIATIONS[1]

abs.—abstracts(s)
acct(s).—account(s)
agr.—agricultural, agriculture
agron.—agronomy
Amer.—America, American
analyt.—analytical
ann(s).—annual(s)
app.—appendix
appl.—application, applied
appls.—applications
approx.—approximate, approximately, approximation
approxs.—approximations
Apr.—April
Ariz.—Arizona
assoc.—associated, association
assocs.—associations
Aug.—August
auth.—author(s)
av.—average

bibliog.—bibliography
bien(s).—biennial(s)
biol.—biological, biology
bot.—botanical, botany
Brit.—British

C.—centigrade
Ca—calcium
Calif.—California
cent.—central
ch.—chapter(s)
chem.—chemical
Chin.—Chinese
climatol.—climatological
cm.—centimeter(s)
Co—cobalt
Co.—County
col.—college
Colo.—Colorado
comp.—composition
concl.—conclusion(s)
cond(s).—condition(s)
conserv.—conservation
construct.—construction
contrib(s).—contribution(s)
cos—cosine
CP—crude protein
cu.—cubic
C.V.—coefficient of variation
cwt(s).—hundredweight(s)

Dan.—Danish
d.b.h.—diameter breast high
Dec.—December
Del.—Delaware
dept.—department
devlpmt.—development
diam.—diameter
digest.—digestible, digestion, digestive
distrib(s).—distribution(s)
DM—dry matter
dm.—decimeter

E.—east
east.—eastern
ecol.—ecological, ecologist(s), ecology
econ.—economic(s)
ed(s).—edition(s), editor(s)
e.g.—(exempli gratia), for example
elect.—electrical
Eng.—English
equip.—equipment
estab.—establish, establishment
etc.—(et cetera), and so forth
exp.—exponent, exponential
expt.—experiment, experimental
expts.—experiments
extr.—extract

F.—Fahrenheit
Feb.—February
fert(s).—fertilizer(s)
fertil.—fertilization
fig(s).—figure(s)
Finn.—Finnish
Fla.—Florida
Flem.—Flemish
Fr.—French
ft.—feet, foot

g.—gram(s)
Ga.—Georgia
geog.—geographic, geographical
Ger.—German
Gr. Brit.—Great Britain

ha.—hectare
hr(s).—hour(s)
ht(s).—height(s)

[1] To avoid repetition, abbreviations for some plurals are indicated with (s) as Acct(s). instead of Acct. and Accts.

i.e.—(id est), that is
Ill.—Illinois
illus.—illustrated, illustration(s)
impr(s).—improvement(s)
in.—inch, inches
Ind.—Indiana
inform.—information(s)
inst.—institute(s)
intermed.—intermediate
introduct(s).—introduction(s)
invest(s).—investigation(s)
irrig.—irrigated, irrigation
Ital.—Italian

Jan.—January
Jap.—Japanese

K—potassium
Kans.—Kansas
kg.—kilogram(s)

La.—Louisiana
lab., labs.—laboratory, laboratories
LAI—leaf area index
lb.—pounds(s)
log(s)—logarithm(s), logarithmic

m.—meter(s)
mangt.—management
Mar.—March
math.—mathematical, mathematics
Md.—Maryland
Mg—magnesium
mg.—milligram
Mich.—Michigan
min(s).—minute(s)
mm.—millimeter(s)
mo(s).—month(s)
Mont.—Montana
morph.—morphological, morphology

N—nitrogen
N.—north
Na—sodium
N.C.—North Carolina
n.d.—no date
NE.—northeast
Nebr.—Nebraska
Nev.—Nevada
New Zeal.—New Zealand
NFE—nitrogen-free extract
N.J.—New Jersey
N. Mex.—New Mexico
no(s).—number(s)
north.—northern
northeast.—northeastern
northwest.—northwestern
Nov.—November
n.s.—new series
NW.—northwest
N.Y.—New York

observ(s).—observation(s)
Oct.—October
Okla.—Oklahoma
Oreg.—Oregon
organ.—organization
orig.—original
oz.—ounce, ounces

P—phosphorous
p., pp.—page, pages
Pa.—Pennsylvania
peren(s).—perennial(s)
perm.—permanent
pH—hydrogen-ion concentration
physiol.—physiological
phytosociol.—phytosociological, phytosociology
Portug.—Portuguese
p.p.m.—parts per million
prelim.—preliminary
prob(s).—problem(s)
prod.—produce, production
psychol.—psychology
pt(s).—part(s)
pub(s).—publication(s)

recom(s).—recommendation(s)
ref(s).—reference(s)
res.—research
rev.—review(s), revision
rpt(s).—report(s)
Russ.—Russian

S—sulfur
S.—south
sci.—science, scientific
SE—starch equivalent
SE.—southeast
sect(s).—section(s)
Sept.—September
sin—sine
soc.—society
sociol.—sociological, sociology
south.—southern
southeast.—southeastern
southwest.—southwestern
sp.—species (singular)
Sp.—Spanish
spp.—species (plural)
sq.—square
sta(s).—station(s)
statis.—statistic(s), statistical
subj(s).—subject(s)
sum.—summary, summaries
supp(s).—supplement(s)
Sw.—Swedish
SW.—southwest

TDN—total digestible nutrient(s)
temp(s).—temperature(s)
Tex.—Texas
topog.—topographic, topography

transl.—translated,
translation(s)

univ.—university
U.S.A.—United States of America
U.S.S.R.—Union of Soviet
Socialist Republics
util.—utilization

Va.—Virginia
var., vars.—variety, varieties
viz—(videlicet), namely
vol(s).—volume(s)

W.—west
Wash.—Washington
west.—western
Wis.—Wisconsin
wk(s).—week(s)
wt(s).—weight(s)
Wyo.—Wyoming

yd(s).—yard(s)
yr(s).—year(s)

°—degree
%—percent, percentage
<—less than
>—greater than

AUTHOR INDEX

☆ U.S. GOVERNMENT PRINTING OFFICE: 1967—217-875