REPORT OF THE CHIEF OF THE BUREAU OF CHEMISTRY AND SOILS

United States Department of Agriculture,
Bureau of Chemistry and Soils,
Washington, D. C., August 31, 1932.

Sir: I present herewith the report of the Bureau of Chemistry and Soils for the fiscal year ended June 30, 1932.

Respectfully,

Henry G. Knight,
Chief of Bureau.

Hon. Arthur M. Hyde,
Secretary of Agriculture.

INTRODUCTION

The Bureau of Chemistry and Soils directs its efforts toward the conservation and more profitable utilization of the soil resources of the United States and to the conversion of farm products, by-products, and residues into farm profits. The primary activity is applying scientific knowledge to those problems that have a direct bearing upon the stabilization and prosperity of American agriculture. Some of these problems are: Classification of land; reduction of losses from soil erosion; maintenance of soil fertility; profitable utilization of crop surpluses and farm wastes; better adaptation of some farm products to market or industrial requirements; development of uses for heretofore unutilized plants; discovery of new uses for minor crops to replace overproduced crops; development and substitution of domestic for imported agricultural products; and protection of agricultural products and property from loss and destruction.

There is little question of the desirability or even the necessity of classifying agricultural land if agricultural efficiency is to be increased. Adapting our agriculture to meet our domestic needs and at the same time putting lands to uses for which they are best fitted under present economic conditions are problems of national importance. We have considerable evidence which indicates that the agricultural plant of the United States is too large to meet present domestic demands. Of the 350,000,000 acres of land now in harvested crops, probably about 100,000,000 acres may be classed as marginal or submarginal and would be better adapted for other purposes such as grazing, forestry, and recreation. If these marginal or submarginal lands were withdrawn from cultivation, the total acreage of arable fields would still be sufficient to supply satisfactorily all domestic needs, and agriculture would be placed in a more stable condition. Further, better information on the adaptability of the remaining 250,000,000 acres is decidedly important in avoiding overproduction of certain commodities and giving best returns to the farmer. More than 50 per cent of the agricultural area of the country has been surveyed and mapped and the soils classified in sufficient detail for the purpose of making a land classification. This work has been carried on by this bureau in cooperation with the several States.

Already more than 21,000,000 acres of land in the United States, formerly in cultivation, has been rendered useless for agricultural purposes by soil erosion. The surface soil has been washed or completely removed from many more millions of acres, markedly reducing the agricultural value and spreading distress

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over large areas. What nature has required thousands of years to produce, man has destroyed in the course of one or two generations. Notwithstanding our present abundant supply of arable land this erosional destruction can not continue without imperiling the most vital resource of the Nation. This bureau, in cooperation with the Bureau of Agricultural Engineering, is carrying on investigations in developing satisfactory and efficient methods of reducing this enormous loss.

At the same time, the soils of many areas are becoming less fertile, because of soil washing, cropping, and other influences, while at all times agricultural industry is being brought to a higher stage of efficiency. Critical studies of fertilizer requirements based on soil type are needed, as are studies of methods that will decrease the cost of producing fertilizer materials. Already, striking discoveries and developments have been made by the bureau. In former years organic fertilizers, Chilean nitrate, leguminous crops, or stable manure were depended upon for nitrogen; to-day there are a number of sources, not the least of which is the production of synthetic nitrogen, which make this country independent of foreign countries in securing such materials, and cheaper methods for the production of phosphatic and potash fertilizers are now being developed.

Knowledge of the food requirements of plants and the fertilizer deficiency of soils is much greater than it was a few years ago. Recent work of this bureau has indicated quite clearly that certain elements, formerly not considered necessary, are absolutely essential for healthy plant growth. Critical studies of these minor soil amendments are being made.

BETTER UTILIZATION OF AMERICAN CROPS

While crops are produced primarily for food, feed, or fiber, there is an ever-widening industrial utilization of certain crops. Corn is now converted into its constituents—starch, oil, etc.—and by conversion methods these basic materials find markets in new forms such as corn sirup, corn sugar, cattle feed, etc. Cottonseed, formerly a waste product, now yields linters, hulls, oil, cattle feed, and fertilizers as basic materials; and from these are derived 30 or more industrial products, among them rayon and cottonseed oils. In this manner industry creates outlets for surpluses and farm wastes.

While there is a limit to the amount of foodstuffs which a nation can consume, there seems to be no limit to the utilization of farm products for other purposes. Every new use developed for a farm crop or a farm surplus widens the market and increases the demand for the products of agriculture.

The potential possibilities of capitalizing the fruits of research in this field are exceedingly great. In the development of industrial uses for agricultural materials a study often shows that a particular product can be changed to meet better the demand of industry.

The bureau has focused its attention chiefly upon the problems relating to farm products that are outstanding in national importance, determining their chemical composition and seeking new methods and processes of utilizing them. The 15 leading crops of the United States, in the order of their monetary value for 1930 according to the latest statistical reports of the department, are given in Table 1.

TABLE 1.—*Production and value of 15 leading crops, 1930*

Crop	Production	Value	Crop	Production	Value
		Million dollars			*Million dollars*
Corn, bushels	2,060,185,000	1,349	Oranges, boxes	[1] 54,559,000	191
Hay (tame and wild), tons	74,214,000	877	Barley, bushels	304,601,000	118
Cotton:			Apples, do	101,004,000	94
Fiber, bales	13,932,000	793	Sugar beets, tons	9,199,000	66
Seed, tons	6,185,000		Tomatoes, do	2,218,828	54
Wheat, bushels	858,160,000	515	Dry beans, bushels	23,063,000	54
Oats, do	1,277,764,000	403	Grapefruit, boxes	18,690,000	50
Potatoes, do	333,210,000	297	Sweetpotatoes, bushels	53,663,000	48
Tobacco, pounds	1,635,210,000	211	Total		5,119

[1] Estimated.

As a preface to the more detailed account of this bureau's various activities during the past year, the following brief paragraphs list phases of agriculture in which the work of the bureau bears an important relation to each of these 15 leading farm crops of the United States.

Corn.—Utilization of cornstalks for fiber board; utilization of corncobs for furfural production; utilization of the lignin of cornstalks in producing dyestuffs, chemicals, and other useful commodities; investigation of the food value of the proteins of corn; utilization of corn sugar in producing citric acid, gluconic acid, and other useful chemicals, by means of the fermentative action of microorganisms; prevention of rancidity in corn products; utilization of corn meal and corn flour in commercial bread and cake making; prevention of losses from dust explosions in corn-products plants; improvement in clarifying conversion liquors for manufacture of corn sirup and corn sugar.

Hay.—Investigation of the losses which result from the spontaneous heating and ignition of hay and the discovery of methods for reducing the annual losses, direct and indirect, from this cause, which are estimated to exceed $80,000,000 a year; investigation of the hay losses caused by rain.

Cotton.—Cultural practices and fertilizer treatment to combat the ravages of root rot of cotton; studies of cropping systems and cultural methods of checking erosion on cotton lands; effect of placement on the efficiency of commercial fertilizer used for cotton and the response of different soil types; study of the composition of the cotton plant; improvement of methods for analyzing and evaluating cottonseed; study of the composition of cottonseed oil and of methods for improving its quality; improvement of the feeding value of cottonseed products; investigation of the food value of cottonseed proteins; prevention of losses from fires in cotton gins and cotton-oil plants; study of the use of cottonseed flour by commercial bakeries as an adjunct in making a higher-protein bread; investigations in improving the quality of calcium arsenate as an insecticide for controlling the cotton boll weevil; studies upon the waterproofing, fireproofing, and mildew proofing of cotton fabrics.

Wheat.—Study of the food value of wheat bran and wheat proteins; increasing the protein content of wheat; improving the baking qualities of wheat flour; industrial utilization of wheat straw in producing fiber board, paper, gas, chemicals, etc.; prevention of dust explosions in threshing machines and grain elevators; study of environment on the composition and baking quality of wheat products; study of the utilization of wheat germ in commercial baking; prevention of spoilage of wheat-flour products as a result of rancidity.

Oats.—Study of the food value of oat proteins; utilization of oat hulls in producing furfural and other products; utilization of oat straw; prevention of losses from dust explosions in cereal mills and feed-grinding plants.

Potatoes.—Utilization of surplus and cull potatoes in starch production; dehydration of potatoes; study of the food value of potato proteins; utilization of potato flour and potato starch in commercial baking; determination of the relative efficiency of concentrated fertilizers and the best methods of placement in several of the more important potato-producing areas; special consideration of potash hunger and magnesium deficiency with reference to soil type.

Tobacco.—Study of the nicotine of tobacco as an insecticide; study of new insecticides for controlling tobacco pests; prolonging the life of shade cloth used in growing tobacco.

Oranges.—Utilization of surplus and cull oranges in manufacture of orange juice, orange oil, cattle feeds, etc.; chemical composition of oranges as affected by spraying, freezing, etc.; vitamins of oranges; improvement of food value of oranges; improvement of color of oranges by ethylene treatment and effect of this upon the vitamin content of oranges; study of fumigants and oil emulsions for controlling insects that infest orange trees; utilization of orange oil and orange peel in commercial cake making; determination of the effect of commercial fertilizers, including the minor elements, upon yield and quality of oranges and other citrus fruits with reference to soil type.

Barley.—Investigations on the chemical composition of American barleys and of the malts made from them; investigation of the process of pearling barley.

Apples.—Utilization of pomace and apple waste; improvements of processes for dehydrating apples; production of apple cider and vinegar; removal of spray residues from apples; investigation of new insecticides for controlling insects infesting apple orchards; production of ursolic acid from apple skins and its

utilization in varnish manufacture; in connection with the soil survey, detailed studies of the adaptation of soil type to varieties of apples as well as the effect of soil characteristics upon tree growth and fruiting.

Sugar beets.—Studies of fertilizer requirements of the principal soil types used for growing sugar beets, including the effect upon purity of juice as well as upon yield; investigations of chemical composition of sugar beets and other factors which influence the process of manufacturing beet sugar, made with the object of increasing yield of sugar and improving its quality; utilization of sugar-beet residues; effect of storage, freezing, and other conditions upon composition of sugar beets.

Tomatoes.—Improvement of processes for canning and utilizing tomatoes; manufacture of tomato-seed oil; pigments of the tomato; vitamins of tomatoes; benefit of growing tomato seedlings in a rich medium before transplanting.

Dry beans.—Food value of bean proteins; utilization of bean flour for increasing the protein content of commercial bakery products.

Grapefruit.—Utilization of cull and surplus grapefruit; canning of grapefruit; maturity standards for grapefruit.

Sweetpotatoes.—Utilization of cull and surplus sweetpotatoes in producing high-quality starch; study of the proteins of the sweetpotato; utilization of sweetpotatoes in manufacture of malt sirups; studies of fertilizer requirements of soils in the principal sweetpotato-growing regions.

While much research work of the bureau is concentrated upon the crops of chief monetary importance, a great deal of investigation is also devoted to other farm crops not enumerated in the preceding list (such as vegetable tanning materials, peaches, lemons, rice, peanuts, soybeans, honey, cane and maple sugar, cane, maple, and sorghum sirups, etc.), the total annual production of which for 1930 had a market value of over $225,000,000.

Other activities of the bureau, while not directly related to crop production, nevertheless have an important relationship to utilization of products either grown or produced on the land. Among the more important of these products are domestic hides and skins, which have an estimated annual value of approximately $150,000,000, and naval stores (turpentine and rosin from turpentine farms), with an estimated annual value of over $50,000,000. Some of the accomplishments of the bureau in these fields are briefly summarized as follows:

Hides and skins.—Studies on taking off, curing, and handling hides and skins have resulted in improvement in the quality of these necessary raw materials for making shoes and other leather goods.

Naval stores.—The development of the steam still from the fire still commonly used in the United States has given large naval-stores operators equipment that yields them higher grades of rosin at lower cost. For the small producers an improved type of fire-still setting has accomplished the same end. The naval-stores operator, using the still best adapted to his needs, can improve the grades of his rosin and produce it at reduced cost.

The total annual value of the farm products of the United States that are being investigated by the bureau exceeds $5,500,000,000, according to the census report for 1930. Federal funds expended by the Bureau of Chemistry and Soils in studying problems relating to the chemical composition and the utilization of products which make up so large a proportion of our national wealth amount to only about 0.01 per cent of this sum.

DEVELOPING NEW USES FOR AMERICAN CROPS

A critical study of native plants not utilized at present offers a very enticing field for possible profits. Some of these plants were used as food by the Indians before the advent of the white man, others were recognized as having insecticidal or piscicidal properties, and still others were once used for their active ingredients as medicines. Investigations carried on by the bureau thus far show possibilities of again making use of some of these plants. This, together with the discovery of new uses for minor crops already under cultivation, may be a factor in replacing crops which are now overproduced.

The United States imports considerable quantities of agricultural products, such as starch, tannin extracts, etc., which under proper conditions should be produced in this country. It is highly desirable that the United States be free as possible from dependence on foreign countries for agricultural supplies. The bureau, therefore, is intent on developing domestic sources of such material.

PREVENTING LOSSES OF FARM PRODUCTS FROM FIRES AND EXPLOSIONS

Enormous losses are caused annually by the spontaneous heating and ignition of agricultural products. Numerous instances of actual fires from such cause are on record. The estimated annual loss from farm fires is about $100,000,000; a considerable portion of this loss may be attributed to spontaneous combustion. This represents, however, only a small fraction of the total loss due to spontaneous heating. Haystacks, grain, straw, and piles of manure may heat to a point at which their value is seriously reduced. A critical study of the whole subject is being made in the hope that such losses may be reduced effectively.

Research on the causes and prevention of dust explosions in the industrial utilization of agricultural materials, a subject of interest to the bureau for several years, is yielding very satisfactory results. The annual loss from such explosions and their accompanying fires has been materially reduced because preventive measures advocated by the bureau have been adopted.

The work of the bureau does not have increased production for its object, but rather increased efficiency of production and a gain in the net return for the producer, which, paradoxical though it may seem, eventually results in a reduced cost of products to the consumer.

CHEMICAL AND TECHNOLOGICAL RESEARCH

CARBOHYDRATE INVESTIGATIONS

SUGARCANE

Work during the 1931 sugarcane-grinding season was done at the Houma, La., station in cooperation with the Division of Soil Fertility of this bureau and the Division of Sugar Plant Investigations of the Bureau of Plant Industry. A preliminary investigation was made of the influence of (1) soil type, (2) fertilizer, and (3) variety of sugarcane on the composition of the juice, its clarification properties, the composition of sirups made therefrom, and recovery of sugar.

The results so far obtained indicate that with canes of approximately the same sucrose content the type of soil has an important influence on the quality of the juice and on the yield and quality of sugar. In extreme cases variations in soil type resulted in an increase of as high as 100 per cent in the proportion of nonsugar compounds in the juice. The color of the juice and of sirup made from it varied greatly, and in extreme cases was about four times as dark in some juices as in others. Refining raw sugar produced from darker-colored juices is more expensive, and direct-consumption white sugar from such canes is likely to be of inferior quality. Some juices contained three times as much silica and sulphates as did other juices. One result of this condition is excessive scale on heating surfaces, which necessitates frequent cleaning and additional expense during evaporation of the juice for production of sugar. Moreover, high ash content is always associated with a lower sugar yield.

Although not so pronounced as the differences resulting from variation in soil type, marked differences in color and nonsugar content of the clarified juices and sirups resulted from different varieties of sugarcane and from variations in fertilizers. These results give a new insight into the influence of various cultural factors on the composition of sugarcane juice and its suitability for recovery of sugar. Continued investigations along this line are expected to yield information that will enable planters to effect additional economies in growing sugarcane for sugar production.

SUGARCANE SIRUP

Sugarcane for sirup production is grown on thousands of farms in the United States and is a substantial cash crop on which many small farmers place great dependence. The farm price varies more than 200 per cent, depending on quality. The best price is obtained only for sirup of sufficiently high quality for direct consumption. Sirup of lower grade is sold as a raw material for blending purposes and brings a correspondingly lower price. An estimated increase of $1,500,000 to $2,000,000 annually in the income of farmers producing this sirup would result if substantial improvement were made in the approximately 60 per cent of the crop which is marketed.

Tests on the use of decolorizing carbon for improving the color and flavor of farm-made cane sirup were made. Methods of applying the carbon and subsequently removing it were investigated under farm conditions, and tests were made with farm-sirup evaporators of various types. The use of decolorizing carbon for improving the quality of cane sirup has been found practicable under certain conditions of operation and the experimental work is being actively continued. The composition and origin of sediments in cane sirup have been investigated and means of eliminating them are being developed. An improvement in the method of applying invertase to prevent sucrose crystallization is being further investigated.

SORGO SIRUP

Sorgo is grown for the production of sirup on many thousands of farms in the United States. Recently the annual value of sorgo has been estimated at about $14,500,000 and that of the sirup made from it at more than $24,000,000, representing a considerable increase in value. At present the price obtained by the farmers varies over 200 per cent, depending on quality. Substantial improvement in the average quality of the sirup marketed would increase the annual return to sorgo growers by $1,500,000 to $2,000,000 a year.

The principal defects in quality of the lower-grade farm-made sorgo sirup are strong flavor, dark color, turbidity and sediment, occasional sugaring (crystallization of either sucrose or dextrose), and jellying. Experiments on the use of decolorizing carbons to improve color and flavor have been made in the same manner as for sugarcane sirup. Particular attention has been given to eliminating the so-called jellying of sorgo sirup which renders it practically unmarketable, and practical means applicable to farm conditions are being devised to effect diastatic conversion of the starch, which is responsible for the jellying. Experiments were also made on the controlled use of lime and calcium carbonate to improve the flavor of inferior grades of sorgo sirup by reducing excessive acidity.

HONEY

A method has been devised for clarifying honey by electrical neutralization and flocculation of its colloidal constituents by action of colloidal materials of opposite electric charge. This treatment produces brilliant clarity, reduces foaming and scum formation, prevents granulation over long periods of time, and reduces caramelization on heating, thus eliminating objectionable characteristics that have restricted the marketability of honey. Improving commercial quality in this manner would undoubtedly widen the field of use of honey and would be of great financial benefit to the entire honey industry. The obstacle to the immediate commercial use of this method is the difficulty of applying the flocculating agent and removing the resulting flocculated material without diluting and reconcentrating the honey. A great variety of methods and technics for overcoming this difficulty have been tested with encouraging results.

MILK SUGAR

The greatest waste in the dairy industry is that of sweet and sour whey. Approximately 4,000,000,000 pounds of sweet whey and 1,500,000,000 pounds of sour whey are produced annually by the domestic dairy industry. In addition to casein, which is now utilized, the principal valuable constituent of whey is milk sugar. On a basis of 60 per cent recovery, approximately 165,000,000 pounds of milk sugar could be produced annually in the United States, as compared with approximately 10,000,000 pounds that were produced in 1930.

The bureau, in cooperation with the Bureau of Dairy Industry, has investigated the possibility of using milk sugar in certain confectionery products. By using a substantial proportion of milk sugar the required physical characteristics can be obtained, and since milk sugar has only a limited degree of sweetness these products are free from the excessive sweetness to which many consumers object. Milk sugar has valuable dietetic properties. Through its use bacteria that produce toxic products in the intestines may be supplanted by bacteria of a type favorable to health. Another valuable characteristic of these lactose products is their unusually high retention of moisture.

An investigation of various technical factors necessary to the solution of this problem has been made. In cooperation with dairy interests tests have

been made on various grades of milk sugar with a view to determining the quality of milk sugar required for this purpose and a suitable price at which it could be produced.

UTILIZATION OF CULL AND SURPLUS SWEETPOTATOES

A large proportion of field-run sweetpotatoes (the second largest vegetable crop in the United States) grown for market is graded out as culls (oversized and undersized) and is largely wasted. In 1931 the proportion of culls was reported to have reached 50 per cent in some localities. Present methods of utilizing culls are inadequate.

The method recently devised by the bureau for producing white starch of high quality from sweetpotatoes has been improved, with the result that the yield has been increased, the process simplified, and the quality of starch has been rendered uniformly excellent. Possible uses for this starch are being investigated. In 1929 over 28,000,000 pounds of white potato starch was imported into the United States in spite of a duty of 1¼ cents per pound (subsequently increased to 2½ cents). Imported white potato starch, because of its superiority in quality, has been selling at about one-half cent per pound above the domestic product.

All but a small proportion of the imported potato starch is used in the textile industry. It is believed that sweetpotato starch of a quality satisfactory for this purpose can be produced at a satisfactory price. Some properties of pastes prepared from sweetpotato starch, such as viscosity and penetrating power in cotton yarns, have been investigated, and the results indicate that this starch is suitable for sizing for cotton textiles. Some properties of sweetpotato starch have been studied with an eye to other possible uses, and an investigation on modified starches and dextrins prepared from sweetpotato starch has been started. The purpose of these investigations is to reveal uses that would absorb practically the entire output of culls. It is estimated, on the basis of carload shipments of marketable sweetpotatoes, that if all sweetpotato culls could be sold at a price equal to that which they would bring for use in starch production, the return to growers would be increased by some $3,000,000 a year.

CARBOHYDRATES IN WILD DOMESTIC PLANTS

There are indications that inulin, a constituent of chicory root, is less objectionable in the diet of persons suffering from diabetes than are other carbohydrates commonly available. Diabetes is now so prevalent that a suitable carbohydrate diet is of great importance.

The bureau has devised a method for producing inulin of high purity by a simple and cheap process of crystallization from water. The most suitable source for this cheap production process is chicory, now grown in limited quantities in the United States for use as a beverage. About 1,000 pounds of inulin has recently been prepared on a semi-industrial scale. So far as is known, this is by far the greatest quantity of inulin ever prepared at one time. Inulin is now available only in limited quantity from chemical-supply houses at a cost of about $30 per pound. It is planned to place substantial quantities at the disposal of medical specialists on diabetes, thus making possible a definite decision on its suitability in the diet of diabetics. If the decision is favorable, the production of inulin would not only be of humanitarian value but would also provide an increased market for chicory.

Other uses for inulin are also being investigated. It seems possible that this carbohydrate, which bears somewhat the same relation to levulose as starch does to dextrose, may prove to have a substantial place in the diet and may possibly provide an additional and desirable variation.

In addition the carbohydrates of 15 other plants were investigated. Those of *Carum gairdneri* were studied with particular respect to starch and sucrose contents at various stages of growth.

FOOD-RESEARCH INVESTIGATIONS

PRESERVATION OF FRUIT JUICES AND PULPS

During the past year a very important project was developed by the bureau at San Jose, Calif., in quick freezing of fruit pulps. This material is easily prepared by thoroughly washing the fruit, pitting it if necessary, and passing

it through a special sieve. The pulp is mixed with a sirup made by dissolving granulated sugar in water by the aid of heat. The amount of sirup added varies according to the acidity, nature of the fruit, and the purpose for which the pulp is to be used. Apparently from 22½ to 25 per cent of added sugar results in a product satisfactory to the average consumer. The experiments have included a quick freezing of this sweetened pulp at temperatures ranging from —30° to —50° F. After freezing, the material has immediately been placed in cold storage at a temperature ranging from 4° to 10°. So far, the quality of the material packed in cans has been superior to that of the material put up in paraffined containers. Vacuum closure improves some of the products, especially those having a tendency to darken when exposed to air. The fruits used were apricots, peaches, pears, plums, prunes, cherries (canned), strawberries, raspberries, Young dewberries, blackberries, figs, guavas, mangoes, cranberries, crab apples, Feijoias (*Sellowiana*), and persimmons.

Many of these frozen pulps could be served as desserts just as they came from the cans after nine months or more storage if refrozen or held at a lower temperature than heretofore stated. They have the consistency of ice cream and carry the aroma, flavor, and color of the fresh fruit to a remarkable degree.

Contact was made with one of the largest manufacturers of ice creams in Los Angeles, whose firm prepared strawberry ice cream and raspberry, apricot, and pear sherbets. The manufacturers were highly pleased with the experiment and enthusiastically offered their aid.

Indications are that after a storage period of several months most of these products can be kept for a considerable length of time at temperatures around 40° to 45° F. without actual spoilage. It is possible, of course, that the flavor will deteriorate on too prolonged storage. This must be tested further, but certainly short periods of holding the defrosted material with subsequent refreezing do not appreciably alter the color, aroma, or flavor.

ETHYLENE TREATMENT OF FRUITS AND VEGETABLES

Satisfactory data were obtained from a series of experiments on the effect of ethylene in coloring a green-yellow variety of tomato known as Golden Ponderosa. It was found that for this variety there was some reduction in the time required for coloring if the tomatoes were picked at the green-mature stage, or when they had reached full size, but had not begun to color.

SULPHURING AND DRYING FRUITS

In experiments on drying pears both sundrying and dehydration were used in order to ascertain whether the sulphuring period might be reduced to a few hours instead of the 48 hours commonly used. Blanching before and after dehydration was tried, and partial sundrying and dehydration. Samples were also blanched before and after sulphuring. It was found possible to reduce the sulphuring period to 12 hours if sufficient amounts of sulphur dioxide gas could be liberated in the sulphuring cabinets.

MICROBIAL FOOD SPOILAGE AND DETERIORATION

It is recognized that accidental defrosting of frozen fruits and vegetables with subsequent refreezing might occur. A study has been made to determine whether such a subsequent refreezing would destroy botulinus toxin if it had been formed during the period of accidental defrosting. Botulinus toxin has been prepared in culture and frozen by both the quick and the slow method. In both cases the strength of the toxin remained undiminished as shown by the determination of the minimum lethal dose injected subcutaneously into guinea pigs. Further tests showed that toxin frozen, defrosted, and then refrozen fifteen times was not appreciably diminished in strength.

The possible significance of *Clostridium botulinum* in the spoilage of defrosted frozen-packed vegetables was studied in fresh peas. The materials were inoculated with the botulinus spores, frozen, defrosted, and held under various conditions. Some samples were heavily inoculated with *C. botulinum* spores, others lightly inoculated, and others were not inoculated. Four types of containers were included—tin cans, glass jars, monotubs, and rectangular cardboard boxes.

A total of 192 containers have been examined (72 tin cans, 48 rectangular cardboard boxes, and 72 glass containers). The *Clostridium botulinum* organ-

ism was isolated from 23 of the 64 uninoculated controls and recovered from 32 of the 64 lightly inoculated, and from every container that had been heavily inoculated. These results show conclusively that freezing does not materially affect the spores of *C. botulinum.*

In no case was toxin demonstrated when the containers were defrosted immediately or when they were placed in an ice refrigerator for 3½ days. All the toxic materials were obtained when the containers were allowed to stand at room temperature for 3½ days or when defrosted immediately, then cooked in brine, and allowed to stand at room temperature for 3 days. All the toxic materials were visibly spoiled. These results indicate that such products should be kept frozen until cooked for consumption and that extensive education of the distributor and the housewife should accompany the marketing of frozen-packed fruits and vegetables.

FERMENTATION AND HEATING OF FARM PRODUCTS

Continued reports on farm fires seem to indicate that flammable gases produced by the fermentation of hays may play an important part in spontaneous ignition. In recent experiments uninoculated alfalfa hay fermented under anaerobic conditions yielded large quantities of gas. Although the production of flammable gases was slow at the start of the fermentation, subsequent analyses showed that the evolved gas contained 23 per cent methane and a small percentage of hydrogen. These fermentations were of the "swamp" type; that is, the hays were entirely submerged in water. Experiments are now in progress to determine if flammable gases can be produced under conditions actually occurring in the interior of a heating haystack where the hay is anaerobic and may contain from 40 to 50 per cent water.

PHYTOCHEMICAL INVESTIGATIONS

During the past year considerable progress has been made in developing interest in the possible production and commercial utilization of ursolic acid and the hydrocarbon fraction obtained from apple waste and other plant materials. It has been estimated roughly that 500,000 pounds of each fraction could be recovered annually from the by-products that result from the manufacture of cider and vinegar and the dehydration of apples.

PLANT PIGMENTS

Two important investigations now under way are the studies of color in apples and tomatoes. Marked progress has been made in the study of apple color, particularly in the isolation and identification of the parent substance from which the desirable color is produced in the fruit. A considerable quantity of tomato pigment has been isolated with the view to making a complete study of its chemistry and gaining more complete information that will aid in solving some of the tomato-color problems.

Work on plant pigments has included the isolation of further quantities of tomato pigments from American and foreign sources, to determine whether the coloring matter is the same in Italian, American red, and American purple tomatoes.

CHEMISTRY OF PLANT PRODUCTS

During the past year a study of the nitrogen distribution in orange juice has been made. Amino, amide, ammonia, and total nitrogen were determined in barium, lead, phosphotungstic, and alkaline mercury precipitates, and in the filtrates from these. The separation and identification of bases, amino acids, and amides has been completed. Stachydrine and arginine were isolated in considerable quantities, while smaller amounts of choline, asparagine, and aspartic acid were separated. Traces of histidine and of purines were indicated. The results of this work have been prepared for publication.

PHARMACOLOGICAL STUDIES ON FOODS

A new project, pharmacological studies on foods, has been started during the past year in quarters established at Stanford University in California, under an agreement between the bureau and the university. It is concerned with acute

and chronic intoxications that may result from consuming food contaminated with insecticides, food preservatives, and metals which may occur naturally in foods, or as a result of canning and cooking processes.

A report dealing with the acute and chronic forms of fluorine intoxications was completed in January.

RANCIDITY IN FOOD PRODUCTS

The effect of light on the deterioration of oil-bearing foods was shown in a recent study by food-research chemists of the bureau.

In one test two lots of the same corn-germ meal were stored side by side for about a year, one in a glass bottle exposed to the direct sunlight and the other in a glass bottle wrapped in black paper. The meal in the wrapped bottle was fresh and sweet when removed; that in the unprotected bottle was spoiled and had a very rancid odor.

In another test a set of vials, one containing lard, one butter, and one salad oil, was placed in each of 10 compartments, each compartment was covered with glass of a different shade, and the whole was exposed to sunlight for a number of weeks. At the end of the experiment the material kept under grass-green glass was still sweet, while that kept under glass of all other shades of green, as well as under different shades of blue, purple, yellow, orange, and red, was distinctly rancid. The same results were obtained when oil-bearing foods were wrapped in cellophane of varying hues.

This study offers manufacturers of oil-bearing foods a practical method by means of which rancidity will be delayed and monetary losses resulting from it reduced.

PRESERVATION OF EGGS

A semicommercial application of the vacuum-carbon dioxide method for treating eggs in the shell with oil was made during the past year. It demonstrated that treating the shells of low-grade eggs will not improve them, but that oil does protect the quality of high-grade eggs.

By placing numerical values on flavors a comparison of fresh and stored oiled eggs was made. More than 500 eggs were tasted by five judges. Analysis of data obtained in this study shows that freshly laid eggs have a characteristic flavor and that they can be distinguished from stored eggs. Little or no correlation between the flavor and the "candle grade" of stored eggs was found.

Further studies of the force necessary to crack oiled and unoiled eggs have shown that while there is a definite correlation between shell thickness and the force necessary to cause cracking, oil does not affect the cracking strength.

COMPOSITION AND UTILIZATION OF FLORIDA ORANGES

The new citrus-fruit laboratory of the bureau at Winter Haven, Fla., was officially opened in October, and active canning operations were started in November. Up to the end of the fiscal year approximately 800 cans, three hundred and fifty 8-ounce jars, and 1,300 bottles of orange juice had been prepared under various experimental processes. In flash pasteurization and capping in a vacuum, vacuums as high as 27 inches have been obtained. In general they have averaged 25 inches. The juice is flash pasteurized in jars, cooled to approximately 70° C., and then subjected to a vacuum until it starts to boil, at which point the container is immediately capped and then cooled. Juice prepared by this method has kept remarkably well, and tentative results seem to indicate that it will keep better than juice processed by any of the other methods.

The flash-pasteurization and steam-closing method created vacuums as high as 20 inches and proved effective for closing bottles and cans. This method failed to work satisfactorily on jars, but probably would be more effective than attempting to close them by means of a mechanically produced vacuum.

Before being pasteurized, juice extracted in an atmosphere of carbon dioxide possessed a peculiar taste, but this was not apparent after pasteurization.

Carbonated orange juice was prepared from an orange sirup and water lightly carbonated. The sirup was made by adding to every 3 liters of juice 1.5 kilos of sugar and 66 grams of citric acid. One part of this sirup was then diluted with 2 parts of carbonated water. The bottled beverage was either sterilized by being heated at 145° F. for 30 minutes, or preserved with one-twentieth per cent sodium benzoate. It is too soon to judge the keeping quality of the juices put up by these different methods.

THE NATURE OF ENZYME ACTION

In order to learn something of the connection between catalase action and the darkening of fruits, the cause of the great difference in catalase activity between supposedly similar preparations has been investigated. It was found that the enzyme exists in two states, active and inactive, and that the inactive enzyme becomes active upon the addition of oxidizing agents. The action of these oxidizing agents is not on the enzyme itself, but on some substance which accompanies it, which in the oxidized state is therefore the activator of the catalase.

This activator is heat stable and may be prepared free from enzymes by boiling liver juice. It is replaceable by certain known substances, namely, cystine, oxidized glutathione, and insulin. It apparently contains disulphide sulphur, but the behavior of cystine (and perhaps of glutathione) indicates that it is a more complicated compound, probably resembling insulin.

The value of this work is threefold. It shows the necessity of revising all previous estimates of the catalase content of fruits and vegetables on which certain conclusions have been based with regard to respiration and response to plant stimulants. Although inactive catalase may often be present, it has hitherto not been measurable. The work further shows a definite physiological connection between the processes of hydrolysis and of oxidation, and shows how this connection works. The sulphydryl derivatives are known to be activators of proteolysis, and the disulphide derivatives activate oxidation. The condition of the activator of catalase, therefore, whether oxidized or reduced, determines whether the cell at the moment is hydrolyzing or oxidizing. The work further indicates the possible existence of an insulinlike substance in many animal and vegetable tissues. This has a distinct bearing on the problem of the mode of action of insulin, and it may indicate a potential source of insulinlike material which would be of economic value.

Preliminary exeriments in the fall of 1931, conducted with apples, showed that several substances besides sulphur dioxide, now used, inhibit discoloration. The ions of the alkaline earths do this, also the halogens; the latter inversely in proportion to their atomic weights. Calcium chloride was also found to be a fairly satisfactory inhibitor. Of the organic substances which were found to inhibit the darkening, glutathione is most powerful. The darkening was, on the other hand, accelerated by catalase and peroxidase. Close investigation of possible activators and inhibitors of these ferments continues.

INDUSTRIAL FARM PRODUCTS DIVISION

HIDES AND SKINS

The work of correcting poor practices in skinning and curing hides has been continued among butchers and dealers. Its object is to improve the quality of hides and skins so that they may reach the tanner in the best condition. It is aimed directly to bring greater returns to producers of hides and skins, as well as to users of leather, by reducing a yearly waste of approximately $20,000,000 caused by poor handling.

Cooperation with the Bureau of Agricultural Economics has been continued in distributing, explaining, and introducing to practice, through this bureau's hide specialists, the schedule of tentative market classes and grades of kips and calfskins recently issued by the Bureau of Agricultural Economics.

Noteworthy progress has been made in isolating at least one class of the organisms that cause typical reddening of salted hides and skins, a trouble of long standing in the hide and leather trade. By direct inoculations with these cultures, typical reddening has been reproduced on salted calfskin and on several laboratory media of varying sodium chloride content up to saturation. Detailed studies of these reddening organisms are being continued.

TANNING MATERIALS

To meet the steady decrease in established sources of tannin for making leather, efforts to discover and develop new natural sources of tannin and to conserve existing supplies are now under way.

In 1930 there were more than 250,000 cords of hemlock bark on the logs cut for lumber in Washington and Oregon alone. There is little question of a reasonably high content of desirable tannin in this bark. Four large trial lots

of bark, of about 20 tons each, are now being collected for use in obtaining significant data on the best methods of handling and curing, on costs, and on other origin factors. These lots will be processed commercially into several types of tannin extracts for the purpose of obtaining further data on production and costs, and of determining and demonstrating, on a large scale with tanners, the comparative merits and value of this waste bark and its extracts.

Among several materials from the Virgin Islands, the bark of tan-tan, the leaves of West Indian mahogany, and the inner core of the seed pods of the West Indian mahogany were found to have, respectively, 15.6, 15.8, and 47.6 per cent of tannin.

A commercial tanner, following specifications in United States Service Patent 1757040, which was taken out by the bureau on ferrochrome tanning for securing a joint chrome and iron tannage, has obtained highly satisfactory results from large-scale tannery experiments. This fundamental research has made available to American tanners a new and useful tannage that yields a leather having a satisfactory natural color without bleaching or additional dyeing. Laboratory samples tanned seven years ago show no outward evidence of deterioration.

LEATHER

A new machine for measuring the folding endurance of leather has been developed by the bureau. It is being studied for its practical applications to certain types of leather and of services involving much folding or flexing.

The results of an elaborate study on the deterioration of leather, obtained from a natural-aging experiment of eight years' duration, have been published. They are of great value in pointing out a more scientific approach to the development of more resistant leathers and more efficacious treatments for preventing decay. The special feature of this work is the direct proof that vegetable-tanned bookbinding leathers absorb from the air harmful quantities of sulphur-acid gases which accumulate in the leather and help to cause its early rotting.

NAVAL STORES

Construction of the naval stores field laboratory on a 10-acre tract in the Osceola National Forest at Olustee, Fla., donated for the purpose by the United States Forest Service, began on September 9 and is now nearing completion so far as funds permit. This station is the culmination of years of efforts by the industry to establish a station where naval-stores problems can be solved, and where the best methods and equipment for production are at all times accessible for information, inspection, and guidance.

Work on the effect of water-soluble matter in crude pine gum upon the quality of rosin obtained was continued. The soluble matter in water collected with the gum was at times 2 pounds per gallon. It consisted principally of tannin and other vegetable matter. It was found that this soluble matter reduced the clarity of the rosin but did not materially change its color.

Research on components of rosin was continued. Resin acids were prepared from slash-pine scrape. From these crystalline sodium pimarates were prepared, relatively free from sapinates.

Pine gum was treated directly with alkali, the resulting soap separated from oxidation products and trash, and the soap-turpentine-water mixture distilled with steam under reduced pressure to remove the turpentine. Antifoaming apparatus was devised for handling these heavy soap solutions during vacuum distillation.

In preliminary work on the nature of the coloring matter in rosin it was found that equal concentrations of the same rosin yielded solutions of different color in different solvents. When a glacial acetic acid solution of an oxidized rosin, having a color equal to that of a solution of F rosin, was reduced with hydrogen the color was raised to that of a solution of WG rosin. When the solution was exposed to the air the color darkened in 1 day to M, in 2 days to H, and in 4 days to G grade.

Further investigation of the atmospheric oxidation of dry rosin showed that the rate of oxidation increased to some extent with increasing fineness of the particles. Below 60-mesh size the rate of oxidation was practically constant.

Turpentine in fresh gum.—Information that will serve as a basis for improvement in the American system of turpentining is being sought. Variations during the chipping season in the quantity and properties of turpentine in fresh

gum from different varieties of pine and from trees of different ages and types of growth are being investigated. The flow of gum was found to vary widely from time to time. There was a decided and unexpected reduction in the flow during the last two weeks of July; although the weather had been very hot and presumably favorable to the flow, there were frequent showers and daily electrical storms, which have been observed to exert a healing effect on new faces. Cold weather in October was reflected in markedly decreased yields of gum. Unseasonably warm weather during November caused a decided increase in yields.

Composition of turpentine.—In order to promote more extensive use of turpentine as a raw material for chemical products, fundamental research on the composition of American turpentine, the separation of components, the formation of derivatives, and the determination of properties is in progress.

A study of the component distribution trend in the products of commercial turpentine-still operation was made. A paper giving the results of this study, entitled "The Component Distribution Trend in Commercial Turpentine-Still Operation," was prepared for publication. Two papers on the work in turpentine have been published: An Improved Gauze Plate Rectifying Column was published in Industrial and Engineering Chemistry; The Fractionation of American Gum Spirits of Turpentine and Evaluation of its Pinene Content was published as Technical Bulletin 276.

FARM FABRICS

An entirely new conception of the mode of action of the metallic-oxide type of flame-proofing agent was gained during the past year. It was found that stannic oxide produces a catalytic decomposition of the cellulose molecule into carbon and water. The correctness of this view was checked in three different ways: (1) When untreated fabrics and fabric treated with stannic oxide were completely burned in a rapid stream of air, a larger part of the carbon was recovered as carbon dioxide from the treated fabric than from the untreated fabrics. (2) more water vapor was obtained from the treated fabric than from untreated fabric when both were heated under similar conditions in the absence of oxygen; and (3) when treated and untreated fabrics were heated under similar conditions in a stream of oxygen-free nitrogen until most of the volatile matter was driven off, 60 per cent more carbon was retained in the treated material.

Much trouble and expense is caused by the tearing of bags containing fertilizer and other materials that exert a deteriorating chemical action on them. Experiments indicate that in some degree and for a short period copper alginate protects burlap bags against injury by dilute acids. When the treated bags were kept in contact with carbonated superphosphate of lime for six months they lost more than half their original strength. Burlap bags coated with asphalt and lined with kraft paper lost only 15 per cent of their strength under the same conditions.

PAPER

The bureau assists the Government and scientific societies in preparing specifications that make possible the procurement of papers best suited for definite purposes, and gives technical advice on any paper problem brought to its attention.

The United States Government uses large quantities of many kinds of paper. More than 25 years ago this bureau commenced to prepare specifications for them and has continued to do so, in cooperation with the Government departments. The practice has effected annual savings ranging from $50,000 to $500,000. Publishers of periodicals, by adopting similar specifications, have made annual savings estimated at more than $500,000.

The bureau has continued to cooperate with the Joint Committee on Printing of Congress, the Government Printing Office, and the Federal Specifications Board in preparing specifications for paper for Government uses, and with the American Chemical Society in work on papers for scientific journals. Cooperative work has been done with the Bureau of Plant Industry to determine the characteristics of blotting paper suitable for use in seed-germination tests.

Paper used for legal records, historical documents, scientific publications, State laws, legislative journals, and Federal, State, county, and municipal records should be sufficiently durable to withstand service and storage indefi-

nitely. Such papers must be made of the most durable raw materials and by the best methods. They must be free from injurious constituents and must be stored or used under conditions that will not cause them to deteriorate. Rotten and crumbly paper causes serious loss and expense to libraries and to public offices charged with the keeping and storage of records.

The effect of hydrochloric acid, sulphuric acid, and aluminum sulphate on the physical properties of the highest-grade record waterleaf rag paper has been investigated. Small quantities of these chemicals caused rapid deterioration, and the deterioration increased as the acidity was increased. Hydrochloric acid caused the greatest and most rapid deterioration. Folding endurance of the paper was lowered more than its bursting or its tensile strength. The results of the investigations indicate that no matter how carefully made or how good the fibers are, papers that are expected to endure for many years must contain little, if any, free acid. Technical Bulletin No. 334, The Effect of Inorganic Acids on the Physical Properties of Waterleaf Rag Bond Paper, gives details of this work.

DESTRUCTIVE DISTILLATION OF FARM WASTES

At the new field station at the Iowa State College, Ames, Iowa, yields from destructive distillation of cellulosic raw materials obtained from various States have been studied with a semicommercial retort and the necessary accessory apparatus.

With this retort short runs were made on ground corncobs, chopped cornstalks, barley straw, oat hulls, whole corncobs, elevator screenings, furfural residues (from Iowa), wheat straw (from Minnesota), cottonseed hulls, peanut shells, pecan shells (from Texas), rice hulls (from Arkansas), flax straw (from South Dakota), and cottonseed hull bran (from Alabama). The retort, with the exception of the feed device, operated satisfactorily on all these materials; the feed device operated perfectly on granular or ground materials but is not correctly designed for fibrous materials such as straw. Bulky material, such as whole corncobs, also caused feeding difficulty. Demonstration runs have been made for various visiting groups to interest industrial manufacturing concerns that use agricultural raw materials in destructive distillation in utilizing the collected by-products of their several industries.

It was necessary to devise new methods of analysis for these studies. It appears that in an operation of such size longer runs are necessary in order to establish and maintain optimum operating constants. Additional equipment is being installed for this purpose.

FERMENTATION STUDIES ON FARM AND OTHER WASTES

Work on the biochemical decomposition of cellulosic plant materials, cornstalks, and other farm wastes, using packing-house sludge, sewage, etc., as a source of nitrogen, is in progress. The rate, degree, products, and method of breakdown of the various plant constituents have been examined, both at room (mesophilic) and at high (thermophilic) temperatures, on the whole plant, and on the separate constituents. Indications to date are that (1) packing-house wastes are the better source of nitrogen; (2) decomposition of plant material proceeds faster at the higher temperature, though eventually the net yield of evolved gas is approximately the same as at the lower temperature; (3) components of the thermophilic gas are different from those of mesophilic gas, and (4) lignin is not easily attacked under the conditions of the experiment.

Following laboratory studies on the production of organic acids from beet pulp by thermophilic fermentation, large-scale fermentations are being tried in a pilot plant.

OIL, FAT, AND WAX INVESTIGATIONS

SOYBEAN OIL

A study of the oil content and the characteristics of the respective oils in nine authentic varieties of soybeans has been made. The proteins of these soybeans have also been investigated by the protein and nutrition division of this bureau. The varieties examined included A. K., Chiquita, Dunfield, Haberlandt, Illini, Mammoth, Manchu, Peking, and Virginia. The oil content ranged from 15.6 per cent in the Mammoth beans to 21.85 per cent in the A. K. variety.

The beans of all the other varieties except the Chiquita (having an oil content of 16.7 per cent) contained from 18 to 19.28 per cent of oil. Unless soybeans contain 17 per cent of oil or more, they can not be considered satisfactory for the commercial expression of oil and manufacture of meal for stock feed.

In view of the importance of finding varieties containing oils that give either unusually low or unusually high iodine numbers, and that would be especially adapted for food or technical uses, investigation of other varieties appeared particularly desirable. Further work has been undertaken, and to date the oils from 18 other varieties from Japan and Chosen (Korea) have been investigated; the quantity of oil and proteins as well as the iodine number of the oils has been determined for each variety.

BURBOT OIL

During the past year a study, in collaboration with the Bureau of Fisheries, of the chemical and physical properties of burbot-liver oil and its value in nutrition as a source of vitamins A and D was made. The liver constitutes about 10 per cent of the body weight of the burbot. Depending on the condition of the fish, the liver contains anywhere from 30 to 56 per cent of oil. These fish inhabit the Great Lakes, and in recent years the annual catch has been over 600,000 pounds. These studies revealed the fact that this liver oil is similar in chemical and physical characteristics to that from cod livers. The other collaborators found that burbot-liver oil prepared under commercial conditions is from three to four times as potent in vitamin A as good grades of medicinal cod-liver oil.

APRICOT-KERNEL OIL

Because of the rapidly growing interest in local utilization of the apricot pits separated in the dried-fruit industry in California, a study of apricot-pit oil is being made. A sizable sample of the kernels was examined and found to contain 4.8 per cent of moisture, 48.2 per cent of oil, and 25.4 per cent of proteins. The expressed oil gave an iodine number of 108, a saponification value of 190, and contained 3.6 per cent of saturated and 90.6 per cent of unsaturated acids. The unsaponifiable matter amounted to 0.72 per cent.

ANALYTICAL METHODS

In the two previous reports will be found an extensive discussion of the study of methods of analysis for evaluation of cottonseed in connection with the department's interbureau committee on the sampling and grading of commercial cottonseed. As stated before, the work of this laboratory consists primarily in studying methods of dividing the samples received so as to obtain representative portions for analysis, and the methods involved in determining moisture, oil, free fatty acids, and proteins.

The present investigation has shown that it is necessary to make a complete separation of the meats (kernels) from the portion of seed taken for the free fatty-acid determination by the method now being used. Further study of this problem has shown that it is also essential to extract practically all the oil from the separated meats by cold percolation with petroleum ether before attempting to determine the free fatty acids. As data have now been obtained by specially planned experiments sufficient to definitely warrant these conclusions, the attention of all those engaged in analyzing commercial cottonseed has recently been called to them.

PROTEIN AND NUTRITION INVESTIGATIONS

PROTEINS OF CEREALS

A large part of the protein of many cereal grains belongs to a class called glutelins, which is not so well characterized as are the other classes of proteins. The percentages of the amino acids, cystine, tyrosine, and tryptophane in glutelins prepared from wheat, rice, rye, barley, oats, and buckwheat have been determined by colorimetric methods. The relatively high percentages of the nutritionally essential cystine and tryptophane in the glutelins of wheat and rice indicate the superiority of these two cereals in food value over the others studied.

A new set of factors has been developed for converting the percentages of nitrogen in foods and feeds into protein equivalents. These factors will give the true protein content more accurately than will the indiscriminate use of the conventional factor 6.25 now generally employed.

PROTEINS OF SOYBEANS

The unusually wide range of differences in the characteristics of several soybean varieties has raised the question whether there may be a difference in the protein nutritional value of different varieties. Information on possible differences in these values would be important in selecting soybeans to be grown for the production of seed intended for use as food or feed.

Ten soybean varieties were studied and showed variations in the content of the amino acids, cystine, and tryptophane sufficiently great to be significant from the standpoint of nutritional value.

SUGARCANE JUICE

Investigation on fresh cane juice, expressed in the laboratory from different varieties of cane stalks shipped from Louisiana, has shown that the total nitrogen content of the juice differs widely in the several varieties studied, ranging from 0.01 to 0.02 per cent. Following essentially the same technic as was used in the investigation on molasses, the different types of nitrogenous compounds have been separated into groups. The percentages of amide nitrogen, amino, and nitrate nitrogen also differed in the juices of the different varieties of cane.

ALKALI-TREATED PROTEINS

Food proteins differ greatly in their digestibility. Cooking improves the digestibility of certain proteins. The effect of dilute acids and alkalis also has a marked effect. In view of the meager knowledge of the relative digestibility of the different proteins in foods, studies have been started to determine the rate of liberation of certain nutritionally essential amino acids when various proteins are digested or hydrolyzed. Experiments on casein from milk show that this protein begins to break down very quickly both on treatment with dilute acids and alkalis and on digestion with pepsin. Although there is no evidence that free cystine is liberated, colorimetric determinations gave color values for this amino acid which exceed that recorded for the normal cystine content of casein.

STABILITY OF VITAMINS A AND D

Experiments conducted during the past year have shown that the amount of cod-liver oil of known strength which may be added to a feed is an uncertain criterion of the vitamin D value of the mixture after it has been held in storage. These experiments have shown that (1) when cod-liver oil is mixed with a ration containing grains there is a slow but definite loss of vitamin D; (2) when cod-liver oil is mixed with pure quartz (fine sand) there is a more rapid disappearance of vitamin D than when the oil is mixed with feed; (3) when cod-liver oil is mixed with a salt mixture, such as is used to supply all the mineral elements in experimental rations, there is a very rapid disappearance of vitamin D. These observations indicate that during storage vitamin D is lost by oxidation and the rate of oxidation can be catalyzed by certain mineral elements.

EFFECT OF FREEZING ON VITAMIN POTENCY OF FRUIT JUICES

As a result of the recent development in applying quick-freezing methods to foods, large quantities of frozen fresh orange juice have been marketed. Orange juice is one of the best sources of vitamin C and is being used extensively to supply this vitamin in infant feeding. Vitamin C is readily destroyed during processes used in preparing many food products. Little is known, however, about the effect of freezing under different conditions upon vitamin C in such products as fruit juices.

In order to obtain information on this subject, feeding studies have been conducted to determine the vitamin C potency of frozen orange juice prepared under various conditions by the food research division. Juice was frozen (1)

without precautions to exclude air, (2) in an atmosphere of oxygen, and (3) in an atmosphere of nitrogen.

Vitamin C tests on the material made immediately after its preparation did not reveal any change in vitamin potency due to treatment of the juice. Tests now in progress on juice that has been in cold storage (0° F.) do not indicate a marked loss in vitamin content.

COTTONSEED MEAL

Continued investigations on the nutritive value of cottonseed meal have yielded valuable results. Cottonseed meals were prepared in an experimental mill under controlled commercial conditions which represented the extreme variations in commercial practice in heat treatment, both as to time and temperature of cooking before oil extraction. Exhaustive feeding tests on these meals were conducted with both rats and guinea pigs to detect any residual toxicity. These experiments indicate that the toxicity of the meals is inversely proportional to the time and temperature of cooking of the kernels before expression of the oil. Seven varieties of raw cottonseed grown in different sections of the Cotton Belt were tested in biological assays for toxicity. The wide variation in gossypol content of seed that has been reported as a result of chemical determinations, was not confirmed. In view of the fact that ether. one of the reagents used in gossypol determination, has been shown to be an effective detoxifying agent, it is believed that bioassays are more dependable than chemical analyses for measuring this toxicity.

COLOR AND FARM-WASTE INVESTIGATIONS

BAGASSE CELLULOSE

An outstanding accomplishment of the bureau during the year has been the working out of a method for producing a high-grade cellulose from sugarcane bagasse at small cost. Interest in this accomplishment, of those countries in which the utilization of sugarcane bagasse is an important problem, has been evidenced by numerous requests for information on this subject.

INDUSTRIAL FERMENTATIONS

Among some promising results of the past year's work on industrial fermentations have been (1) the discovery of a mold giving 60 per cent yields of citric acid on dextrose, (2) the discovery of a mold giving as high as 50 per cent yields of gluconic acid with a submerged growth, (3) the discovery of a mold which will form between 20 and 30 per cent fat in its mycelium, and (4) the discovery of a mold producing an unknown crystalline material insoluble in water. The citric acid process originally worked out in the Department of Agriculture and then placed on an industrial basis has flourished during the last year. In addition to the domestic production, on which figures are not given out, more than 2,000,000 pounds of this material were shipped to Europe during the first five months of 1931. This is an instance in which a domestic product, developed as a direct result of agricultural research, has entirely displaced a foreign material in this country and is making its competition felt abroad.

LIGNIN INVESTIGATIONS

Although 30 per cent of the dry material in all vegetation is lignin and its annual production is estimated at 40,000,000 tons, the determination of its composition is one of the great chemical enigmas. Its solution offers possibilities for profitably utilizing one of the greatest farm wastes of the United States. The bureau is working steadily on this problem and within the past fiscal year has made progress in identification of the various fragments into which the lignin molecule is broken by heat or other means.

Some work has also been done on the conversion of the lignin sulphonic acids in sulphate liquor into tanninlike substances, but this work is not yet completed.

Investigation on the destructive distillation of lignin was completed during the year. The oily distillate was found to be a complex mixture and quite a number of compounds, chiefly phenols, were isolated and identified. Among

them were: Phenol, o-cresol, guaiacol, creosol, 1-vinyl-3-methoxy-4-hydroxy benzene, 1-n.propyl-3-methoxy-4-hydroxy benzene, and triacontane. A dimethoxy carboxylic acid $C_8H_6O_2(OCH_3)_2$ was isolated but not definitely identified. The discovery of triacontane is of special interest, as the presence of a 30-carbon chain in the lignin molecule has not previously been postulated.

Work on modification and degradation of lignin has been carried on along a number of lines. One of these is the distillation of lignin with zinc dust in an atmosphere of hydrogen. This particular piece of work has been brought to completion, and the paper reporting it is now awaiting publication. Catechol, guaiacol, n.propyl guaiacol, and anisic acid are among the products formed in this manner. Some work has also been carried out on the nitration of lignin.

INSECTICIDE INVESTIGATIONS

INSECTICIDAL PLANTS

The researches on the constitution of rotenone that have been conducted during the past several years culminated during 1932 in a complete determination of the structural formula; an investigation of the possibility of synthesizing it has been begun. It has been found that rotenone-spray deposits are subject to photochemical decomposition, accompanied by considerable loss in toxicity, and that this decomposition may be retarded by admixture of a black material like lampblack. Numerous derivatives of rotenone have been investigated for toxicity to both goldfish and insects, in an effort to find a correlation between structure and toxicity to serve as a guide in developing new and simpler insecticides. Of these derivatives dihydrorotenone appears most promising in that its toxicity is nearly equal to that of rotenone, and it is inherently more stable toward light. Improvements have been made in methods of extraction and analysis, and various spray preparations containing rotenone have been developed.

The study of deguelin, tephrosin, and toxicarol has also led to practically complete determination of their structural formulas, and they have been found closely related to each other and to rotenone.

The investigation begun last year of the large number of miscellaneous fish-poisoning plants was systematically continued during this year. Of the more than 70 materials tried 16 species are considered promising enough for further study. These are: *Apurimacia michelii*, Bejuco chilio, *Ceratiola ericoides*, *Covillia tridentata*, *Cracca virginiana*, *Cracca vogelii*, *Croton tiglium*, *Diospyros maritima*, *Eremocarpus setigerus*, Fohla tingui, *Ichthyomethia piscipula*, Manzanillo comun, Mochongoko, Sinihuite, *Spatholobus roxburghii*, and *Urechites suberecta*.

Preliminary attempts to separate the active principles from certain of these plants, notably *Cracca virginiana* and *Spatholobus roxburghii*, were unsuccessful.

A resin obtained from *Croton tiglium* showed high toxicity to fish and insects, and its chemical nature will be carefully studied.

PHARMACOLOGICAL TESTS OF INSECTICIDAL PLANTS

A toxicological comparison of the action of nicotine and neonicotine (anabasine) upon guinea pigs, rabbits, frogs, and earthworms, and a pharmacological comparison of the same two compounds in their action upon blood pressure, respiration, and isolated organs, were undertaken and completed. Toxicity studies upon toxicarol and deguelin administered orally and by injection to guinea pigs, rabbits, and white rats were carried on, and a pharmacological comparison of these two materials with rotenone in their effect upon blood pressure, respiration, rate of destruction, and elimination, and upon isolated organs, was instituted.

SYNTHETIC ORGANIC INSECTICIDES

Both anabasine and methyl anabasine differ from the synthetic materials in that they are optically active. Attempts were accordingly made to separate the synthetic materials into their optically active components, in order to carry the identification to the final step, but these attempts were unsuccessful.

Attempts to develop methods of synthesis for this group of compounds were continued. It was found that, in contrast to the behavior of nicotine, methyl

anabasine can be converted into anabasine by long treatment with hydrochloric acid, and this may explain some of the difficulties encountered in previous attempts to prepare neonicotine from α, β- dipyridyl.

Tertiary amyl, benzoyl, chloracetyl, anisoyl, trimethyl galloyl, and furoyl isothiocyanates were made. Most of them were of low toxicity and in addition were subject to decomposition into even less toxic compounds. The benzoyl and trimethyl galloyl compounds were the most stable and promising.

Normal amyl phenyl, isoamyl phenyl, azelyl diphenyl, and benzoyl phenyl thioureas and azelyl di α- naphthyl dithiourea were studied. The first four showed no toxicity to fish in moderate concentrations, and the last was too insoluble to test. This class of compounds apparently offers little promise of furnishing effective insecticides.

SPRAY RESIDUES

In studying arsenic on apples, investigations of the influence of spray composition and spray schedules upon the amount of the residue, and of the efficacy of numerous washing procedures in removing the residue were made. Special attention was paid to the alkaline washes because of their greater promise in removing oil-protected deposits. Many phases of the Gutzeit method for arsenic determination were studied in an effort to make this universally used procedure more reliable and accurate. The possibility of using the Deniges molybdate method as a simple substitute for the Gutzeit test was shown to be rather remote.

A cooperative project with the Bureau of Entomology on the arsenical residues remaining in cigar and cigarette tobaccos after dusting with lead arsenate and Paris green, respectively, was concluded.

Further studies on the quantity of fluorine present at harvest time on apples that had been sprayed with fluorine-containing compounds were conducted and certain relationships between type of spray and size of residue were revealed.

Two good qualitative methods of testing for the quantities of rotenone likely to be present as spray residues on apples were developed, and one method has been found capable of giving fair quantitative results.

FLUORINE INSECTICIDES

The investigation of fluorine-containing compounds as insecticides was continued. Means of improving the dusting and spraying characteristics of the fluoaluminates were sought, and found in the expedient of mixing with the fluoaluminate equal molecular proportions of precipitated silica. Batches of such mixtures containing the fluoaluminates of sodium, potassium, and ammonium, respectively, were prepared for experimental use.

Three United States patents covering methods of manufacturing fluorine-containing insecticides were issued to R. H. Carter, of the bureau, and assigned by him to the Government and the people of the United States.

FUMIGANTS

Several fumigants, namely, hydrocyanic acid, hydrogen sulphide, ethylene oxide, carbon dioxide, and propylene dichloride were investigated from various angles during the year.

The particular one of the four isomeric propylene dichlorides that is used for fumigation was very carefully purified and used for the determination of specific gravity and of vapor pressure from room temperature to the boiling point.

In the study of resistance to hydrocyanic-acid fumigation by the citrus red scale in certain sections of California, the chemical work of the past year has been concerned with three phases—design of apparatus, development of methods of analysis, and control of fumigations in laboratory and field in order to correlate scale mortality with dosage. Many laboratory fumigations were made under known, controlled conditions, with mixtures of hydrocyanic acid and carbon dioxide, hydrogen sulphide, and ethylene oxide. It appears that ethylene oxide is not very toxic to red scale and that the toxicity is not appreciably increased by carbon dioxide. Mixtures of hydrocyanic acid and ethylene oxide containing relatively small proportions of the latter are less toxic than the same quantity of hydrocyanic acid alone.

HOMOLOGUES OF PARIS GREEN

Investigational work on the compounds resembling Paris green that are formed by copper arsenite and the members of the acetic-acid series of organic acids was completed during the year. Large batches of the greens made with stearic, palmitic, and lauric acids were prepared so that these compounds may be tested for insecticidal efficacy. The stearic compound is being tried in field tests for control of the codling moth.

OIL EMULSIONS

Because a method of determining just how much oil is deposited on sprayed foliage is of fundamental importance to a study of oil emulsions such a method was developed. In experiments made with a highly purified mineral oil containing almost no fraction attackable by strong acids, it was found possible to estimate the spray deposit with satisfactory accuracy by extracting both the spray oil and the natural-leaf wax or oil from the leaves and then destroying the leaf oil with concentrated nitric acid. Later, the method was extended to cover the use of less refined oils by adopting the expedient of correcting the recovered volumes to allow for the proportion of oil destroyed, as determined by control experiments run under identical conditions. By the use of this method the influence of emulsifier concentration and oil concentration upon the amount of oil deposited, and in turn the correlation between this and the insecticidal efficiency of oil emulsions, was exhaustively studied. These experiments were made jointly with the Bureau of Entomology.

PUBLICATIONS

During the fiscal year 1932 the insecticide division published 35 reports of its work in various scientific journals, and in two department publications, Miscellaneous Publication 117, Bibliography of Ethylene Dichloride, and Miscellaneous Publication 120, A Digest of the Literature of Derris (Deguelia) Species Used as Insecticides, 1747–1931. The Review of United States Patents Relating to Pest Control in multigraphed form was mailed to nearly 1,500 persons each month to and including March, after which shortage of funds compelled its discontinuance.

DUST-EXPLOSION INVESTIGATIONS

Twenty dust explosions in industrial plants were investigated during the fiscal year. These explosions resulted in the death of 8 persons, injuries to 59 others, and property damage amounting to $1,466,850. They occurred in grain elevators, feed plants, flour mills, woodworking establishments, linseed-meal plants, and other industries.

The structure at the Arlington testing station in which dust explosions are produced to determine the venting area necessary to prevent structural damage has been changed at various times in order to incorporate newly developed venting equipment or to try some recommended venting practice. As at present constructed the arrangement of the structure is quite flexible, and provision can be made to install and test under different explosion pressures pivoted sash, hinged sash, swinging steel doors or panels, roof ventilators, automatic sash-venting equipment, and door checks, as well as different areas of fixed glass.

Samples of dust obtained from industrial companies in various sections of the country were tested for explosibility, and reports were prepared, together with recommendations for dust-explosion prevention. The samples included cork, sodium resinate, baking powder, ivory nut, dyestuffs, oats, alfalfa, cinnamon, tapioca, pyrethrum, pyrites, glucose, and other dusts.

A study of operating conditions and new construction features, with special attention to dust-explosion hazards, was made during the year.

A revision of the dust-explosion prevention code for flour and feed mills has been prepared and was considered as a progress report at the Atlantic City meeting of the National Fire Protection Association. Further attention will be given the code at the next meeting of the committee before it is presented to the association for adoption.

The chemical engineering division continued to cooperate with the National Fire Waste Council of the Chamber of Commerce of the United States and with a number of State colleges, firemen's organizations, and fire-prevention associations in conducting short-course schools of instruction for firemen. At these schools the engineers of the division presented the recent accomplishments in dust-explosion prevention of interest to firemen by means of specially prepared motion-picture reels and demonstration apparatus.

SPONTANEOUS IGNITION OF HAY

Experiments on the spontaneous heating and ignition of hay were continued in the specially constructed barn on the animal husbandry farm at Beltsville, Md.

During this fiscal year observations were made on five consecutive experiments, the first being started in June, the second in July, the third in August, the fourth in September, 1931, and the fifth in June, 1932. In these experiments such basic factors as quantity, moisture content, compactness, and aeration of the hay were varied in order that their effect on the self-heating of hay might be studied.

Temperatures throughout the hay were recorded by means of thermocouples and a potentiometer. Samples of hay and gases were collected at different points for analysis. Special studies on the loss of dry matter undergone by hay during fermentation and on the effect of horse-manure inoculum as a possible stimulant or agent conducive to spontaneous heating were made.

A quick method of determining the moisture content of hay was devised. This is a distillation method using xylene, and by means of it satisfactory results can be obtained in the field within 15 minutes.

The temperatures recorded in these experiments were far below those necessary to cause ignition. These studies have shown very definitely that the range of conditions necessary for spontaneous heating to continue and progress until ignition occurs is very narrow, complex, and puzzling.

So far as alfalfa is concerned the bureau's research and experiments indicate that (1) as a safety measure the moisture content of loose hay placed in barns should not be over 30 per cent. It is unlikely that hay of this moisture content will heat spontaneously much beyond the normal sweating stage; (2) mows of hay of 10 tons or less are not apt to heat spontaneously to a dangerous degree; (3) the addition of salt to moistened hay will inhibit bacterial growth and will delay but not prevent mold development (this delay in microbial development may be long enough to permit the curing of the hay); and (4) hay too wet and too densely packed will not ignite spontaneously; such hay, however, will undergo fermentation and the development of molds to an extent that renders it unfit for feeding.

The annual loss from the burning of barns and other farm property as a result of spontaneous ignition of agricultural products has been estimated to be at least $20,000,000, which is 20 per cent of the total estimated loss of $100,000,000 annually from fires on farms. The spoilage of hay by spontaneous heating, but in which actual ignition does not occur, is even more serious.

The results of a careful, conservative estimate lead to the conclusion that at least one-tenth of the harvested grass crop of this country, at an estimated value of $63,200,000, is lost as the result of spontaneous heating occurring between the time it is cut and the time when it is used.

Only in recent years have fires from this cause been carefully investigated in this country. Through the cooperation of county agents of the United States and the fire marshal of the Province of Ontario, Canada, the bureau has received numerous reports of cases of spontaneous heating and ignition of hay. Of 18 such cases in the United States in 1931, for which figures are available, the aggregate loss was $63,850. No one hay predominated as a source of such fires, although clover or alfalfa, either alone or in combination with other hays, was involved in the majority of the cases. Ignition of baled hay has also been reported. In 91 per cent of the cases the hay was in barns.

Eighty-nine per cent of the fires occurred during the following months: 39 per cent in August, 22 per cent in July, 17 per cent in June, and 11 per cent in September.

The length of time before fires break out is important. In the cases reported, the average number of days between the date of storage and the date of outbreak of fire was 43, the minimum being 2 days and the maximum 330 days.

COOPERATION WITH NATIONAL ORGANIZATIONS

The bureau continues to exert leadership of the farm fire protection committee of the National Fire Protection Association. This committee, in cooperation with the agricultural committee of the National Fire Waste Council, Chamber of Commerce of the United States, has prepared and released a handbook, Prevention and Control of Farm Fires. This reference book of 168 pages, the first of its kind on the subject, covers all phases of farm-fire hazards and protection.

SOIL INVESTIGATIONS

SOIL SURVEY

An inventory of resources is one of the fundamental requirements for the success of any business enterprise. The soil survey reports and maps constitute an inventory of the soil which comprises for the farmer a most important asset. The information gathered by the soil survey enables the individual farmer to work out a cropping system by which he can make the best of his soil resources. In the readjustment of cotton farming in the Southeastern States as the result of the boll-weevil invasion a knowledge of the location and distribution of different soil types enabled the farmers to replace advantageously part of their cotton acreage with alfalfa. In the tobacco districts information obtained through the soil survey has made it possible for the farmer to pick out fields where the soil is capable of producing the quality of tobacco demanded by the market. This information has been worth hundreds of thousands of dollars to the farmers of the South and East. In the West the soil survey has been of incalculable value in the extension of acreage of special crops, and the avoidance of areas where accumulation of salts and development of alkali are a menace.

In developing reclamation projects the soil survey has proved to be of fundamental importance, since a knowledge of the soil types makes it possible to avoid costly mistakes that would follow the carrying of water to lands not suited to agricultural development.

The soil survey reports and maps serve a very valuable purpose in developing and interpreting the work of the agricultural experiment stations and in the farm-management plans developed by county agricultural agents. Experimental results secured on a soil type in one section of the State may be applied to similar soil types in other localities where sufficient knowledge of the soil is available. The character of the soil is a most important factor in land appraisal. Land banks, insurance companies, real-estate brokers, tax assessors, and State officials are beginning to base their valuations largely on soil maps whenever they are available.

Practically all departments of the Government make use of the soil survey reports and maps or call upon the soil survey experts of the bureau for service.

In addition to their strictly agricultural uses soil survey reports and maps are used by health boards, life insurance companies, oil geologists, road engineers, cement manufacturers, advertising agencies, and numerous other business enterprises. The cost of the soil survey averages between 2 and 3 cents per acre.

During the year the soil-survey work has been carried on, as in the past, in cooperation with State organizations, usually the experiment stations. In most of the States this work has been carried on from the same point of view and for the same purpose as in the past. In North Dakota, however, the State has inaugurated the work of land classification for taxation purposes. The actual details of the work are left to the several counties, to be worked out in cooperation with the agricultural experiment station at Fargo. The bureau has been actively cooperating in this work, which is practically identical with the regulation soil-survey work. A larger number of men are assigned to this State, therefore, than to most of the other cooperating States. The land classification based on the results of the soil survey, which brings out the relative productive capacity of the soils, when combined with economic data, furnishes a sound basis for land taxation. This work during the present summer is being carried on in McKenzie County and a number of other counties are preparing to undertake similar projects.

Money has been appropriated by the Legislature of New York State to undertake a complete soil survey of the entire agricultural area of the State. This

bureau is cooperating in a comprehensive program which includes not merely the regulation soil-survey work but also detailed field studies of soils on Long Island to determine the possible influence of soil character on the growth of truck crops. A similar kind of work is being carried on in Monroe and Orleans Counties, where a preliminary survey has shown that soil character has an important effect on the growth of apple and other fruit trees.

During the fiscal year 1932 detailed surveys covering a total area of 30,569 square miles were carried on in 79 areas of 28 States and in Puerto Rico. In addition to these, reconnaissance surveys covering 7,455 square miles were made in Montana and Minnesota. Tables 2 and 3 show the details of areas covered and their distribution.

TABLE 2.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1932*

State or territory	Area	Area surveyed	
		Square miles	*Acres*
Alabama	Dallas County	[1] 303	193,920
	Lauderdale County	[1] 544	348,160
	Wilcox County	[1] 566	362,240
	Winston County	349	223,360
California	Alturas area	[1] 805	515,200
	Lodi area	407	260,480
Colorado	Brighton area	332	212,480
Georgia	Decatur County	[1] 314	200,960
	Hall County	[1] 145	92,800
Idaho	Bonner County	332	212,480
Indiana	Cass County	221	141,440
	Knox County	[1] 142	90,880
	Randolph County	447	286,080
Iowa	Franklin County	[1] 421	269,440
	Marion County	563	360,320
	Monroe County	61	39,040
Kansas	Bourbon County	170	108,800
	Kingman County	580	371,200
	Woodson County	503	321,920
Kentucky	Fayette County	[1] 242	154,880
Maryland	Queen Annes County	[1] 316	202,240
Michigan	Bay County	[1] 197	126,080
	Cheboygan County	96	61,440
	Oceana County	60	38,400
	Oscoda County	[1] 423	270,720
	Saginaw County	351	224,640
	Schoolcraft County	496	317,440
Mississippi	Greene County	[1] 378	241,920
	Marion County	[1] 108	69,120
Montana	Gallatin Valley area	[1] 169	108,160
	Lower Yellowstone area	242	154,880
Nebraska	Dundy County	[1] 664	424,960
	Holt County	881	563,840
	Rock County	144	92,160
	Sherman County	[1] 443	283,520
	Valley County	570	364,800
New Mexico	Lovington area	[1] 848	542,720
New York	Broome County	570	364,800
	Monroe County	54	34,560
	Orleans County	[1] 135	86,400
	Rensselaer County	[1] 420	268,800
	Steuben County	[1] 874	559,360
North Carolina	Brunswick County	[1] 152	97,280
	Chatham County	[1] 236	151,040
	Surry County	[1] 282	180,480
	Washington County	327	209,280
North Dakota	McKenzie County	510	326,400
Ohio	Adams County	[1] 293	187,520
	Athens County	196	125,440
Oklahoma	Alfalfa County	82	52,480
	Carter County	400	256,000
	Craig County	[1] 399	255,360
	Grant County	[1] 379	242,560
	Greer County	644	412,160
	McIntosh County	294	188,160
	Mayes County	102	65,280
	Woodward County	[1] 630	403,200
Oregon	Umatilla County	[1] 189	120,960
Pennsylvania	Armstrong County	172	110,080
	Franklin County	133	85,120
	Indiana County	[1] 390	249,600
	Wayne County	221	141,440

[1] These figures do not include portions of these areas surveyed in preceding years.

TABLE 2.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1932*—Continued

State or territory	Area	Area surveyed	
		Square miles	*Acres*
Puerto Rico	Soil survey of	[1] 219	140,160
South Carolina	Abbeville County	[1] 226	144,640
	Edgefield County	107	68,480
Texas	Bee County	[1] 563	360,320
	Cass County	289	184,960
	Falls County	290	185,600
	Hardeman County	530	339,200
	Scurry County	[1] 37	23,680
	Wheeler County	[1] 480	307,200
	Williamson County	208	133,120
Virginia	Augusta County	695	444,800
	Nansemond County	[1] 152	97,280
	Rockbridge County	[1] 149	95,360
West Virginia	Randolph County	[1] 821	525,440
Wisconsin	Barron County	[1] 132	84,480
Wyoming	Johnson County	[1] 2,837	1,815,680
	Sheridan County	[1] 917	586,880
Total		30,569	19,564,160

[1] These figures do not include portions of these areas surveyed in preceding years.

TABLE 3.—*Areas surveyed and mapped in the several States during the fiscal year ended June 30, 1932, and areas previously reported*

DETAILED

State or Territory	Work during 1932	Work previously reported	Total	
	Square miles	*Square miles*	*Square miles*	*Acres*
Alabama	1,762	55,140	56,902	36,417,280
Arizona	----------	3,945	3,945	2,524,800
Arkansas	----------	15,547	15,547	9,950,080
California	1,212	32,519	33,731	21,587,840
Colorado	332	5,405	5,737	3,671,680
Connecticut	----------	1,704	1,704	1,090,560
Delaware	----------	2,276	2,276	1,456,640
Florida	----------	15,160	15,160	9,702,400
Georgia	459	35,237	35,696	22,845,440
Idaho	332	11,500	11,832	7,572,480
Illinois	----------	6,770	6,770	4,332,800
Indiana	810	19,287	20,097	12,862,080
Iowa	1,045	46,576	47,621	30,477,440
Kansas	1,253	14,985	16,238	10,392,320
Kentucky	242	5,300	5,542	3,546,880
Louisiana	----------	17,431	17,431	11,155,840
Maine	----------	2,197	2,197	1,406,080
Maryland	316	13,643	13,959	8,933,760
Massachusetts	----------	8,811	8,811	5,639,040
Michigan	1,623	27,696	29,319	18,764,160
Minnesota	----------	10,920	10,920	6,988,800
Mississippi	486	29,931	30,417	19,466,880
Missouri	----------	37,177	37,177	23,793,280
Montana	411	2,520	2,931	1,875,840
Nebraska	2,702	56,293	58,995	37,756,800
Nevada	----------	652	652	417,280
New Hampshire	----------	1,411	1,411	903,040
New Jersey	----------	9,895	9,895	6,332,800
New Mexico	848	1,438	2,286	1,463,040
New York	2,053	28,180	30,233	19,349,120
North Carolina	997	44,374	45,371	29,037,440
North Dakota	510	16,878	17,388	11,128,320
Ohio	489	16,796	17,285	11,062,400
Oklahoma	[1] 2,930	14,547	17,477	11,185,280
Oregon	189	15,001	15,190	9,721,600
Pennsylvania	916	18,699	19,615	12,553,600
Puerto Rico	219	1,149	1,368	875,520
Rhode Island	----------	1,085	1,085	694,400
South Carolina	333	25,217	25,550	16,352,000

[1] Le Flore and Texas Counties, Okla., were included in reconnaissance work in 1930 and 1931. In this report they have been included in detailed work.

TABLE 3.—*Areas surveyed and mapped in the several States during the fiscal year ended June 30, 1932, and areas previously reported*—Continued

DETAILED

State or Territory	Work during 1932	Work previously reported	Total	
	Square miles	*Square miles*	*Square miles*	*Acres*
South Dakota		8,286	8,286	5,303,040
Tennessee		11,198	11,198	7,166,720
Texas	2,397	56,930	59,327	37,969,280
Utah		2,419	2,419	1,548,160
Vermont		1,175	1,175	752,000
Virginia	996	11,235	12,231	7,827,840
Washington		10,752	10,752	6,881,280
West Virginia	821	21,958	22,779	14,578,560
Wisconsin	132	26,527	26,659	17,061,760
Wyoming	3,754	5,121	8,875	5,680,000
Total	30,569	828,893	859,462	550,055,680

RECONNAISSANCE

Alaska		31,915	31,915	20,425,600
Arkansas-Missouri		58,000	58,000	37,120,000
California		32,135	32,135	20,566,400
Kansas		39,960	39,960	25,574,400
Michigan		1,322	1,322	846,080
Minnesota	2,673	5,837	8,510	5,446,400
Montana	4,782	42,257	47,039	30,104,960
Nebraska		53,064	53,064	33,960,960
North Dakota		39,240	39,240	25,113,600
Ohio		41,420	41,420	26,508,800
Pennsylvania		41,405	41,405	26,499,200
South Dakota		41,400	41,400	26,496,000
Texas		152,855	152,855	97,827,200
Vermont		9,124	9,124	5,839,360
Washington		16,540	16,540	10,585,600
Wisconsin		14,425	14,425	9,232,000
Total	7,455	620,899	628,354	402,146,560

PEAT INVESTIGATIONS

During the fiscal year 1932 peat investigations continued the nation-wide inventory of the character and quality of peat resources in the United States. This research included a further study of the sequence of peat layers and characteristic profile features of peat deposits of regional importance; cooperation with the soil survey in the description and classification of organic soils in Virginia, North Carolina, and Minnesota; selection of representative profile samples from Ohio, Indiana, and Wisconsin for laboratory analysis of physical properties and chemical composition of organic matter; and experimental tests conducted at Arlington Farm, Va., in cooperation with the United States Golf Association, to determine the effects of special grades of peat products upon mineral soils.

The existence of a large acreage of peat land in this country provides an opportunity for broadening home markets and incomes, and it emphasizes the importance of information on the uses for which particular groups of peat deposits are economically adapted. Inquiries on this subject are becoming numerous.

SOIL-EROSION INVESTIGATIONS

Since the formulation of a definite plan for a national program of research on basic principles of soil-erosion processes and on methods of erosion control, as governed by definite soils (a program originated by H. H. Bennett, of this bureau, in 1926, on the basis of his wide soil experience), much has been accomplished in (1) arousing farmers and agricultural specialists of the Nation to a realization of the cost of this form of continuous land depreciation and (2) in starting practical methods of slowing down the wastage in regions where previ-

ously practically nothing was being done. The establishment of soil-erosion experiment stations in the various major land divisions of the country especially susceptible to erosion, together with an aggressively prosecuted educational program relating to the evil, has done more to arouse the country to the extent of the damage and the need for combative methods than had the combined efforts of all the agencies involved in the past. For the first time research methods are being applied to this exceedingly diversified problem of land impairment and destruction by erosion, according to a comprehensive scientifically coordinated plan, involving the cooperation of the Bureau of Agricultural Engineering, the State experiment stations, and other agencies.

A new erosion station was installed during the year near La Crosse, Wis., to work out the rates of erosion and the necessary corrective measures for the extensive unglaciated area of southwestern Wisconsin, southeastern Minnesota, and adjacent parts of Iowa and Illinois. On this, the upper Mississippi Valley erosion station, livestock will be brought into the program to determine its relation to practical erosion-control plans for the area.

When the heavy losses of soil, determined at the erosion stations, are considered in connection with the enormous extent of land subject to serious washing, it becomes apparent that the investigations now being carried on can not be neglected. The obvious economic necessity for continuing this program becomes even more a matter of vital national importance since millions of acres of formerly good land have been destroyed, so far as the ability of farmers to make practical use of them is concerned.

More than 1,000,000 acres of crop land were terraced in Texas alone during 1931. In some localities farmers are beginning to adopt the comparatively inexpensive strip-cropping method of reducing soil losses in such a way as to assure extensive use of this method in the control of both wind and water erosion. Under this method strips of thick-growing, water-retarding, soil-saving crops serve as a powerful agency in slowing down the rate and amount of run-off and therefore in reducing the severity of soil washing. The system is being tested at all the erosion stations, and in every instance has given highly promising results. As an example, at the black-land erosion station in central Texas, near Temple, there was no run-off whatever during 1931 from the experimental plots devoted to this method of control.

Results obtained with the hole-digging cultivator developed at the western Kansas erosion station have been highly satisfactory thus far. Loss of rainwater from fallow land at that station has amounted to only 1½ per cent of the total precipitation where the land was scarified with this machine, as against 34 per cent from an untreated area immediately alongside, handled according to the prevailing local method. There was comparatively little soil erosion from this specially treated area on June 8, 1932, when 2 inches of rain fell in 15 minutes.

Accurate measurements have shown that soil is being lost from moderately steep slopes (8 per cent) of the Corn Belt, on the important Shelby loam soil, at the rate of about 1 inch annually, where the land is used continuously for corn. This means the removal of the entire layer of fertile topsoil from such slopes within about 10 or 12 years, and the consequent exposure of comparatively infertile, stiff clay subsoil, which produced in the fairly good corn year of 1931 only 14 bushels of corn per acre (on land which had been cultivated 40 years), at the Bethany erosion station, as compared with 51 bushels from land still retaining its topsoil, broken out of bluegrass sod 5 years previously. Continuously cropped cornland lost soil at the Bethany station in 1931 at the rate of 104.7 tons per acre from a controlled plot 146 feet long on an 8 per cent slope. One 1-inch rain on June 5, 1932, caused a soil loss from this plot at the rate of 19½ tons per acre. The corresponding water loss was 39.7 per cent of the total precipitation. A plot 73 feet long on the same slope, similarly controlled and planted to corn, lost soil during 1931 at the rate of 84 tons per acre, with a corresponding run-off amounting to 30 per cent of the rainfall. The June rain referred to removed soil from this shorter plot at the rate of 15.7 tons per acre, with a water loss amounting to 49½ per cent of the precipitation.

In other words, in this region length of slope considerably affects the rate of soil loss. Also, since no water enters these controlled plots from the upper ends, these losses can be taken as an approximate measure of the losses to be expected from similarly cultivated slopes, regardless of the method of intercepting water from above. Soil loss from alfalfa grown on the same slope and soil type, receiving the same rainfall and having the same protection from water flowing down the slope, was only 0.36 ton per acre, with an accompanying water loss of

only 2.2 per cent of the precipitation. The losses from corn grown in a 3-year rotation, in plots immediately alongside, were 53.3 tons of soil per acre and 24.3 per cent of the rainfall. These data show the powerful effect of vegetation and soil-incorporated organic matter in erosion control. Moreover, they indicate that in this locality terracing alone can not be expected to give anything like the effective control that will result from terracing plus those crop rotations which build up the humus supply of the soil.

An interesting experiment at the Bethany station indicates the possibilities of controlling erosion by using good farm methods, both with and without terracing. Three badly eroded fields were selected for this study. One was handled in accordance with poor farm methods (as a check), another under good farm methods, and a third under good farm methods plus terracing. The terraced areas in 1931 produced 26.4 bushels of wheat per acre, as compared with 23.9 bushels per acre for the unterraced area on which good farm methods were practiced. In 1932 the terraced area produced 0.67 ton of dry hay per acre, as compared with 0.92 ton per acre for the unterraced area under good farm practice, and 0.29 ton for the area farmed according to poor methods (the three areas being seeded in the same manner). Thus, while the terraced area gave, the first year, an increase in yield of wheat amounting to 10 per cent above that of the unterraced area handled according to good farm practice, the results of the second year showed an increase of 37 per cent in the yield of hay from the unterraced area under good farm methods, as compared with that from the terraced area, and a 217 per cent increase, as compared with that from the unterraced area cropped according to poor farming methods. The advantages of good farm practice on eroding soil, both with and without terracing, are thus obvious. During the first year some variation in the moisture conditions resulted because snow drifted from the south slope occupied by the unterraced good-farm-practice field to the north slope occupied by the other two fields, indicating that short-time results can not be stated as conclusive.

At the western Kansas erosion station loss of rain water during 1931 from native sod on a 5 per cent slope was 0.05 per cent of the total precipitation. This was accompanied by a soil loss of 0.0025 ton per acre. Corresponding losses from clean-tilled Kafir (following wheat) were 11.8 per cent of the rainfall and 20.85 tons of soil per acre. In other words, native sod held back two hundred and thirty-six times as much of the rainfall and eight thousand three hundred and forty times as much soil as did Kafir. From wheat growing on slightly eroded soil immediately alongside the plots from which these losses were measured, the run-off amounted to 2.8 per cent of the total rainfall and the erosion to 0.27 ton per acre, whereas, from wheat grown on severely eroded land (surface removed down to subsoil) 15.4 per cent of the railfall was lost, along with 3.4 tons of soil per acre. This means that in growing wheat in western Kansas, eroded land (of the extensive Colby silt loam type) is losing five and one-half times as much of the rainfall and twelve and one-half times as much soil as is land still retaining a considerable part of the original topsoil. Wheat on uneroded soil at this station produced 26.7 bushels per acre in 1931 (a good wheat year), as compared with only 5 bushels on severely eroded land of the same original type, occupying the same slope.

It has been definitely shown at several of the erosion stations that soil washing speeds up on some of the extensive soil types of the country. At the Arkansas-Louisiana-Texas sandy lands erosion station, near Tyler, Tex., Kirvin fine sandy loam planted to cotton on an 8 per cent slope in 1931 lost 16.6 per cent of the rainfall and 15.8 tons of soil per acre, whereas, from deeply eroded soil of the same original character immediately alongside planted to cotton the corresponding losses were 17.6 per cent of the rainfall and 55 tons of soil per acre. This shows that on this very extensive soil both erosion and run-off increase as erosion progresses. It is important to note that where there was Bermuda sod the losses from the same soil and slope amounted to only 2.5 per cent of the rainfall and one-half ton of soil per acre.

At the central piedmont station, near Statesville, N. C., during 1931 the extensive Cecil sandy clay loam lost from a 10 per cent slope of bare ground 69.8 tons of soil per acre, along with 26.2 per cent of the rainfall. Where cotton was planted the losses were 11.9 tons of soil per acre and 11.7 per cent of the rainfall, the slope and soil being the same. Where the soil was deeply eroded the loss where cotton was planted amounted to 20.3 tons per acre, although the corresponding loss of water was only 7.2 per cent of the rainfall. From land planted to Lespedeza (the same soil and slope) the loss of soil was 1.5 tons per

acre (average of two plots), while the water loss amounted to 10.4 per cent of the rainfall. The rainfall for the year was 44.5 inches. This fell in 74 different rains, 33 of which caused run-off and erosion. These measurements show the extreme importance of checking erosion in the Piedmont region. The effectiveness of Lespedeza in doing this points to the absolute necessity of including more soil-saving crops of this nature in the regional cropping schemes.

SOIL-FERTILITY INVESTIGATIONS

COTTON SOIL-FERTILITY STUDIES

Field experiments to determine the fertilizer requirements of cotton were continued on five soil types in Georgia, and increasingly valuable data have been secured. The experiment on each soil type includes 43 plots replicated three times and comprising 9 acres. In four of the experiments four years' results have been secured, and in one, two years' results. These experiments are carried on in cooperation with the Georgia Agricultural Experiment Station on farmers' land controlled by the station.

An experiment on Cecil sandy loam has been under way at the Georgia station for 10 years, cotton, wheat, and corn being grown in rotation under the triangle system of fertilizer experimentation. The first five or six years' results in fertilizing corn and wheat showed that nitrogen was the principal limiting factor. A 6–6–3 fertilizer ratio, applied at the rate of 800 pounds per acre, has given largest yields and greatest profit, but in the last three years potash deficiency has occurred when this fertilizer ratio was used, indicating that 3 per cent potash is not sufficient.

Experiments to determine the best ratio of inorganic to organic nitrogen in fertilizer mixtures for cotton on Cecil clay loam at Youngsville, N. C., and on Ruston sandy loam at Fayetteville, N. C., show that the best results are obtained on these soils with a ratio of approximately 80 per cent inorganic to 20 per cent organic nitrogen. The inorganic-nitrogen carriers included a number of compounds of synthetic origin. The organic-nitrogen materials were largely by-products of vegetable and animal origin. These experiments are carried on in cooperation with the North Carolina Experiment Station and leading cotton growers.

POTATO SOIL-FERTILITY AND FERTILIZER INVESTIGATIONS

Field investigations in Maine, New York, New Jersey, Pennsylvania, and Virginia, in cooperation with the respective State agricultural experiment stations and leading potato growers, show that on certain types of soil, notably the sandier types and those possessing a high degree of acidity, certain plant-food deficiencies occurred. Magnesium was shown to be deficient under such conditions, and it was further shown that certain seasonal conditions influenced the degree of response to magnesium compounds. As a result of this work fertilizer manufacturers are including magnesium compounds in certain of their fertilizer formulas.

SUGAR-BEET SOIL-FERTILITY INVESTIGATIONS

In 1931 there were 720,000 acres devoted to growing sugar beets. The value of the crop was $46,958,000. The average increase from the use of phosphate alone on sugar beets has been about 3 tons per acre at a cost of $2 an acre for fertilizer.

When the Division of Soil Fertility began its fertilizer studies in 1921 to determine the extent to which fertilizer can be profitably used on different soil types used for sugar-beet production almost no fertilizer was being used on this crop. To-day its use has been extended to all sections of the country where sugar beets are grown, and to crops other than sugar beets, particularly crops grown in rotation.

The experiments of the past year tend to show that phosphoric acid is the limiting plant-food factor in growing sugar beets; also that different soil types and different cultural practices affect the production of sugar beets.

SOIL-FERTILITY INVESTIGATIONS WITH SUGARCANE

Experiments being conducted on the principal soil types of Louisiana in different localities indicate the best fertilizer mixtures for the various soil types.

Nitrogen alone in some cases produces the largest yields, and at least 12 per cent nitrogen in a 20 per cent mixture is required for the best results under average commercial plantings.

A report on the first year's results of a comparative study on sugarcane-juice analysis has been completed. The results show that the different fertilizer materials materially influence the chemical composition of the juice and that these reactions are of great importance to the industry in affecting methods of manufacture of sugar, particularly clarification processes.

The fertilizer-ratio experiments at the Houma station, begun in 1928 in cooperation with the Bureau of Plant Industry, were completed last year after harvesting the plant cane, P. O. J. 213, and three ratoon or stubble crops. The highest yield of plant cane of 46.94 tons per acre and 7,100 pounds of sugar were obtained by using a 4–16–0 (N–P_2O_5–K_2O) mixture in this field, when nitrogen was the controlling factor due to effective green-manure practices.

An experiment to determine the effect of different rates of application of nitrogen in the form of nitrate of soda and sulphate of ammonia was also concluded after the harvesting of plant cane and three ratoon crops.

A complete analysis of the major soil types of the sugarcane belt is being made, and it is expected that a report will be made before the close of the fiscal year. Among the soil types being studied are Yazoo silt loam, Lintonia silt loam, Yahola very fine sandy loam, and Sharkey clay.

CONCENTRATED-FERTILIZER EXPERIMENTS ON PROMINENT SOIL TYPES

Results beneficial to farmers and fertilizer manufacturers were obtained in 1932 from field experiments with concentrated fertilizers in Maine, New Jersey, New York, Pennsylvania, and Virginia. The work was conducted on important soil types with potatoes, corn, and vegetables. Comparative studies of ordinary, double-strength, and treble-strength fertilizers on four farms in Aroostook County, Me., and elsewhere disclosed that the highly concentrated fertilizer mixtures after standing for several months remained in excellent physical condition, could be drilled uniformly with the farmer's planting machine, and gave yields equal to those obtained with ordinary-strength fertilizer mixtures. The latter result possesses considerable economic importance, in that the use of concentrated fertilizers means a significant lowering of fertilizer cost, less storage and handling, and greater convenience in planting.

Experiments with concentrated fertilizers which have been in progress in North Carolina, South Carolina, Georgia, and Florida are being continued.

The addition of calcium, magnesium, and some of the heavy metals, such as copper and manganese, to concentrated fertilizers has increased crop yields on a number of soil types. Concentrated fertilizers containing very small additions of these chemicals have produced as large yields of cotton on Cecil clay loam in Georgia and Norfolk sandy loam in North Carolina and of tomatoes and other truck crops on calcareous soils in Florida as have ordinary commercial fertilizers. Without the added chemicals, crop yields were smaller from concentrated fertilizers than from commercial fertilizers.

COTTON ROOT-ROT INVESTIGATIONS

In tests of fertilizers with varying ratios of nitrogen, phosphoric acid, and potash, those containing readily available nitrogen and phosphoric acid were effective in accelerating growth of plants and favoring early maturity of cotton on the major soil types of the black-land area of Texas. The hastened maturity resulted in materially greater yields at the early pickings of cotton, constituting a means of avoiding losses from killing of plants by root rot later in the season. The yields from fertilized plots at the first picking in many cases approached or even exceeded the total yields from corresponding plots on unfertilized ground.

In experiments on the effects of midsummer subsoiling on root-rot-infested soils, losses from the disease in the succeeding cotton crop were reduced to very small proportions. On Houston clay and Houston black clay the proportion of dead cotton in the latter part of August was in one case reduced from 40 per cent on unsubsoiled ground to 5.5 per cent on subsoiled ground. In another instance the percentages of dead cotton were 67 and 8.8, respectively.

The results indicate that the rational use of fertilizers and a practice of modified tillage, in conjunction with crop rotation, soil conservation, and other

measures to maintain or restore fertility, offer promise as means for directly or indirectly controlling cotton root rot in the black-land area of Texas.

Chemical studies show that soils low in soluble phosphoric acid are conducive to cotton root rot, and this disease is minimized on soils containing an appreciable quantity of water-soluble phosphoric acid.

FERTILIZER INVESTIGATIONS WITH PECANS

Field-fertilizer experiments with pecans are being continued in Florida, Georgia, North Carolina, Louisiana, and Texas. In general, response to fertilizer is greatest when mixtures containing all three fertilizer constituents, nitrogen, phosphoric acid, and potash, are used. On the sandy soils of the Southeastern States nitrogen is most influential in producing tree growth, nut yield, and size of nuts, but it is necessary to use both phosphoric acid and potash on most soils, especially on the lighter ones of the coastal plains. In the southwestern pecan belt, including Louisiana and east Texas, favorable results have been secured from the use of nitrogen, phosphoric acid, and potash, singly and in combinations. Over the entire pecan belt the effect of fertilizer varies with climatic and soil conditions. During the extremely dry crop year of 1931, in pecan orchards which were untilled and in which native vegetation was allowed to grow, or where heavy summer cover crops were grown, fertilizers either had no effect on the trees or on the nuts or had a detrimental effect because of the vegetation, which robbed the trees of moisture. Under the same soil conditions in orchards that were clean tilled or had light cover crops fertilizers had a good effect on tree growth and nut yield.

A method of determining the oil content of pecans, based on the Babcock method of determining butterfat in milk and cream, has been devised. It shortens the time of determining the oil content of pecans from approximately 18 hours to 30 minutes. With slight modifications it is applicable to other oil-bearing seeds.

FERTILIZER INVESTIGATIONS WITH SWEETPOTATOES AND POTATOES

Field experiments with sweetpotatoes on Norfolk loamy fine sand in Currituck County, N. C., and with potatoes on Bladen fine sandy loam in Beaufort County, N. C., were continued in cooperation with the North Carolina Agricultural Experiment Station.

On Norfolk loamy fine sand sweetpotatoes give best results with fertilizers containing 3 to 4 per cent nitrogen, about 6 per cent phosphoric acid, and 8 to 10 per cent potash. Prior to the beginning of the experiments fertilizers which contained only 3 per cent potash were used. The use of increased amounts of potash has given growers larger yields and better potatoes.

Fertilizers containing nitrogen derived from mineral and synthetic sources and potash from low-grade potash materials have been detrimental to newly set sweetpotato plants, causing many to die and checking the growth of those that survived. The investigations show that these cheaper fertilizers can be used with less injury to sweetpotato plants if applied to the side of the row, broadcast over the top of the row, or used as a side dressing about two weeks after the plants are set.

Many experiments, in which methods and time of applying fertilizers to sweetpotatoes were compared, also showed that broadcasting the fertilizers over the row after the plants had been set and had become well rooted gave yields averaging 25 bushels per acre more than when the fertilizer was applied under the row before transplanting the plants, as is usually done.

When fertilizers, made according to the analysis suggested by the experiments, with nitrogen and potash derived from the cheaper sources of material, were broadcast on top of the rows after the sweetpotato plants were well rooted, yields of 240 bushels per acre were secured, as compared with 100 bushels as an average production in the State. Sweetpotato growers of the section have generally adopted the fertilizer analysis and methods of application recommended. The result is that the young plants suffer less injury, the stands are better, yields larger, and profits greater.

Results secured in the fifth year of the experiment with potatoes on Bladen fine sandy loam accord with those secured in previous years in showing that a fertilizer containing 5 per cent nitrogen, 9 per cent phosphoric acid, and 4 per cent potash gives larger yields than do fertilizers in which other proportions

of the ingredients are used, and that 2,000 pounds per acre is the most profitable quantity. Fertilizer containing nitrogen, of which 80 per cent is derived from mineral or synthetic sources and 20 per cent from organic sources of vegetable or animal waste origin, has given best results.

INVESTIGATIONS WITH CITRUS AND TRUCK CROPS

Experiments with strawberries, tomatoes, and peppers are under way at branch stations of the Florida Agricultural Experiment Station at Springhead and Bradenton, in cooperation with the State station. Other experiments are being conducted under a cooperative arrangement of several years with growers. Observations made in preceding years are confirmed by the past year's work, in showing that fertilizers containing quickly available nitrogen salts have given best results on such truck crops as cabbages, lettuce, beans, and garden peas. On some of the truck farms where strawberries and peas were grown the use of concentrated fertilizers composed of relatively pure salts reinforced with traces of manganese, zinc, copper, nickel, and boron resulted in more vigorous plants and larger yields than did the concentrated fertilizer alone or fertilizer of ordinary strength.

Cooperative experiments with citrus have been inaugurated in Polk, Brevard, and Indian River Counties in Florida, under agreement with growers for a period of years, to study the effects of fertilizers of ordinary strength and those of concentrated fertilizers of different physiological reaction, on tree growth and on yield and quality of fruit. These experiments should throw light on the soil-reaction problem now so vital in Florida.

STRAWBERRY SOIL-FERTILITY INVESTIGATIONS

Fertilizer experiments, conducted since 1929 and still in progress on the principal soil types used for strawberry growing in eastern North Carolina, show that fertilizer mixtures containing about 6 per cent nitrogen, 8 per cent phosphoric acid, and 6 per cent potash give best results when the vitality of the strawberry plants and the yield and quality of strawberries are considered.

Many fields of the sandy loam soils of the Norfolk, Coxville, and Dunbar types of the Chadbourn, N. C., strawberry district have been found deficient in magnesium, manganese, and potassium. Many crops, including strawberries, corn, oats, and soybeans, show nutritional deficiencies, which may be corrected by the addition of one or all of these fertilizer elements.

Another important fact disclosed by the investigation with strawberry soils is that quick-acting, concentrated nitrogenous fertilizers induce a better root growth of strawberry plants in winter, which in turn leads to larger yields than would otherwise be possible. The vitality of strawberry plants and their vigor under unfavorable weather conditions are influenced by fertilizer materials.

The experimental work has shown that yields are greatly increased when all the fertilizer is applied in late summer or early fall. One thousand five hundred pounds of fertilizer applied in late summer increased the yield from 400 to 500 quarts of berries more per acre than did split applications of fertilizers—that is, one-half applied in summer and one-half in winter. The berries also matured earlier. This change in the time of applying the fertilizer meant an increased profit of about $40 an acre in 1931, when berries sold on these markets at from $2.50 to $4.50 a crate.

SOIL-FERTILITY INVESTIGATIONS ON GREEN MANURING

Chemical studies on green-manure field experiments in progress for three years at the Pontiac experiment station in South Carolina have shown that using commercial fertilizers containing a high percentage of nitrogen and turning under stubble from a previous forage crop maintain the fertility of the soil better than turning under the entire vegetation produced by the preceding forage crop and using a fertilizer containing a low percentage of nitrogen.

It appears more efficient to allow the vegetative matter produced by green-manure crops to lie on the surface of the ground than to turn it under. When turned under in these coarse sands the organic matter decomposes very rapidly and the nitrogen is quickly leached from the soil.

MECHANICAL PLACEMENT OF FERTILIZERS

Experiments on three soil types to determine the effect of different placement of fertilizers on the germination and yield of cotton are in progress, this being the third year of these experiments. These investigations are being conducted cooperatively by the Bureau of Chemistry and Soils, the Bureau of Agricultural Engineering, and the South Carolina Agricultural Experiment Station.

On none of the soil types was there injury to seed or retardation of growth when a 4–8–4 or a 8–16–8 fertilizer was placed to the side of the seed. These fertilizers, used at the rate of 800 and 400 pounds per acre, respectively, when placed in contact with the seed or under it, caused poor germination, poor stands and low yields, and retarded growth. These effects were more severe on sandy soils and sandy loams than on clay loams.

Applications of 8–16–8 fertilizer greater than 400 pounds per acre caused injury to stands on sandy loam and sandy soils, but had no appreciable effect on cotton on clay loam soils.

The field results substantiate those of previous years in showing that the best distance between seed and fertilizer depends upon factors such as character and moisture content of soil and weather conditions. Results from these studies have been helpful in securing good stands of cotton in areas where large quantities of fertilizers are required for cotton production.

Up to 1931 the chief fertilizer-placement studies were with cotton and corn. As the result of a conference at New Brunswick, N. J., at which various agencies were represented, fertilizer-placement experiments were established on prominent potato-soil types in New Jersey. Two field experiments were established, one on Sassafras loam in the vicinity of Cranbury, N. J., and the other on Sassafras sandy loam in the vicinity of Bridgeton, N. J. In these experiments different methods of fertilizer placement were compared, ordinary, double-strength, and treble-strength fertilizer mixtures being applied. Arrangements were also made to conduct fertilizer-placement work on potatoes in Michigan and Ohio. Additional field work was started during the fiscal year in Aroostook County, Me., on Caribou loam soil type; and on the eastern shore of Virginia, on Sassafras sandy loam. The investigational studies with potatoes in these five States are expected to effect a standardization of fertilizer-placement methods as an aid to economical fertilizer practice and thereby to enable manufacturers of fertilizer machines to so design them that they will give uniform fertilizer distribution and placement.

The results for a single season indicate that certain methods of placement have given better results than have other methods. Close proximity of the fertilizer to the seed piece without actual contact appeared best, although in Ohio the influence of rainfall was sufficient to render placing the fertilizer underneath the seed piece and lightly mixing it with the soil, the best. Such variation will make it necessary to accumulate results over a period of several years. The investigational work in these States is conducted in cooperation with the respective State agricultural experiment stations, fertilizer interests, and machinery manufacturers.

BIOCHEMICAL SOIL STUDIES

Studies on the chemical nature of the products of growth of certain soil fungi have been made by the bureau. So far these studies have disclosed the fact that such fungi elaborate uronic acids and a chitinlike material. The latter is of interest in that it is nitrogenous and extremely resistant to decomposition either by chemical reagents or microorganisms.

Data on the carbon-nitrogen ratio in soil are being collected incidentally to general soil analysis, and where the ratio is abnormally high or low some investigational work has been done on the composition of both the nitrogenous and nonnitrogenous constituents.

SOIL-REACTION AND OXIDATION-REDUCTION STUDIES

An investigation of the electrometric titration for the determination of chlorine has been made and the process as previously developed has been modified. It has been found that the process is applicable to practically all American soil types. Manuscript for a publication on this subject has been prepared. New methods of hydrogen-ion determinations, as they are developed or published, have been tested and reported on.

GREENHOUSE SOIL-FERTILITY INVESTIGATIONS

Greenhouse work during 1932 embraced activities primarily associated with field and fertilizer problems.

A comparative study of two prominent soil types which showed definite malnutrition disturbances in the field, owing to a deficiency of magnesium, brought out the fact that optimum growing conditions provided in the greenhouse, particularly as to moisture, largely masked the symptoms observed in the field, such as chlorosis, stunting of vines, and development of necrotic tissue.

Soil-solution studies, in connection with different methods of planting and fertilizing potatoes, were started in conjunction with cooperative investigations undertaken by the Bureaus of Chemistry and Soils, and Plant Industry. These studies include the determination of moisture and nitrates at different depths, soluble-salt concentration, and the recording of soil temperature by means of automatic instruments.

MISCELLANEOUS SOIL-FERTILITY AND FERTILIZER INVESTIGATIONS

Farmers and gardeners are taking special interest in saving money in the purchase of fertilizers and also in the making of composts. Leaflet No. 70 on Home Mixing of Fertilizers has continued to be a very popular and useful publication. To date over 63,000 copies have been distributed. During the year (January, 1932) Miscellaneous Publication No. 136, Conservation of Fertilizer Materials from Minor Sources, was published. An edition of 5,000 copies was printed and has been exhausted. By the distribution of the above-mentioned publications, by individual letters, and by personal advice to visitors help has been rendered to inquirers from all sections of the country and from several foreign countries. Help has been given on problems of soil fertility, such as home mixing of fertilizers, use of lime, preparation of composts, use and care of animal manures, and proper handling of the soil for various crops.

SOIL CHEMISTRY AND PHYSICS INVESTIGATIONS

A special study of the soils of the erosion experiment stations has been conducted, and the results of this investigation have been reported in a technical bulletin. In this study the physical and chemical characteristics of the soils of seven stations have been compared and the data obtained are correlated, so far as possible, with the field data obtained at the stations. The study of these soils is being continued through a detailed examination of the eroded material and that which is dissolved in the run-off water.

A study of the methods of determining organic matter and carbonates in the soil, which has been completed and published, has shown that existing methods are far from satisfactory. The very definite suggestions made for improvement in these methods will be helpful to soil chemists.

The investigation of colloid fractions prepared from a group of representative soils has been completed. The study of these fractions, considered in conjunction with types of colloids previously studied in the bureau, is the basis of a far-reaching general hypothesis on the constitution of soil colloids.

During the last 25 years very marked advance has been made in applying technical methods of petrography to the study of soils. The results have been embodied in a manuscript which has been submitted for publication as a bulletin. It is expected that this publication will be highly useful as a practical guide for a large group of soil students.

A study to determine whether a greater hydrolysis of soil material occurs during the extraction of colloids than under field conditions has been completed. The evidence tends to show that this is not the case. The data have been published as an article in the Journal of Agricultural Research.

Studies of the effect of colloids on the availability of phosphates in the soil, in which it is shown that the colloids of different soil types differ widely, are nearing completion. The results should have a very interesting and important bearing on the practical use of phosphates, with special reference to the effect of different soil types on the availability of soluble phosphates applied in commercial fertilizers.

Likewise, a very extensive and intensive study of soils developed from serpentine is nearing completion. The study was undertaken to ascertain the causes of the low productivity of such soils. The results reveal not one but a number of causes. Apparently such soils always contain abnormal quantities of

chromium, nickel, and magnesium, and in some instances notable quantities of barium. All these components in certain concentrations are presumably injurious in their action upon plants. To which component major importance is to be ascribed has not yet been determined.

A study of certain peat profiles has been made and the amounts of dispersable organic colloids in them determined. The relation between the composition of soil colloids and the soil classification used in the soil survey division has been studied.

Advancement is being made in studying the problem of increasing the value of peat as organic material for soil improvement. This development was made possible as a result of efforts to alter the rate of decomposition of peat under the catalyzing influence of mineral soil.

A very laborious and difficult investigation on the colloidal behavior and the colloidal properties of soil organic matter is being made. A number of entirely new facts on soil organic matter have been developed. Probably the most interesting of these is that organic matter, like the inorganic soil material, is amphoteric.

Considerable progress has been made in a study of the hardpans of Nebraska in the hope of throwing some light on the origin of hardpan in soils. It is expected that the facts developed in this investigation will also have a bearing on the problem of alkali soils.

The lines of investigation enumerated represent the research activities of the division.

An almost equally important and time-consuming function of the division is service work, in which approximately 600 mechanical analyses of soils have been carried out; several hundred identifications of soil and related materials have been made; about 100 chemical analyses of soils and colloids have been made; studies of available plant food and of base-exchange content of a number of analyses of water and soil have been made in connection with the smelter fumes investigations.

A study of certain Chinese soils has been made at the request of the soil survey.

Numerous minor examinations have been made at the request of many different branches of the public service, both Federal and State. The demand for this type of routine work is increasing and the work requires more and more time.

SOIL-MICROBIOLOGY INVESTIGATIONS

The inspection of cultures of legume-nodule bacteria as directed in the appropriation act for the year 1931–32 has covered the products of 25 commercial organizations and 14 State institutions. Six hundred and fifty official samples were handled. These samples represented every brand of commercial inoculant sold to farmers for legume inoculation. The laboratory has been able to test, under strictly controlled conditions, all these products, and to guide the farmer as well as the manufacturer toward obtaining satisfactory results. This inspection has eliminated two worthless products from the market during the past year, but on the constructive side it has helped to make others satisfactory.

In the past there has been much disagreement about the necessity, or even the desirability, of inoculating the seed of legumes planted in the same fields in successive years. Some workers believed it unnecessary and wasteful, assuming that colonization in the soil after one inoculation should be adequate for years of more or less continuous legume cropping. Nevertheless, uncertain results have been common. In 1929 a field of Austrian winter peas with abundant nodules was discovered in which damage rather than advantage from such inoculation was evident. This furnished an opportunity to determine the cause of such a failure. The soil of this field was found to contain nodule organisms in abundance, derived from a native legume, but capable of inoculating the Austrian winter pea without benefit to the crop. Experiments in this field, carried on over two years, have shown that the bad effects of unfavorable inoculation were completely controlled by inoculating the seed with the proper organisms before planting. Such experiments as this emphasize the desirability of inoculating legume seed at each planting with organisms known to be beneficial to that particular crop, to insure predominance of the desirable species over any worthless or harmful forms which may be present. Pea canners in some sections now require such inoculation.

To provide for all such needs the division is continuing to develop a collection of strains of nodule organisms representing all legume crops commonly grown

in the United States, and incidentally many rare and special strains for legumes not commonly grown. The effort to make this collection as complete as possible is justified by the fact it is the only one of its kind in the United States available to all experimenters in the field.

The constant development of new legume-producing areas and the introduction of new legumes from foreign countries to supply particular needs is thus being paralleled as rapidly as possible by the accumulation of nodule cultures favorable to each such crop.

COOPERATION WITH EXTENSION SERVICE AND FARMERS

During the past year about 5,000 cultures of nodule bacteria for alfalfa, sweetclover, soybean, and other legumes were distributed for experimental purposes at the request of individual farmers, Members of Congress, and county agents; the latter used the material to acquaint farmers with the value of this material especially on crops new to their land, such as soybeans, alfalfa, and vetch, heretofore neglected in many sections. The development of commercial sources of such inoculation has been gradually reducing the demands on this division aside from the systematically planned work in cooperation with the extension service.

GREEN MANURE

In the struggle to maintain or increase the level of crop production, green manuring has been commonly recommended. It has been markedly successful in some areas, less so in others, and costly or wasteful at times. The possibility that some of the successes and failures were traceable to soil organisms led to a series of studies during the last five years.

To make the problem concrete and controllable, two naturally acid soils were selected and lots were removed to the greenhouse and established in a series of plots alternately natural and limed to approximate neutrality. In one series, green manure in succulent form was introduced at the 5-inch level into series of plots in both types of soil. In another series the crop was grown on the plot and turned under. Then the course of decomposition and its effects on the soil were followed by a study of samples taken through the whole period.

From the mass of results published, a few items stand out. Succulent green stuff turned under carries great numbers of organisms to the soil. These microorganisms, not those of the surrounding soil, multiply with great rapidity and rot down the materials plowed under. The decomposition process itself was little affected by the acidity or alkalinity of the surrounding soil. The microbiological activities in the surrounding soil remain unchanged outside a very thin zone in actual contact with the decaying organic matter. Under favorable conditions of moisture and temperature, this is a very local but "explosive" activity, consisting predominantly of bacterial development only, not affecting molds or other organisms; great quantities of carbon dioxide are released, flooding the soil and much of it escaping into the air. The nitrate nitrogen present is usually exhausted during periods of very great bacterial activity. Soil acidity was not affected by the process and did not interfere with or accelerate the decomposition of the masses turned under. The presence and decomposition of the root system of the green-manure crop throughout the soil exerts a favorable influence on nitrate formation and brings about a more generally favorable activity than that produced by masses of material brought in and plowed under. While much remains to be done, these results give a better picture of the nature and course of decomposition than was previously available, since the explosive character of such decompositions had not previously been recognized.

SOIL FUNGI

The molds of the soil must be considered among the agents affecting the nature and amount of soil organic matter. Two series of these fungi have been specially studied in the past year—(1) those responsible for initial decay of annual-plant material in the cultivated field and, for contrast, (2) the fungi of the forest floor.

Observation for long periods and over wide areas shows that brown-walled molds such as Cladosporium, Alternaria, and Helminthosporium form the characteristic species on the decaying portion of grasses, weeds, and crop residues, giving a gray to brown or black color to the parts attacked. A series of these

forms were brought together, grown in pure culture with sugar as a sole source of carbon, and analysed. The colonies developed consisted of black-brown slimy masses of mold, which upon analysis yielded lignin in amounts up to 20 and even 30 per cent of the dry weight. In the experiments, these forms were rapid destroyers of sugars, starches, and other quickly decaying substances, rather than of the fibrous elements. Thus they tend to contribute to the lignins which seem to be an important part of the soil organic matter.

The survey of soil fungi on the forest floor was begun during the fall of 1931, and wooded areas in New York, Maryland, Virginia, West Virginia, Tennessee, Kentucky, Ohio, Indiana, and Illinois were examined to establish a basis for interpreting the relations of fungi, other organisms, and tree roots in the decomposing mass that covers the soil itself.

This survey aided in defining the differences between perennial biological situations such as that provided by the forest floor, or to a less extent the pasture or meadow, and the annual environment represented by soils regularly or annually cropped.

In contrast to the fungi of the cultivated field, the characteristic fungi of the forest floor seemed to be devoid of intermediate colors and to consist mostly of colorless or bright-colored forms, which upon the same type of analysis yielded little, if any, lignin. Some of them grew above ground, attacking leaves, twigs, and other fibrous masses, and reducing them in two or three years to unrecognizable forms often without visible accumulation in the underlying soil. The masses of vegetative mycelium produced by the Hymenomycete or fleshy group of fungi upon the forest floor sometimes filled the top layers of the soil over wide areas which had required years of undisturbed growth to develop. Such forms are entirely unable to maintain themselves in cultivated areas. Areas plowed regularly show forms, most of which develop and fruit within a single season. Enough investigation has been done to bring out the marked contrast between the types of organisms in the permanent stand and those in areas producing a different crop each year. The fungi of the meadow and pasture under semipermanent growth conditions occupy an intermediate position and represent a fairly distinct series allied rather more closely to those of the farm than to those of the forest.

FERTILIZER AND FIXED NITROGEN INVESTIGATIONS

The Fertilizer and Fixed Nitrogen Investigations Unit is engaged in developing better methods of fertilizer production. There already exists a fertilizer-producing industry, ample in size and well controlled by State agencies, functioning regularly and supplying current demands. However, this line of manufacture is intricate in character, is undergoing continuous change, is by no means fully supplied with basic scientific data, and is therefore still susceptible to worthwhile improvements and economies. Accomplishments in this field benefit the manufacturers who make the fertilizer and the farmers who use it, as well as the general public, which demands farm products of the highest quality.

Briefly stated, the normal situation, taking 1928 as an average year, is as follows: In that year crops valued at $9,093,217,000 were harvested in the United States from 358,093,000 acres of land; 7,939,483 tons of commercial fertilizer were used, an average of only 44 pounds per acre. The cost of the fertilizer to the farmer amounted to approximately $263,591,000 and was equal to 2.9 per cent of the crop value. This figure differed among the States from practically nothing in some Western States to as much as 18.2 per cent in one Southeastern State.

While fertilizer consumption has been low during recent months, the record of many years shows that the normal annual requirement of the country is 8,000,000 tons, made up of a variety of materials containing a total of 350,000 tons of nitrogen, 800,000 tons of phosphoric acid, and 350,000 tons of potash in a form suitable for growing plants. The fact that fertilizer consumption has at no time during the depression dropped below 50 per cent of the maximum consumption proves conclusively that farmers consider fertilizer an absolute necessity in many lines of agriculture. Even in the face of very low prices incident to abundant production, the farmers seem to have little faith in lower yields as a cure for their individual troubles, since lower yields would increase the unit cost of production if they were brought about by eliminating fertilizers.

The fertilizer-production problem is twofold: (1) Raw materials must be available; and (2) these materials must be so manufactured as to meet the varied requirements of their intended uses. In its supply of raw materials the

position of the United States is improving year by year. The country has long been independent in its phosphate supply, and is now in a strong position in regard to nitrogen. The nitrogen situation has changed greatly in the last few years. In regard to potash there is still much to be desired, but the status of this material already gives assurance that a shortage such as that of the war years can never occur again. The time has already arrived when no foreign group can dictate fertilizer prices to American producers.

There is almost no limit to the possibilities in manufacturing procedure. In the past mere possibilities have in various instances on investigation proved to be extremely valuable industrial processes. In the future other processes not now employed will probably come into use, perhaps as a result of new discoveries or through better understanding of facts now known, or perhaps by a change in economic conditions. This bureau seeks to develop promising new processes, to improve the old methods, to produce new materials, to investigate various raw materials, and to examine and determine the properties of new products suggested for fertilizer use A comprehensive research program for developing the basic data required in solving these problems is being carried out.

The economic set-up surrounding the fertilizer industry is extremely complex. In shaping its research program the bureau has used due diligence in keeping posted on changing conditions throughout the world.

According to the 1930 farm census the farmers of the United States purchased, in 1929, fertilizers and soil amendments valued at $271,000,000. This figure covers purchases of a large variety of commercial fertilizers, manure, marl, lime, and ground limestone. It is very desirable that the purchasers of this material should have the best possible understanding of the character of the material which they require, in order to exercise good judgment in buying it. A publication issued during the year, entitled "American Fertilizers," which is both popular and educational in character, answers many of the questions being asked concerning commercial fertilizer.

NITROGEN

The bureau has taken a leading part in the establishment of the nitrogen-fixation industry in the United States. The present objective is to lower the production cost of ammonia and the cost of converting ammonia into fertilizer materials in order that manufacturers in this country may meet foreign competition and supply farmers with nitrogenous fertilizer at the minimum cost. In the United States agriculture uses three times as much nitrogen as do all other consumers combined and therefore, with the exception of the nitrogen industry itself, agriculture has the greatest interest at stake.

CATALYSTS IN NITROGEN FIXATION

A considerable part of the early work of this unit was devoted to the production of a suitable catalyst for use in the direct synthetic ammonia process under manufacturing conditions. These research activities, which were decidedly successful, are being continued but have recently been more concerned with the factors that influence and determine the activity of catalytic substances. By discovering how and why these substances act as they do a sound basis is being established for the improvement of catalysts and the nitrogen-fixation industry of which they are the vital part.

One line of active investigation is for the purpose of learning more about the catalysts and catalytic reactions involved in the fixation of atmospheric nitrogen. It involves the study of catalysts used in the preparation and purification of nitrogen-hydrogen mixtures, the synthesis of ammonia at high pressures and temperatures, and the oxidation of ammonia to nitric acid. The ultimate goal is to so clarify the character of catalytic reactions that industry will be able more effectively to choose catalytic materials for various industrial chemical processes, particularly those in which nitrogen is used in some form, such as the manufacture of fertilizers or explosives. The information acquired and published is of both industrial and scientific interest.

The work of the year supports the theory that the iron catalysts are particularly active in ammonia synthesis, because nitrogen can react with active iron atoms on the surface of the catalyst to form a surface iron nitride. This nitride in turn is capable of reacting with hydrogen to produce ammonia, with the regeneration of the catalytic iron.

PHYSICAL CONSTANTS OF GASES AND FERTILIZER SALTS

The commercial utilization of gases in reactions at high pressures and temperatures, as in the synthesis of ammonia, created a demand for physical data more accurate than had been available. The early investigations in this unit were limited to hydrogen and nitrogen, the two gases essential to ammonia synthesis; later on the work was extended to include carbon monoxide and methane, both of which are important in the production of hydrogen. Then helium was added to the list because it was desirable to know the compressibility of this chemically inactive gas, which is only slightly adsorbed by most catalysts. This knowledge was required in determining the adsorption of various gases under high pressure. The solubility of hydrogen in water at 25° C. and at pressures up to 15,000 pounds per square inch had been determined. During the past year the solubility of nitrogen in water at 25° and 50° and over a pressure range of from 25 to 1,000 atmospheres was studied, the data on solubility in water being important in the scrubbing process used in gas purification. The solubility of nitrogen at 25° in liquid ammonia over a similar pressure range was also determined. The latter data are useful for calculating the loss of gas after the ammonia-synthesis reaction has taken place and also for determining the amount of gas to be removed from the liquid ammonia before it can be stored or shipped.

By means of sensitive methods, devised by mathematicians of the bureau, for determining slopes of curves, it has been possible to calculate from compressibility data the heat capacities and the cooling by expansion of gases. This obviates direct measurements which are expensive and not feasible over the higher temperature and pressure ranges covered by compressibility data. This represents a very appreciable annual saving to industry.

Important results in the spectroscopic and photochemical investigations on nitrogen and the nitrogen oxides have given definite information on the fundamental steps involved in nitrogen fixation. These results are significant in view of the fact that this information has been sought in world-wide investigations for the past 10 years. An X-ray analysis of American phosphate rock has shown it to be a crystalline compound containing fluorine. This work showed why many of the early efforts of industry to separate the fluorine from the phosphate rock failed. Incidentally, in connection with the analysis of these materials, the X-ray structure of bone was definitely determined.

UREA SYNTHESIS

The desirability of urea as a fertilizer material has long been recognized, and the abundant supply of ammonia from the direct synthetic-ammonia process and the abundance of carbon dioxide, the by-product of the same process, have made its production commercially feasible. Employment of urea for fertilizer has increased rapidly since it became available. It is highly concentrated, containing 46.6 per cent nitrogen, and is ideal for preparing concentrated fertilizers because it leaves no deleterious residue in the soil. The American fertilizer industry used about 20,000 tons of urea in 1930, at a price of about 4 cents a pound. By substituting this for equal amounts of organic and inorganic nitrogen, a saving of about $1,500,000 would be made, and an additional saving of $500,000 in freight would be due to the high concentration of nitrogen in urea. As an ammonia-conversion product it must compete in the fertilizer market with ammonium sulphate, ammonium phosphate, sodium nitrate, calcium nitrate, and ammonium nitrate.

On being mixed, ammonia and carbon dioxide unite almost instantaneously to form a solid compound, ammonium carbamate, from which urea may be obtained by heating to a temperature of 150° C. in a closed vessel. A small plant, constructed by the bureau several years ago for producing urea in this way, was operated to obtain information on the conditions favorable to urea formation; the operation yielded valuable data and also brought out the need for more exact knowledge of the reactions and equilibria involved. A series of laboratory investigations to give the required information was therefore initiated and is still in progress.

Investigations have been continued through the year on the phase relations of the products obtained in synthesizing urea from carbon dioxide and ammonia, and part of the work has been completed. A study of the melting-point diagram of the urea-conversion products was completed and the results published. They

show the relatively low temperature, about 65° C., that it is necessary to maintain in recovering ammonia from the conversion product in order to obtain urea and return the unconverted ammonium carbamate to the system. It was demonstrated further that the product obtained either by employing double the amount of ammonia in the conversion or by adding ammonia after the conversion, remains liquid even below the freezing point of water and may be directly utilized as a nitrogen constituent in preparing mixed fertilizers. Such direct employment of the product, involving the fixation of the excess ammonia by the superphosphate, results in considerable economy in producing urea for fertilizer use and permits the direct addition of larger amounts of nitrogen to mixed fertilizers, thereby producing a material more concentrated than would otherwise be possible.

BIOCHEMICAL AND ORGANIC INVESTIGATIONS

The purpose of the biochemical and organic investigations is to determine the chemical mechanism by which living organisms fix nitrogen, so that this knowledge can be applied to the more economical fixation of atmospheric nitrogen as a commercial operation in the manufacture of both organic and inorganic nitrogenous fertilizers. While certain phases have an industrial objective, others are of direct practical value to the farmers.

Some idea of the economic possibilities of the nitrogen-fixation work accomplished by soil organisms may be gained from the knowledge that approximately 90 per cent of the nitrogen found in soils and elsewhere in nature was fixed by living organisms. Probably at least 2,500,000 tons of nitrogen are now fixed annually in the United States in this manner as contrasted with about 350,000 tons applied in all forms as commercial fertilizers. At 7 cents per pound the nitrogen fixed in nature is worth $350,000,000 annually. Any information of direct practical or commercial value obtained in studies with these organisms is of tremendous economic importance to agriculture.

During the past year marked progress has been made in determining the nature of the chemical reaction involved in the first step in the process of nitrogen fixation by bacteria. Many of the properties of the enzyme responsible for the fixation and the conditions most favorable for its activity have been determined, as have the specific functions of calcium, strontium, and iron. Other studies show that no appreciable quantity of energy, other than for growth, is required to bring about fixation. The perfection of a greatly simplified and cheaper method of producing nitrogenous fertilizers, modeled after nature's simple method, depends largely upon more knowledge about the nature of the bacterial nitrogen-fixing enzyme.

Studies recently completed show that soil humus, long known to stimulate the growth of higher plants, also stimulates the growth of nitrogen-fixing organisms. This unit has recently proved that the stimulation is due primarily to the iron present, which also serves as a catalyst in the nitrogen-fixation process. Additional studies have shown that, aside from its physical effects, the beneficial action of soil humus under ordinary soil conditions is due largely to its ability to hold mineral elements, particularly iron, in a readily available form. Experiments show that nitrogen assimilation and higher plant growth are markedly increased in the presence of a high iron humus, either natural or synthetically prepared.

The details of the chemical and physiological relations existing between legume-nodule bacteria and their hosts are being worked out in the course of determining how the nitrogen is fixed. Studies are also being made with the group of green plants known as blue-green algae to determine the function of chlorophyll in the fixation process. These organisms were isolated in this laboratory and their nitrogen-fixing powers established a few years ago.

Organic fertilizers in the past have mainly been utilized in the form of appropriate waste products. Industrial manufacture offers the best hope of an adequate and cheap supply of the active ingredients. An attractive synthesis of organic fertilizers is that involving the fixation of nitrogen by organic compounds. Considerable preliminary work toward this goal has been completed and published.

POTASH

A variety of potash minerals occur in abundance in various parts of the United States. There are natural potash brines in California and other Western States; there are subterranean deposits of water-soluble potash-bearing salt

in the vicinity of southeastern New Mexico; potash dust is available at widely scattered cement plants; Wyoming leucite, alunite (occurring in Utah and Nevada), Georgia shale and greensand marl (occurring in New Jersey, Delaware, Texas, and other States), are refractory minerals available in quantity sufficient to supply the needs of the sections where they occur and awaiting only the development of an economical process for their extraction. In spite of these natural resources and the progress in their exploitation in California and New Mexico, the country is still largely dependent on imports of potash. This bureau's objective is the very best utilization of the country's fertilizer resources, in order to assure American agriculture in all sections an adequate supply of fertilizer at fair price and transportation cost. The saving in transportation by developing supplies near the consuming area has been kept clearly in view in planning these investigations. Several lines of attack have seemed necessary. The fact that domestic production during 1931 remained at its former level, in spite of additional but idle capacity in the far West, while imports declined only 40 per cent, supports this conclusion. Each raw material offers a separate problem, the solution of which calls for an industrial chemical process.

ACID EXTRACTION METHODS

The utilization of nitric, sulphuric, and hydrochloric acids in treating potash ores insoluble in water has been studied.

Nitric acid is desirable in this treatment, since it is now a cheap industrial reagent, and particularly because it yields agricultural nitrates. When nitric acid is applied to Wyoming leucite, satisfactory extraction is obtained with the formation of potassium and aluminum nitrates. A method of separating these substances from their impurities has been found whereby, when the mixed nitrates are roasted, these two constituents combine to form potassium aluminate, freely soluble in water, while all the impurities are rendered insoluble. Nitric acid is evolved and recovered for use again, and the two constituents appear finally as potassium nitrate and high-grade alumina. The data obtained in laboratory experimentation indicate that a commercial method, applicable likewise to Georgia shale, is practicable. The nitration of cement potash, a new product collected from cement kilns, proceeds with facility and yields a product containing 18 per cent K_2O and 9 per cent N, or 27 per cent plant food. The dust readily absorbs nitric oxide and the absorption yields a product having excellent physical properties.

Sulphuric acid applied to Wyomingite and Georgia shale yields results generally analogous to those previously obtained in the study of greensand. Potash and alumina may be separated from the resulting mixed sulphates by the crystallization of alum and its decomposition in the crystalline state by gaseous ammonia, yielding a heavy hydrate of alumina and potassium and ammonium sulphate.

Hydrochloric acid produced from potassium chloride by methods developed in these laboratories has been shown to be a reagent so inexpensive as to warrant its use in industry for the extraction of potash from its ores and likewise for extracting available phosphates from phosphate rock. The recovery of potash from the mixed chlorides being relatively simple, the problem is to recover the by-product, alumina, and particularly to separate it from iron. The thermal treatment of the chloride has been studied to effect selective (1) decomposition and (2) distillation, with preliminary results that give promise of success, with the recovery of hydrochloric acid which can be used again.

FURNACE METHODS

The feasibility of smelting Wyoming leucite had previously been shown. During the last year efforts were concentrated largely on New Jersey greensands. These are more easily mined and are more accessible to market, but contain little more than half as much potash as the leucite. It was shown that more than 90 per cent of the contained potash may be recovered by a brief heat at moderate temperatures in a reducing atmosphere. A number of tests on greensand in experimental blast furnaces gave uniform high volatilization of potash (84 to 90 per cent), but because of the large amount of silica and iron present the slag production is enormous and results in high smelting cost. However, the iron should share the smelting cost, since each ton of potash in greensand is accompanied by 2½ tons of iron, which may leave the furnace as

high-grade pig iron. Potash smelting with pig iron as a by-product seems economically attractive. A suggested improvement in the process consists of applying an acid treatment that results in concentration of the potash values and subsequently smelting this concentrate in the blast furnace.

The recovery of potash from alunite involves the recovery of the alumina, its chief constituent. Furnace processes heretofore employed have rendered the alumina insoluble and therefore unavailable for use except as refractories and abrasives. Low-temperature methods have been successfully used to avoid this difficulty. It has been found, for example, that by adopting potash salts other than sulphate as reagents, the furnacing of alunite with the required amount of potassium chloride effects the convenient decomposition of the mineral with all the potash reappearing as the sulphate. The cost of this operation is justified by the present premium offered for potash in this form. This reaction, it is believed, will yield the alumina in a form so pure as to permit its access to the most preferred market.

PHOSPHATES

A detailed study of the chemical constitution and composition of the commercial grades of domestic phosphate rock was completed. Special attention was given to less common elements, such as manganese, chromium, vanadium, iodine, copper, zinc, and arsenic, which may affect plant growth. This study shows that phosphate rock is comparatively rich in iodine and may possibly serve as a source of this element in iodine-deficient soils. Certain western phosphates contain vanadium in sufficient quantity to suggest commercial recovery in connection with fertilizer manufacture. This work has contributed to the development of a successful process for recovering high-grade phosphate from materials formerly wasted; such a process will increase the life of our phosphate resources by at least 25 per cent. These investigations have also definitely established the fact that domestic rock is composed of calcium phosphate and calcium fluoride, and that methods for converting phosphate rock into quickly available fertilizers succeed only so far as they effect decomposition of this complex compound. This opens up possibilities for new methods of phosphate-fertilizer manufacture.

Investigations looking to the elimination of the acid-concentration and drying steps in triple-superphosphate manufacture are under way. Results indicate that efficient reaction between phosphate rock and dilute acid can not be obtained. However, promising results were obtained by using mixtures of sulphuric acid and dilute phosphoric acid as made by the sulphuric-acid process. It appears possible to eliminate artificial drying by treating the wet product directly with anhydrous ammonia. Such procedure results in superphosphates containing up to 30 per cent or more of available phosphoric acid and up to 10 per cent of ammonia, thereby furnishing a concentrated fertilizer of superior physical condition. A thorough study of this process is being made.

During the year work on the treatment of superphosphates with ammonia and the availability to plants of the water-insoluble product was continued. As a result of this work the official laboratory method for determining available phosphoric acid was changed in such a way as to permit a 100 per cent increase in the direct use of free ammonia in fertilizer mixtures. If fully taken advantage of by the fertilizer industry, this increase would normally amount to 80,000 tons of anhydrous ammonia per annum, having a wholesale value of about $8,000,000. These investigations have also brought out facts which seem destined, upon further development, to bring about radical changes in prevailing ideas on the phosphate fertilization of crops. The change in the official method was based on comprehensive tests. The availability of hydrated tricalcium phosphate and of ammoniated superphosphates containing varying amounts of ammonia was determined by submitting samples of these materials and of standard phosphates to a number of laboratories throughout the country for collaborative study. The relative fertilizer value of these materials was also determined in an extensive series of pot tests conducted in collaboration with 21 State experiment stations. These showed that the fertilizer efficiency of hydrated tricalcium phosphate and heavily ammoniated superphosphates is similar to that of steamed bone meal. All three materials compare favorably with superphosphate in their effect on crops when used on acid soils, but their value is less when used on neutral or alkaline soils. It has been found, however, that about 90 per cent of the tillable soil in the States that use 75 per cent of the fertilizer consumed in this country is acid in reaction; accordingly, the

Association of Official Agricultural Chemists ruled that the interests of all concerned called for making the described change in the testing method.

Data on the chemical and physical properties of the calcium phosphates secured as a result of the study made on the ammoniation of superphosphates have been used in developing a commercial process for preparing a non-caking dicalcium phosphate.

PHOSPHATE-SMELTING METHODS

Work on blast-furnace methods of smelting phosphate rock was carried on through the year in conjunction with the investigations on extracting potash from its insoluble ores. Additions and improvements in the experimental furnace plant were made, mainly in the equipment for recovering the product from the furnace gases. The main effort of the year was aimed at a more definite knowledge of the influence of the character of the rock, of the fuel, and of the blast on the smelting costs. Results indicate that smelting costs are quite independent of the quality of the rock and the fuel and are therefore favored by low prices. Blast temperature is the determining factor, and low moisture content in the blast helps greatly. These factors have received special attention. Glaucosil as a drying agent for the blast is being studied.

MIXED-FERTILIZER TECHNOLOGY

More than 90 per cent of the fertilizer materials consumed in the United States are used in the form of mixed fertilizers. As a result of the new developments that have taken place since the World War, many new materials have been placed on the market at greatly reduced prices per unit of plant food, and therefore the average cost of mixed fertilizers has also been reduced. Comparatively little attention was given during the same period to the most effective use of fertilizers. Their efficiency remained about the same or actually decreased because of the poor mechanical properties of many of the new materials. The question of the most effective use of fertilizers is therefore of special importance at this time.

The efficiency of fertilizers may be increased (1) by increasing the uniformity with which they are distributed in the field (2) by adjusting the position of the fertilizer in the soil with respect to the seed so as to secure the optimum balance between its burning effects and its availability to the roots of the plant, and (3) by improving the quality of the fertilizer.

The property of fertilizers that interferes most seriously with their uniform distribution is that known as hygroscopicity—the absorption of water which results in caking. This property varies greatly in different materials. Ammonium nitrate is the cheapest material containing ammonia and nitrate nitrogen that can be prepared, but its excessive hygroscopicity prevents its use in fertilizer mixtures Cost is therefore not always a determining factor in the use of fertilizers.

Caking necessitates the expense of re-treating in order to restore the fertilizer to a marketable form, or, in the case of caking after the purchase by the consumer, requires labor and time in reducing the fertilizer to a condition in which it may be properly drilled. The knowledge acquired in the course of these investigations should also be of value in developing wet methods for preparing mixed fertilizers, since it serves to give beforehand an idea of the nature of the products obtained by any proposed method.

A review of the methods of preparation, plant-food content, and properties of various new fertilizer materials and mixtures was prepared. This was incorporated in the report of the President's Muscle Shoals Commission in 1931.

A study is being made of the heat developed when fertilizer mixtures are treated with relatively high percentages of ammonia. The object of this study is to determine the possibility of applying the heat of the reaction in bringing about an automatic granulation of the mixture and thereby preventing such an accumulation of heat as might bring about the decomposition of the more unstable components of the mixture.

A study is also being made of the possibility of incorporating limestone or dolomite in synthetic-fertilizer mixtures in sufficient quantity to supply the calcium and magnesium needs of plants and to neutralize the effect of the acid-forming components of the mixture.

The work, previously referred to, on preparing potassium nitrate by reaction of nitrogen peroxide on potassium chloride has been continued during the year.

New equipment has been designed for purifying the gaseous reagents used in the work and for studying the oxidation of nitrosyl chloride, one of the products of the reaction.

Very pure samples of potassium nitrate, potassium chloride, and sodium nitrate were prepared for use in the determination of the specific heats of these salts from room temperature down to near the absolute zero.

The cooperative work referred to in last year's report was repeated during the present year with results that agreed closely with those obtained previously. It was found that fertilizer salts are carried in a vertical direction by the capillary rise of soil moisture, but that there is very little lateral movement of fertilizer materials in the soil. The concentration of soluble salts that are brought in contact with the seed thus varies with the placement of the fertilizer. Seedlings come up very rapidly when the soil solution in contact with the seed contains from 0.05 to 0.2 per cent of salts. When the concentration of the soil solution contains either less than 0.05 per cent or between 0.3 and 1 per cent, germination is delayed but not prevented. No germination takes place when the concentration of salts in the soil is in excess of 3 per cent.

Methods of applying fertilizers to cotton were studied in cooperation with the Bureau of Agricultural Engineering, the South Carolina Agricultural Experiment Station, the National Fertilizer Association, and the soil-fertility division of this bureau. The effect of particle size on the efficiency of fertilizer is being studied in cooperation with the soil-fertility division and the South Carolina Agricultural Experiment Station.

A study of the effect on plant growth of the fluorine content of phosphatic materials is being made in cooperation with the University of Arkansas. Tests on the relative availability of water-insoluble phosphates in soils of varying acidity (pH) are also being made in cooperation with the agricultural experiment stations of Delaware, Oklahoma, West Virginia, and Connecticut.

Samples of new types of fertilizer materials and models illustrating various properties of fertilizers have been prepared for department exhibits held in different parts of the country throughout the year.

INFORMATIONAL AND EDITORIAL SERVICE

The 71 new departmental publications from this bureau printed in the past fiscal year include 44 soil-survey reports, 8 technical bulletins, 5 circulars, 5 miscellaneous publications, 2 leaflets, 1 farmers' bulletin, and 6 articles in the Journal of Agricultural Research. In addition to these publications, 17 articles from this bureau have appeared in the 1932 Yearbook of Agriculture.

A total of 175 articles on various phases of the bureau's work have been published in outside journals and periodicals in addition to timely information which this bureau has furnished to newspapers through cooperation with the press service of the department.

Below is given a detailed list of the bureau's official publications printed during the past fiscal year.

PUBLICATIONS OF THE BUREAU OF CHEMISTRY AND SOILS ISSUED DURING THE YEAR JULY 1, 1931, TO JUNE 30, 1932

TECHNICAL BULLETINS

No. 241. Analyses and Composition of California Lemon and Orange Oils.

No. 270. The Chemotropic Responses of the House Fly, the Green-bottle Flies, and the Black Blowfly. (Joint publication with the Bureau of Entomology.)

No. 276. The Fractionation of American Gum Spirits of Turpentine and Evaluation of its Pinene Content by Optical Means.

No. 291. The Effect of Air Drying on the Hydrogen-Ion Concentration of the Soils of the United States and Canada.

No. 310. The Visual Spectrophotometry of Dyes.

No. 316. The Physical and Chemical Characteristics of the Soils from the Erosion Experiment Stations.

No. 317. A Critical Laboratory Review of Methods of Determining Organic Matter and Carbonates in Soils.

No. 319. The Fractionation, Composition, and Hypothetical Constitution of Certain Colloids Derived from the Great Soil Groups.

FARMERS' BULLETIN

No. 1678. The Safe Use and Storage of Gasoline and Kerosene on the Farm. (Joint publication with Bureau of Agricultural Engineering, Bureau of Agricultural Economics, and National Fire Protection Association.)

CIRCULARS

No. 183. Factors for Converting Percentages of Nitrogen in Foods and Feeds into Percentages of Protein.
No. 185. New Fertilizer Materials.
No. 190. Buckwheat Milling and its By-products.
No. 192. Progress Report on Mechanical Application of Fertilizers to Cotton in South Carolina, 1930.
No. 216. Production of Organic Acids from Carbohydrates by Fermentation: A Digest of the Literature.

JOURNAL OF AGRICULTURAL RESEARCH ARTICLES

Studies of Lignin in Wheat Straw with Reference to Lodging.
The Influence of Nitrogen, Phosphoric Acid, and Potash on the Number, Shape, and Weight of Potato Tubers. (In cooperation with the New Jersey Agricultural Experiment Station.)
The Decomposition of Green Manures Grown on a Soil and Turned Under Compared to the Decomposition of Green Manures Added to a Fallow Soil.
The Decomposition of Vetch Green Manure in Relation to the Surrounding Soil.
Effects on Cotton of Irregular Distribution of Fertilizers.
Characteristics of Dispersable Organic Colloids in Peats.

LEAFLETS

No. 82. Controlling Small Gullies by Bluegrass Sod.
No. 85. Strip Cropping to Prevent Erosion.

SOIL SURVEYS

Mecosta County, Mich.
Clear Lake area, Calif.
Santa Ynez area, Calif.
Belmont County, Ohio.
Wilson County, Kans.
Butler County, Iowa.
Williamsburg County, S. C.
Jerome area, Idaho.
Union County, Iowa.
Paradise-Verde area, Ariz.
Thayer County, Nebr.
Gila Bend area, Ariz.
York County, Nebr.
Victoria County, Tex.
Harford County, Md.
Cook County, Ga.
Jackson County, Miss.
Cecil County, Md.
Crawford County, Mich.
Kalkaska County, Mich.
Martin County, N. C.
Calvert County, Md.
Pierce County, Nebr.
Marion County, Oreg.
Doniphan County, Kans.
Person County, N. C.
Gates County, N. C.
Fort Collins area, Colo.
Miami County, Ind.
Saline County, Nebr.
Stanton County, Nebr.
Socorro and Rio Puerco areas, N. Mex.
Dixon County, Nebr.
Elbert County, Ga.
Freehold area, N. J.
Cedar County, Nebr.
Winnebago County, Wis.
Beauregard Parish, La.
Franklin County, Ala.
Johnson County, Kans.
Anne Arundel County, Md.
Pocahontas County, Iowa.
Trempealeau County, Wis.
Placerville area, Calif.

MISCELLANEOUS PUBLICATIONS

No. 117. Bibliography of Ethylene Dichloride.
No. 120. A Digest of the Literature of Derris (Deguelia) Species used as Insecticides, 1747–1931.
No. 126. Fertilizers for Cotton Soils.
No. 136. Conservation of Fertilizer Materials from Minor Sources.
No. 143. American Fertilizers.

YEARBOOK ARTICLES

Fruit Preservation by Freezing Presents Many Problems for Research.
Lignin, Farm By-product, Now Wasted, May Supply Cheap Organic Chemicals.
Furfural, a Product of Farm Waste, Has Many Industrial Uses.
Utilization of Straws and Stalks Lags as Other Materials Compete.
Sweetpotatoes Yield Fine White Starch by a New Process.
Citrus By-products Market is Growers' Safeguard in Years of Overproduction.
Turnips Converted into Appetizing Sauerkraut in the Same Way as Cabbage.
Turpentine and Rosin Supply Essentials for Numerous Industries.
Eggs Oiled by Vacuum Carbon Dioxide Method Keep Better in Storage.
Chemical Utilization of Farm By-products Has Large Prospects.
Fertilizer Combining Superphoshate with Free Ammonia Succeeds.
Potash Extraction from United States Deposits Studied in Promising Experiments.
Fertilizer Industry Making Adjustments to Complex Economic Requirements.
Fertilizer Sources Ample for Midwest, Cost Cut by Higher Concentration.
Fertilizer Experiments Show Phosphate is Chief Need in the Middle West.
Fertilizer Placement of Vast Importance in Cotton-Growing States.
Soil-Erosion Problem Under Investigation in National Control Program.

U. S. GOVERNMENT PRINTING OFFICE: 1933