REPORT OF THE CHIEF OF THE BUREAU OF CHEMISTRY AND SOILS, 1933

United States Department of Agriculture,
Bureau of Chemistry and Soils,
Washington, D.C., August 31, 1933.

Sir: I present herewith the report of the Bureau of Chemistry and Soils for the fiscal year ended June 30, 1933.

Respectfully,

Henry G. Knight,
Chief of Bureau.

Hon. Henry C. Wallace,
Secretary of Agriculture.

INTRODUCTION

The vital problems of agriculture change from one era to another. Any program of scientific research in behalf of agriculture must be based upon a clear comprehension of present needs and economic trends. Although there are some phases of the agricultural situation in which the physical sciences can be of little or no assistance, there are important problems to the solution of which they alone hold the key. It is of the highest importance that all scientific agricultural research, both State and Federal, be directed to basic agricultural requirements and that such research be coordinated with the economic corrective measures that are now being instituted.

In the progress of civilization based on the scientific conquest of nature, the world pauses at intervals to learn better how to use the facilities that science and invention have provided and to correct economic and social maladjustments in order that the fruits of this conquest may be distributed more uniformly throughout the social body. Under such conditions less emphasis is placed on man's relation to nature, and far greater stress is placed on man's relation to man. This is our present situation in economic depression.

This condition creates the illusion that man has acquired too great a mastery of nature for his own good. In the hysteria of the moment it is even proposed to declare a moratorium on scientific research because of the assertion that it has been responsible for overproduction. Historical perspective is needed in considering the matter. Not less, but more, research is required, but it must be brought to bear in some new directions and with a sense of the strategy dictated by economic and social considerations. Discriminating direction of scientific research and increased perception of economic and social needs are imperative. Scientific effort must harmonize more closely with the growth requirements of a balanced industrial structure. It is fitting that the initiative in this direction be taken by Government-sponsored scientific research.

A phase of recovery from former economic depressions has been the creation of additional wealth in the form of new agricultural areas, the building of railways and the general commercial development associated therewith. Conquest of physical frontiers and the pioneering involved therein are largely a memory of the past. The frontiers of the future are those of the mind, and both economic research and scientific effort must assume increased importance as the complexity of the social and industrial structure inevitably increases.

Agricultural scientific research is not associated exclusively with increased production, as many suppose, but it can be applied to conserve agricultural cap-

ital, to reduce cost of production, and to promote increased utilization and consumption of farm products. Achievements along these lines can be immediately and directly applied in a constructive manner to meet present needs. This is the basis of the work of the Bureau of Chemistry and Soils.

The research program of the Bureau harmonizes with and supplements the purpose of the Agricultural Adjustment Act. It has definite, constructive value in promoting agricultural recovery. This may be seen from the following general discussion of the economic significance of the work of the three administrative units of the Bureau, and from the subsequent more detailed account of the progress made by each unit during the past fiscal year.

CHEMICAL AND TECHNOLOGICAL RESEARCH

Agricultural research has heretofore been almost wholly occupied with the problems of production. The time is now at hand when much greater stress in scientific and inventive accomplishment must be placed upon more extensive and more profitable utilization of farm commodities, the development of new products and the opening of new markets.

It has not been sufficiently realized that scientific research is capable of influencing materially the channels of use and distribution of farm products. That this is true is self-evident when one considers that research and invention have already had a tremendous influence in molding and shaping the existing industrial and commercial organization for the processing and utilization of farm products, which is now studied in statu quo by market specialists.

Progressive manufacturing industry has not been content to allow its markets to remain in a static condition. Our great industrial corporations have been depending, to a continually increasing extent, upon their research departments to devise new or improved products, thus providing the necessary flexibility to combat adverse conditions and to develop new markets and stimulate old markets. In discussions of present economic problems much has been said regarding the possible influence of new products and of new industries in providing a stimulus to business and in increasing employment.

The work of the scientist is indispensable to unlock the door to these potential markets and must be accomplished before the market specialist can function. Agriculture may well demand that those principles which have been so well utilized by the manufacturing industry be applied also for its benefit. Expansion of markets in this manner should go hand in hand with measures designed to control production in relation to consumption demand.

With the multiplication of manufacturing processes and the great increase in secondary and tertiary products derived from raw materials, the course of agricultural commodities through the channels of distribution, processing, and manufacture prior to consumption is continually becoming more involved and complicated. The farmer stands at one end of this line and the ultimate consumer at the other. A complete visualization of this industrial picture, not only from the marketing standpoint but also from the standpoint of the technological processes and the scientific factors involved, is indispensable both for the control of production in relation to consumption and for the development of new uses and new market outlets for agricultural materials.

The interest of the farmer cannot terminate with the production of his crops. He is necessarily concerned with the manner of their utilization, the trend of existing markets, and the possibility of developing new uses and new markets, particularly for surplus, culls, and waste. In fact, no one is as vitally interested in this matter as is the farmer, for it is his products which seek a buyer. Hence, the initiative in such developments must usually fall upon him or upon State or Federal agencies acting in his behalf. After the necessary initial research has been done, further developments can be effected through ordinary commercial channels.

It is therefore important to have in the Department of Agriculture a scientific and technological agency which is in a position to visualize the flow of farm products through the various industrial processes for which they serve as raw materials and which, with this background in view, can increase marketability and devise new uses and new market outlets for farm surplus, culls, and waste, with resulting increase in crop diversification. The Chemical and Technological Research Unit of the Bureau performs such a function.

The economic significance of the work of this unit is indicated in the following discussion of its various phases.

IMPROVEMENT IN QUALITY AND BETTER ADAPTATION TO MARKET REQUIREMENTS AND PREFERENCES

Economic maladjustments in the marketing and distribution of farm products are frequently caused by physical, as well as human, factors and these can be corrected by scientific research. In many cases better marketability would result if quality were such as to conform more closely to market requirements and preferences. This can usually be attained at little or no additional production expense. The solution of some scientific or technological problem is usually required to accomplish this end. This work in some cases refers to primary farm products and in other cases to derived commodities produced on the farm. Its nature can be shown better by a few examples than by discussion.

Oranges, lemons, and grapefruit, although sound and mature, are frequently unsalable because they have not developed the color expected by the consumer. By a harmless treatment with ethylene gas, such fruit may be made to develop rapidly the characteristic yellow color. Commercial use of this method has substantially increased the value of the Florida orange crop by making fruit available for an earlier market than would otherwise have been possible. This treatment is also used for hastening development of color in apricots and for softening pears for cannery use.

Farm-made sirups (maple, sugarcane, and sorgo) are a cash crop, valued annually at $17,000,000, on about 450,000 small farms. The bulk of this sirup is marketed. The farm value varies by as much as 300 percent from high grade to low grade. Improvement in production methods resulted in substantially higher prices in 1932 in sections where these methods were used.

The United States produces about 65 percent of the world's supply of naval stores (turpentine, rosin, pine oil, and related products from the pine tree). Improvements in methods of producing rosin resulted in a substantial increase in the proportion of high-grade rosin, with consequent increase in value to producing farmers. The domestic soybean crop has been increasing steadily during recent years and has proved to be valuable for crop diversification. Maintenance of the economic position of the crop and its profitable expansion are dependent on utilization of the oil, which in turn depends upon the production of oil of certain chemical characteristics which make it suitable for technical use.

SUBSTITUTION OF DOMESTIC FOR IMPORTED COMMODITIES

It is not wise to attempt to produce in this country certain crops which are not well suited to domestic agriculture. It must also be recognized that in the international exchange of commodities, a sufficient quantity of goods must be imported to permit payment for exports.

On the other hand, there are a number of products, derived from agricultural commodities, which are now imported into the United States in considerable quantities and which may profitably be replaced by products derived from domestic farm commodities. Such substitutions would fit logically into the scheme of domestic agriculture, would correlate well with existing crops and industries, and would contribute materially to diversification and to farm income.

For instance, an increase in the domestic supply of leather-tanning materials is desirable. Over 90 percent of the heavy leathers are made with vegetable tanning materials. Over 60 percent of the domestic supply of tannin is now derived from the chestnut tree, which will soon be nonexistent because of blight. The other principal vegetable tanning material, quebracho, is imported. Research on western hemlock bark has indicated its value as an additional tanning material.

Another instance of substitution of a domestic for an imported product is the development of an industry which it is anticipated will supply sweetpotato starch to cotton mills in replacement of imported potato starch, thereby providing a market for cull sweetpotatoes which are now largely wasted.

PREVENTING DETERIORATION OF HARVESTED CROPS

Serious deterioration of certain crops occurs with considerable regularity after harvesting. This results either in actual destruction in some cases or in such impairment of quality as greatly to reduce market value. This deteriora-

tion is the more serious because it occurs after full expense of growing and harvesting the crop has been incurred. Production control obviously should start at the source and should not involve erratic destruction or harvested crops. It is estimated that at least one tenth of the harvested hay crop, which had a farm value of $632,000,000 in 1931, is lost by spontaneous heating occurring between the time of cutting and of consumption. The sugarcane crop in the continental United States is subject to great deterioration and loss of sugar during the period between harvesting and grinding, and under certain weather conditions a large part of the harvested crop has been lost. Losses of these two crops can be reduced materially by suitable methods of storage (and also of curing in the case of hay). Work on these problems is under way.

PREVENTION OF FARM FIRES

Farm fires (in farmhouses, barns, and nearby buildings) annually destroy some 3,500 lives and over $100,000,000 worth of property. The latter represents a fire loss equivalent to an annual tax of about $19 on each farm in the United States. Various measures which have been introduced have resulted in a material reduction in these losses. Safety codes for dust-explosion prevention have been developed. In work on the handling of grain, threshing machines have been so improved as to result in direct saving in insurance against dust explosion and fire hazards.

INSECTICIDES

Orderly production and marketing of many crops is impossible without the systematic use of insecticides. Cheaper insecticides are needed in order to reduce production costs. Development of insecticides of greater suitability for specific purposes is a factor of increasing importance, not only in relation to insect control, but also with respect to removal of residues from marketed fruits and vegetables in order to reduce the health hazard. Food-law regulations regarding insecticidal residues are becoming more stringent in both domestic and foreign markets. Chemical washing solutions for removing these residues have been devised. However, a more important result is the development of insecticides which are effective against insects, but are not poisonous to man.

FINDING USES FOR NEW OR EXPANDED MINOR CROPS

The substitution of new crops, or the expansion of minor crops, for which markets are already available is desirable in order to utilize profitably some of the acreage which is withdrawn from staple crops for purposes of production control. In the Bureau's work on this subject, the industrial uses of various derived products obtained from certain crops have been examined in order to find a suitable place in the economic scheme for these new, or expanded, crops and their industrial derivatives. Even though there may be no apparent competition between existing crops and these new, or expanded, crops, their secondary products may be in conflict with the result of definite, adverse effect on price.

In this instance, it is of little economic advantage to "rob Peter to pay Paul." Such additional crops must fit nicely into the economic picture and supply existing needs and deficiencies which are not otherwise filled. Crop rotation and soil suitability are important factors. However, the most urgent consideration is suitable market outlets which do not have an adverse effect on the price of other farm commodities. Such outlets can, in many cases, be created by scientific research directed with understanding of industrial requirements.

Various illustrations of work done by the Bureau in this field will be found in subsequent portions of this report. Among these may be mentioned, particularly, research on greater utilization of the chicory crop and on new, substantial crops of insecticidal plants. It has been found that the wild plant, devil's shoestring, which is common throughout the United States is an important source of rotenone, one of the most powerful contact insecticides known. The new insecticide, neo-nicotine, developed by the Bureau, has recently been found in a Russian weed, *Anabasis aphylla*. Experimental plantings have been started in California. With the development of these crops the farmer will grow insecticidal plants, which will serve the twofold purpose of profitable crops and more suitable insecticides.

The Agricultural Adjustment Administration has recently organized a Replacement Crops Section for the purpose of assisting farmers to shift production from surplus basic crops to other crops so as to obtain a better balance than now exists. The problem of use of the idle land, which has appeared in every State where acreage reduction has taken place or is contemplated, is said to be one of the most important facing the administration.

PROFITABLE UTILIZATION OF FARM SURPLUS, CULLS, AND WASTE

In addition to control of production of farm commodities in relation to consumption, which is to be effected under the guidance of the Agricultural Adjustment Administration, there is a second step which must be taken in order to complete the scheme of properly adjusted production and utilization of farm crops. This second requirement is the intensive utilization of all that is produced on controlled acreage, so as to afford the farmer the maximum return for his investment in labor and soil fertility.

There are two types of agricultural residue. The first consists of the stalks, stems, hulls, cobs, etc., which are necessarily grown in producing marketable portions of crops. Not only are these residues largely unutilized, but a labor cost is incurred before they can be separated from the marketable portions and discarded. Agricultural residue of the second type results from the rejection of culls and off-grade material (principally from fruits and vegetables) in the market grading of farm commodities. It has become recognized that it is more profitable to grade many agricultural products and adjust the price according to grade than to sell the product on a field-run basis at a flat price. The criterion of the extent to which it is profitable to carry the grading of farm products is the net price obtained for total production.

The grading of agricultural commodities, even when justified by a better net price, is the cause of a substantial proportion of culls and off-grade material. Hence, the more profitable utilization of these byproducts is a problem of importance which goes hand in hand with the protection of market quality through application of grading standards. Profitable byproduct utilization of this material serves to support the market grades and makes possible a desirable flexibility of marketing policy. Thus, in years of relatively large production it may be possible to divert more of the crop into byproducts, and in periods of underproduction it may be profitable to sell a greater proportion through the usual market channels. Such diversification of use is particularly important for perishable crops.

This principle has been successfully applied by citrus-fruit growers through the organization of a cooperative byproducts industry, which resulted from research by the Bureau. The citrus-byproducts industry acts as a balance wheel for the citrus crop through its ability to divert surplus fruit into noncompetitive channels. This enterprise is now the world's largest producer of lemon oil, orange oil, and citrus pectin. It is also a large producer of citric acid, which not only supplies the domestic market but is shipped to Europe.

Another instance is the recent development by the Bureau of a process whereby starch of fine quality can be produced from cull sweetpotatoes. This starch, which is noncompetitive with cornstarch, has been found suitable for use in cotton mills to displace imported potato starch. A byproduct sweetpotato starch industry is now being developed in the South. Such byproduct industries for utilization of culls and surplus are important not only for the purpose of providing farmers with a profitable market for material that would otherwise be largely wasted, but also from the standpoint of furnishing an economic stimulus to the entire community through construction of buildings, purchase of equipment, and employment of labor.

The byproduct sweetpotato starch industry, for instance, is being promoted by business men in rural trade centers for the purpose of placing in the hands of farmers cash which can later be exchanged for needed merchandise. There are many crops the economic status of which could be materially improved by organization of associated byproduct industries. Scientific and technological research is usually required in such developments for the purpose of ascertaining valuable constituents, devising methods of extraction or processing, and properly coordinating products with uses.

The farmer is primarily a producer of food and secondarily a producer of raw materials for clothing. However, the great bulk of agricultural production serves as food for man and animals. Recent studies by the Department of

Commerce of the per capita consumption of principal foodstuffs in the United States during the last 30 years show a remarkable change in habits of food consumption. There have been pronounced increases in per capita consumption of dairy products, fruits, and sugar, and a startling decrease in per capita consumption of cereals. During this 30-year period the vogue of breakfast foods has increased greatly, so that the decline in consumption of wheat flour is greater even than is indicated by the decline in per capita consumption of cereals as a group. Per capita consumption of meats, fats, and oils showed only small changes.

It seems probable that the increase in sedentary occupations and the greater popular attention which is being given to diet are factors in these changes in food habits. Calculations based on per capita consumption of each of the important food groups show that the total weight of food consumed annually by the average individual has changed very little during these 30 years. However, there has been a distinct consumption trend away from certain concentrated foods to foods such as fruits, vegetables, and milk, which are of relatively high water content. This is corroborated by the decrease in per capita food consumption calculated on a dry basis.

On the other hand, various studies of the expenditure of income of nonagricultural families for the groups "food", "clothing", "rent", "fuel", and "miscellaneous" show a progressive increase during recent years in the miscellaneous expenditures as compared with expenditures for food, although this relationship is, of course, influenced by prosperity and depression conditions. There are no data to show what portion of the miscellaneous expenditures is spent for the scores of constantly increasing manufactured articles of various kinds which are used today by every individual, family, and business enterprise. It is certain, however, that an outstanding result of scientific research and invention, which are the distinguishing characteristics of our present industrial era, is the tremendous increase in the number and variety of manufactured articles in common use.

To what extent does the farmer profit from this development by furnishing the necessary raw materials? Casein, the principal byproduct of the dairy industry, is used in the sizing of paper. Butyl alcohol, an important constituent of the quick-drying lacquers, so extensively used today, is produced by a fermentation process from corn. Cotton linters, which 20 years ago were used only for mattresses, now serve as a base for a great variety of products, such as lacquers, surgical dressings, sausage casings, rayon, etc. The proportion of cotton used for nonclothing purposes has increased steadily during recent years. Other examples could be given. Nevertheless, what has been done so far is merely a beginning in the industrial use of agricultural raw materials.

This is distinctly an industrial age, and progress in expanding markets for agricultural products lies to a great extent along industrial lines. Food requirements have definite limitations and it is very difficult to increase total per capita demand for foodstuffs. On the other hand, the consumption demand for industrial products is elastic. Creation of new products creates new wants and therefore new markets. Research thus stimulates consumption. Greater industrial utilization of farm products increases diversification which in turn contributes to market stability.

There is no manufacturing industry that has the proportion of potentially valuable, poorly utilized residue that is produced by agriculture. Such problems of utilization of byproducts have already been solved by industrial research laboratories, and their solution has frequently meant the difference between profit and loss. Agricultural industry is a laggard in the solution of this problem. This is a point upon which agricultural research should be more directly centered. The potential increase in income to farmers is vast because the full expense of producing this material has already been incurred and additional utilization represents practically clear profit.

The utilization of farm waste is equivalent to the creation of new, noncompetitive crops with cost of production already covered. Much of this waste will be used for industrial, nonfood purposes, and the diversification of use resulting therefrom will substantially increase market stability. "Farming for industry" promises to be an important development of the future.

SOIL INVESTIGATIONS

THE SOIL SURVEY

The inventory of soil resources of the United States which is supplied by the Soil Survey assumes particular importance today when the success of the Government's national policies of land use is vital to the welfare of this country.

For years the Bureau of Chemistry and Soils has been building up a classification of our agricultural lands which furnishes a scientific guide to the relative productive capacity of soils in every important agricultural region of the country. This classification includes more than 1,000 soil types in the maps and detailed reports of the Department on approximately one half the entire agricultural area of the United States. For each of these soils the surveys furnish information as to comparative fertility, crop adaptations, surface soil and subsoil texture, condition of drainage, and local adaptation to farm economy.

Immediate necessity for increasing farm income and the buying power of one third of our population, on the one hand, requires drastic decreases in the supply of major crops to meet lowered domestic and world demand. The obligation to conserve soil fertility—our basic national capital—on the other hand, requires that the millions of acres taken out of cultivation from the principal staple crops which are now overproduced, be utilized to the greatest advantage and maintained in a suitable state of fertility. Thus, the soil-survey reports which have served as practical working handbooks to assist thousands of farmers in making the best use of their soils now afford information of immediate value in the formulation and application of national land policies.

In the removal of surplus lands from cultivation the definite, scientific information afforded by the soil survey on practically every type of land encountered will be of value: (1) In making readjustments of lands to other than staple crops; (2) in correctly allocating certain soils to forestry and other soils to grazing; and (3) finally in supplying scientific data on the basic characteristics and special capabilities of each soil, so that the millions of acres which are withdrawn from cultivation or are shifted to range or forest shall become a national asset of increasing value, rather than an immeasurable capital loss.

SOIL EROSION

What has been said regarding the importance of the soil survey with respect to national land-use policies applies with equal force to the work on soil erosion. Loss of soil fertility by erosion is undermining both the capital investment and the earnings of farmers throughout the United States. Erosion surveys indicate that: (1) 35,000,000 acres of formerly cultivated land has been essentially destroyed for crop production; (2) approximately 125,000,000 acres of land now in crops has lost all or most of its topsoil; (3) that about 100,000,000 acres of land now in crops is rapidly approaching the condition of no. 2; and (4) an additional area is suffering from erosion in some degree.

Fully 75 percent of the land in the United States is subject in some degree to soil-impoverishing erosion wherever it is used for the clean-tilled crops. The annual cost of this destructive force in farm lands impoverished or ruined, highways damaged, reservoirs and irrigation ditches filled, and valley lands overflowed is estimated at not less than $400,000,000. The Bureau, at its 10 regional erosion stations, has established facts in regard to the extent and rate of soil erosion and has developed methods of erosion control which are of practical importance to a majority of the farmers of the United States and are of immediate value in the Government's present program of farm relief and crop adjustment.

The following are among the important facts which have been developed since the Bureau began its work on erosion control in 1928: Erosion varies widely with soil character, slope, and rainfall. Thick-growing vegetation is one of the most powerful agencies of erosion control. Practical measures of erosion control call for trees and thick-growing vegetation, rotations of soil-saving crops, use of tillage operations that favor absorption of water, and use of engineering structures, such as terraces and soil-saving dams.

The significance of soil character in relation to the erosion problem can be well illustrated by a single example. In 1931 red soil in the piedmont area of

North Carolina (one of the most extensive farm soils of the Southeast) lost 13 tons of soil per acre and 13 percent of the year's rainfall on a 10-percent slope, under cotton; whereas, the Shelby loam (the most extensive corn soil of northern Missouri and southeastern Iowa) lost 105 tons of soil per acre and 28 percent of the rainfall on an 8-percent slope used for corn. The rainfall was about the same, yet the less steep, highly erosive Corn Belt land lost eight times as much soil and more than twice as much of the rainfall as the piedmont land. The practical information on the comparative erosivity of the most important soil types in each major agricultural region, which has been gained from the Bureau's work at its 10 erosion stations, should prove highly valuable in the Department's program of crop reduction by indicating how the land taken out of cultivation can be protected from destructive erosion.

SOIL FERTILITY

The soil-fertility work of the Bureau deals with the soil fertility and fertilizer requirements of important soil types used in the commercial production of various crops, including cotton, corn, wheat, potatoes, sugar beets, sugarcane, sweetpotatoes, strawberries, general truck crops, citrus fruits, and nut crops.

It is desirable, in the interest of economy in production cost, that all cultivated land be used for the specific crops for which it is best suited, subject to suitable crop rotation and control of total production in relation to consumption. In this way unit cost of production may be reduced.

Even though fertilizer is bought at a favorable price, the cost is high if it is poorly adapted to the requirements of specific crops and specific soils. Knowledge of inherent soil fertility, and the relative suitability of the various soil types to specific crops, as well as knowledge of the particular fertilizer required to supplement natural soil fertility for certain crops, are important factors in reducing cost of crop production. Moreover, every acre of crop soil is subject to depreciation and decreased efficiency if proper methods of maintenance are not followed. This is a factor in conservation of invested capital, as well as in cost of production.

Owing to the complex problems presented by a number of prominent soil types and the use of new fertilizer materials of synthetic origin, especially those resulting from the fixation of atmospheric nitrogen, work on fertilizer usage in relation to soil fertility is becoming increasingly important. An important development has been the study of some of the less common elements, such as manganese, magnesium, zinc, and others which may be deficient in the soil or lacking in the fertilizer applied. It has been found, for example, that only by the use of manganese compounds has commercial growing of tomatoes become profitable on certain soils of Florida, that the use of magnesium materials in potato fertilizers overcomes a typical chlorosis of the potato vines due to a deficiency in certain soils, and that the use of zinc compounds is a means of overcoming pecan rosette.

Solution of such problems has made it possible to increase crop diversification and to take advantage of favorable climatic and market conditions in certain areas for growing crops that are in demand, but for which the soil would otherwise not be suitable, even with customary fertilizer applications. In some cases the economic well-being of entire communities has depended on special crops for which all conditions, except the presence of certain of the less common elements in soil or fertilizer, were particularly favorable.

It has been found in these soil-fertility studies that certain soil types produce crops of better quality than others; also that the use of the correct proportions of the plant food elements nitrogen, phosphorus, and potassium, supplemented with the less common elements when required, is an aid in improving the commercial quality of crops. Marketability and crop value have been materially increased by applying these principles to various crops, particularly certain fruits and vegetables.

It is evident that under present agricultural conditions an appraisal of the Nation's soil-fertility resources is important. In connection with the measures that are now being taken to control agricultural production in relation to consumption, it will be essential that the fertility of land withdrawn from cropping be maintained at a normal level. Replacement crops to be grown on land withdrawn from production of staple crops, whether cotton, wheat, or corn, should be factors in soil-fertility maintenance. Judicious fertilizer treatment also may be necessary to insure the satisfactory development of replacement crops. The

soil-fertility work of the Bureau will be of assistance in policies of agricultural adjustment in insuring the return of withdrawn acreage in as good a state of fertility as it was originally, thereby conserving soil capital.

FERTILIZER INVESTIGATIONS

During the past 2 years the expenditures of American farmers for fertilizers decreased less than for labor, feed, and farm equipment. This relatively smaller decrease in the use of fertilizers at a time of such low prices for farm products, poor markets, and depressed conditions, emphasizes the basic importance and absolute necessity of fertilizers in maintaining the productivity of the soil, the quality of farm products, and lower costs of production.

The Bureau's nitrogen fixation research program has played an important part in the establishment in this country of the direct synthetic ammonia process which is a big factor in the nitrogenous-fertilizer situation today. There are now eight plants in the United States, with an annual nitrogen capacity of some 275,000 tons. This capacity, added to that of the byproduct coke ovens, is sufficient to meet the requirements of the country, thus making it independent of foreign monopoly. Prices of nitrogenous fertilizers have dropped consistently since 1925. The average price of sulphate of ammonia from 1907 to 1914 was $58 per ton. During August 1932 it was $17 per ton. The saving in cost to farmers of the nitrogen content of fertilizers during the period 1924–32 is estimated at $125,000,000.

To date, the potash program, as conducted by Federal and other agencies, has succeeded in making the country 60 percent sufficient in its domestic potash supply. The Bureau is actively engaged in research directed to making vast deposits of insoluble potash minerals available to all sections of the country in which they occur, thereby reducing freight charges which now represent a large proportion of the farmer's potash bill.

During recent months the Bureau has developed a new material, ammoniated peat, with a high nitrogen content, which may become an important factor in fertilizer mixtures.

The policy initiated in and fostered by this Bureau for more concentrated fertilizers has resulted during the past 15 years in a 50-percent increase in plant-food content; that is, the present normal consumption of about 8,000,000 tons is equivalent to 12,000,000 tons of the average fertilizer in use before the war. This represents an estimated annual saving in bags, handling, and freight alone of about $12,000,000.

Economy in the use of a fertilizer depends on its efficiency as well as on the initial cost of the product. The cheapest fertilizer is not always the most profitable and is frequently less popular than more expensive materials. The use of efficient fertilizers not only lowers production costs but also provides a means, and in many sections the most effective means, of maintaining an adequate crop production on less acreage, with a resulting reduction in the necessary hours of labor on the farm. Well-balanced fertilizers allow a shortened working day for a given crop return by increasing the crop yield per acre, by increasing the proportion of the marketable crop, by promoting a healthy vegetative growth with consequent decrease in the loss of the crop by disease or by deterioration after harvest, and by hastening maturity with decreased loss by early frosts and autumn storms.

The results obtained with inefficient fertilizers on the other hand, may be and frequently are, the direct opposite of what follows from the use of better balanced mixtures. The success already attained in reducing costs and increasing the quality of fertilizers, which farmers regard as so vital to their livelihood, is a direct contribution to the Department's present program of increasing farm income with accompanying reduction in acreage and working hours.

In the Department's program of reducing cultivated acreage and shifting production from surplus basic commodities to other crops so as to secure a better balance of supply to demand, the maintenance of fertility of the land, and the need of suitable plant food for replacement crops are problems which will require the efficient and economical use of fertilizers. In this as well as in the technical problems involving the use of the great fertilizer resources of the Tennessee Valley, the Bureau can assist in the program of increasing farm income by land and crop adjustments.

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CHEMICAL AND TECHNOLOGICAL RESEARCH UNIT

CARBOHYDRATE INVESTIGATIONS

This work consists of chemical and technological research on the carbohydrate constituents of crops and derived farm products, the value of which is determined largely by the carbohydrate content. In general, carbohydrates constitute about 80 percent of the dry matter of plants. The purpose is to obtain better adaptation to existing market requirements and preferences and to originate new and diversified uses, both for the primary products and for the accompanying culls and wastes, thus promoting more complete utilization of these crops and increasing farm income thereby.

UTILIZATION OF SWEETPOTATO CULLS

In order to protect the value of market grades to the grower a large proportion of culls is rejected from the field-run crop of sweetpotatoes, the second largest vegetable crop in the United States. Starch of fine quality produced from sweetpotato culls by the process recently devised by the Bureau has been tested in cotton mills and found equal to German and Dutch potato starch which is used to a considerable extent in this industry. Development of a domestic sweetpotato starch industry is now taking place as a result of this work. Work on three factories is under way, and others are planned. This industry will have the advantage of low transportation costs on both raw material and products because of contiguity of large sweetpotato-producing sections to southern cotton mills. The residual byproduct pulp will be used as a needed carbohydrate constituent to balance the protein content of cottonseed meal which is now fed extensively to cattle in the South.

This new industry will provide a profitable market for sweetpotato culls, which are now inadequately utilized, thus increasing the cash income of growers. The starch is noncompetitive with domestic cornstarch and is intended to displace potato starch imported because of special properties.

Such a byproducts industry is needed for most fruits and vegetables in order to increase market stability. In abundant crop years a larger proportion of the crop could be diverted into the associated byproduct industry in order to protect the value of market grades. Establishment of this industry is also of general economic value because of construction of buildings, purchase of equipment, and employment of labor.

SUGARCANE

Because of early advent of freezing weather the sugarcane crop in the continental United States must be harvested and ground for sugar and sirup production during a short season. If harvesting is delayed, a considerable portion of the crop may undergo serious deterioration or may actually be lost. Heavy or prolonged rains are especially serious at this time, since they may render the fields impassable and so interfere with a continuous supply of cane for the plantation sugar or sirup house.

A suitable method of storing reserve supplies of harvested cane would go far toward eliminating this large average annual loss which occurs after full expense of growing (and sometimes harvesting) the crop has been incurred. In cooperation with the Bureau of Plant Industry, an investigation of basic factors influencing deterioration of stored cane was conducted for the purpose of devising a suitable method of storage.

Deterioration was lowest at high humidity and greatest at low humidity. Loss of water from the cane by evaporation is a determining factor in deterioration. It was found that deterioration can be kept at a minimum by sprinkling the stored cane at intervals in order to reduce evaporation of moisture. The more mature the cane is at the time of cutting the better it keeps under all conditions of storage.

The CO. 281 variety showed exceptional resistance to deterioration under all conditions. Other varieties, such as P.O.J. 36-M, P.O.J. 213, and P.O.J. 234, usually showed good keeping quality only when well matured. Since one of the hazards to the cane crop in the continental United States is the danger of freezing, tests were made to determine the conditions under which it is advisable to windrow, as this is the only means now employed to combat this hazard. Results so far obtained indicate that well-matured cane can withstand

a temperature of 25° to 27° F. without seriously affecting its keeping quality. If lower temperatures occur, windrowing should be employed. Deterioration which occurs during storage of sound cane consists primarily of inversion of sucrose. Organic nonsugar compounds increase gradually, but the acidity and pH of the juice change very little.

Investigation was continued on the influence of variety, soil type, and fertilizer on the yield and recoverability of sugar per acre, which are the primary factors in the value of sugarcane. These factors, and also the clarifying property of the juice, were studied with reference to suitability of sugarcane for production of sirup from standpoints of sugar content, flavor, and color. There was considerable difference in the ash content of the juice of the same variety of cane grown on different soil types. This has great influence on yield of sugar because of the effect of ash constituents on molasses formation.

Pronounced differences in iron content of the juice of cane grown on different soil types were noted. This has an important influence on the color of the juice and its suitability for sugar or sirup production. Under identical conditions the P.O.J. 36-M variety yielded sugar with less than half the color of sugar from the C.P. 807 variety. Among the fertilizers studied, ammonium sulphate was found to have an objectionable effect on quality of juice. The application of this information will have a direct influence not only on the cost of production but also on the quality and value of the products.

FARM-MADE SIRUPS

Some 450,000 small farms in the United States produce maple, sugarcane, or sorgo sirups. The farm value of these products, including maple sugar, was about $17,000,000 in 1932. The bulk of this production is marketed and is an important source of cash on small farms located over a wide area. Because of defects, such as strong flavor, dark color, "sugaring", turbidity, and sediment, much farm-made sirup is of inferior quality. Such sirup cannot be sold direct to consumers at prevailing market prices. Because of the great spread in price between high- and low-grade sirups there is hardly any other farm crop which offers such an opportunity for relative increase in value. This situation results from the fact that the raw materials, such as sugarcane and sorgo cane, are not sold as such, but are converted on the farm into sirup which is the commodity marketed.

A practical method was devised for use of malt extract in the production of sorgo sirup for the elimination of defects such as "jellying", excessive turbidity, and difficulty in concentrating the sirup to required density, which result from the gelatinization of starch contained in the juice. This solves a difficulty which has in the past been the cause of much poor-quality sorgo sirup.

Decolorizing carbon is used in sugar refining and in other industries for the control of color (and sometimes flavor), but it has not heretofore been feasible to use it for the production of sirup under farm conditions. Means were devised whereby decolorizing carbon can be used with the facilities ordinarily available at farm sirup mills, thus enabling the farmer to use this means of controlling flavor and color in competition with other commercial sirups. The technic of using carbon varies with the type of equipment, particularly the kind of evaporator used. Tests have been completed with most of the types of equipment in ordinary use and suitable directions formulated.

The placing of emphasis on light color and mild flavor in the grading of maple sirup causes a great price differential between grades with severe penalization for no. 3 grade. Yet this grade is not strong enough in flavor for certain purposes, such as use in the ice-cream industry. A method was devised for production of a mild-flavored, light-colored sugar from no. 3 grade of maple sirup together with a residual concentrate which is suitable for the ice-cream and other industries where pronounced flavor is required. It is anticipated that the removal of a material amount of no. 3 sirup from the market for use in this way will strengthen the market for no. 3 sirup used for other purposes.

This information was brought at once to the attention of farmers through county agents. Certain of these improved methods resulted last season in an increase of 25 to 50 percent in the price received by farmers for sirup in sections where the methods were applied.

The development of specialties from sugarcane was continued. The details of the invertase process for producing La Cuite of good keeping quality were

worked out. It is expected that application of the results of this investigation will lead to a wider market for La Cuite, with consequent profitable increase in production. Work on a simplified process of preventing sugaring of sugarcane and sorgo sirups by use of invertase has been completed.

UTILIZATION OF MILK SUGAR

Associated with control of production in relation to consumption there is another step to be taken in order to increase the farm value of many crops. This additional step is the effective byproduct utilization of waste. Since the expense for production of such waste has already been incurred as part of the cost of crop production, additional revenue is largely clear profit.

Casein obtained from whey is an important byproduct of the dairy industry, but the accompanying milk sugar is at present largely wasted. On a basis of 60 percent recovery approximately 165,000,000 pounds of milk sugar could be produced annually in the United States, as compared with current production of about 10,000,000 pounds annually. Wastage of milk sugar is now a liability because of sanitary restrictions relative to disposal by dumping into streams.

Investigation of uses for milk sugar has been continued in cooperation with the Bureau of Dairy Industry. Because of certain specific properties, such as limited sweetness, specific dietetic value, limited solubility, formation of very small crystals in fondantlike masses, and pronounced retention of moisture, this sugar is well adapted for special purposes in several food industries. Considerable information has been developed and industrial tests have been made with satisfactory results.

It is anticipated that increased use of milk sugar resulting from its particular suitability for certain uses would not occur at the expense of other sugars on the market, except possibly to some extent at the expense of imported cane sugar. Milk sugar can be readily produced by dairy cooperatives and in this way dairy farmers can obtain the full benefit of such a development.

INULIN

In certain plants, particularly those of the family of *Compositae*, the carbohydrate inulin plays the same part as a reserve material as does starch in the majority of plants. More profitable utilization of inulin-containing plants depends on knowledge of the properties of inulin or its derivatives in relation to possible commercial uses.

The method for producing inulin of high purity by a simple process devised by the Bureau has been applied to chicory as a possible means of increasing the value of this plant which is now a minor crop. Such an outcome would not only increase crop diversification but would also make possible the profitable growing of this crop for primarily noncompetitive purposes on acreage which is not needed for overproduced crops.

There are indications that inulin 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 and the use of inulin for this purpose would provide a substantial market. A large quantity of inulin was prepared and placed at the disposal of several medical specialists on diabetes who are now investigating its possible value in the diet of diabetics.

Other uses of inulin are being investigated, including production of levulose sirup as a byproduct. Because of special properties of levulose, such as high solubility (making possible the production of noncrystallizing, high-density sirups), high retention of moisture, and retardation of drying, such a sirup would be particularly suitable for certain commercial purposes.

HONEY

The recent annual production of honey in the United States is about 140,000,000 pounds, with a value of about $23,000,000. Extracted honey, as customarily marketed, has not fully met prevailing commercial standards for liquid saccharine products, and this fact has had a limiting effect on consumption. The use of honey in some industries where heating is required is restricted because of excessive caramelization. Granulation is objectionable for some uses, and excessive turbidity, foaming, and formation of scum layers has reduced marketability in some cases.

The Bureau has developed a method whereby honey may be clarified so that a sparkling, clear product can be obtained which is of very attractive appearance and largely free from the characteristics mentioned. Heretofore it has not been possible to use this method of clarification without dilution and reconcentration of the honey, but a method is now being developed whereby clarification can be effected at original density without dilution. It is anticipated that use of this method will widen the market for honey both in this country and for export, particularly to countries where a clear, sparkling, extracted honey, free from granulation, is desired.

FOOD-RESEARCH INVESTIGATIONS

The Bureau's food research deals with the improvement of existing methods and the development of new technological processes for the utilization and preservation of food crops. The subject is studied from the chemical, biochemical, and microbiological standpoints, with particular attention to the development of food and feed products and byproducts and to an understanding of the factors responsible for spoilage and deterioration in quality.

Food production is the dominant phase of agriculture. In 1930 there were in the United States more than 60 field and tree crops whose farm value was over 1 million dollars each, and whose total farm value was more than 4.5 billion dollars. Many of these products went to the fresh-food market, but census statistics show that the processing and manufacture of food and kindred products ranks first among the industries of this country, the value of manufactured food products being over 8 billion dollars annually.

This work has been developed along three major lines:

(1) The more complete utilization of food crops by the development of new food products, by the salvaging of culls, surplus, and waste, and by the further processing of byproducts, thus providing new outlets and extending markets for these crops.

(2) The prevention of spoilage and quality deterioration in both fresh and processed foods, thus preventing losses to growers by prolonging the period of consumption and preventing seasonal dumping.

(3) The development of new or improved methods of food preservation which will facilitate orderly marketing and help to counteract the evils of overproduction by making seasonal products available in satisfactory condition for year-around consumption.

None of this work deals with increasing the production of farm commodities. A more economic utilization of existing production is sought, together with a greater return to the grower. It is essentially practical in purpose and seeks new and profitable outlets for the products of the farm.

FOOD UTILIZATION

PHYTOCHEMICAL INVESTIGATIONS

Investigations were continued on the isolation, identification, and utilization of the constituents comprising the waxy coating of apples and other fruits. During growth, in storage, and on the market the waxy coatings of fruits play an important role because of the mechanical protection they afford against fungal, bacterial, and insect injury, and because of their significance in the application and removal of spray materials and their bearing on scald and other storage problems. Their importance lies in maintaining a normal, healthy condition of fresh fruit or mature vegetables sufficiently long to insure their orderly consumption as food.

Quantitative studies on the surface coating of the apple were completed. Considerable progress was made in isolating and identifying the constituents of the wax of grape, pear, and cranberry skins. The substances ursolic acid and nonacosane which have been isolated from these waxy coatings, can be obtained in quantity from skins and pomace byproducts. They have important industrial possibilities, especially as ingredients in lacquers, stencils, and similar impermeable coatings. Commercial development is being undertaken. Utilization of such waste will add to the value of these crops. Hexuronic acid was separated in crystalline form from oranges, lemons, and grapefruit. Amounts equivalent to the antiscorbutic dose of lemon juice, when fed to guinea pigs, prevented scurvy, thus strengthening the supposition that hexuronic acid and vitamin C are identical.

In studies of fruit from girdled orange trees conducted at the request of the Bureau of Plant Industry it was shown that this practice has little effect on the composition of the fruit.

ENZYMES

Darkening of dried fruit is customarily controlled by sulphuring. There is considerable consumer prejudice against this practice and it is subject to food-law regulation in most countries. Greater consumer acceptance and probably wider markets, both domestic and export, would result if a better method of preventing darkening of dried fruit were devised. With this end in view the nature of the chemical reactions involved is being investigated.

The final reaction in the darkening of apples is apparently catalyzed by peroxidase. The substances involved are hydrogen peroxide as a byproduct of direct tissue oxidation and an oxyacid which has not yet been obtained in the pure state. The latter possesses remarkable reducing properties, but does not seem to be identical with any of the substances asserted in the literature to take part in darkening of other fruits.

Methods were developed for detecting the action of peroxidase toward substances which could not formerly be tested. This permits the measurement of peroxidase in agricultural products and the definition of reaction conditions and end products.

CITRUS BYPRODUCTS

In order to promote utilization of cull and surplus citrus fruit, methods were developed for production of citrus marmalade and marmalade stock in more marketable form for sale in small retail containers or in bulk to manufacturers. These methods are adaptable to oranges and grapefruit, and also to special species of *Citrus*, such as the calamondin, which is grown extensively as an ornamental in the Rio Grande Valley.

ENVIRONMENTAL STUDIES

The composition of foods and feeds, from the standpoint of those minerals which are of proved value for nutrition, is of fundamental importance in the selection of adequate diets, both animal and human. Data available in the literature of this country are exceedingly fragmentary and are of little value in computing the intake and utilization of the mineral elements in nutritional studies. Leafy vegetables, spinach, kale, lettuce, etc., grown in different regions and in several localities in the same region, were analyzed for the ash constituents, such as calcium, magnesium, potassium, manganese, iron, aluminum, copper, phosphorus, sulphur, and chlorine.

FOOD SPOILAGE AND DETERIORATION

PHARMACOLOGICAL STUDIES

Because of the present importance of fluorine insecticides in combating insect pests, an investigation was undertaken to determine the health hazard involved in their use. The addition of 0.0025 percent of sodium fluoride to a well-balanced diet produced abnormal teeth in experimental animals (young growing rats). When the diet is poor, particularly with regard to salt balance, abnormal teeth may be produced in these animals by sodium fluoride added to the diet in concentrations as low as 0.0006 percent.

There is increasing evidence that the toxic action of fluorine is concerned with the metabolic activities of the various tissue cells and that any question relating to fluorine tolerance limit must take into consideration the adequacy of the diet. Additional toxicity studies are under way on cryolite and on sodium and barium fluosilicates.

FOOD POISONING

Freezing is a promising method of food preservation because the frozen product retains the color and flavor of the raw material more nearly than that preserved by any other means. This extension of the season for raw products, and especially vegetables, will vitally affect the market of northern growers,

whose period of production is sharply limited by climatic conditions. Because freezing does not kill all spoilage organisms, but merely inhibits their action, a fundamental study of the possibility of development of toxins in frozen products that are improperly handled at any point up to the time of preparation for the table is being made.

Previous work has shown that botulinus toxin may be produced when frozen and defrosted peas are held at room temperature for 3½ days, but not when held in the refrigerator for the same period. In continuing this study, frozen peas, some of which had been inoculated with *Clostridium botulinum* spores, were held in an ice box at 50° F. for 7 days. None of the uninoculated containers gave any evidence of toxin, but weak toxin was found in a few samples which had received a heavy inoculation.

By previous technic it was possible to isolate *Clostridium botulinum* from about 35 percent of uninoculated containers, whereas, by improved technic developed during the past year, *C. botulinum* was isolated from every uninoculated container and the cultures were typed. It was demonstrated that for prolonged periods of storage a temperature of 15° to 20° F. is not low enough to prevent spoilage of frozen peas when packed in paper containers. This temperature may be low enough, however, for hermetically sealed containers, both tin and glass. Peas packed in vacuum were in better condition in frozen storage than peas packed without vacuum.

EFFECT OF LIGHT ON FOODS

From the standpoint of market demand the farmer is inevitably concerned with maintenance of quality of his products through the channels of distribution. Deterioration in quality is immediately reflected in decreased consumption and lower prices. It has been found that packaging perishable oil-bearing foods in black or green wrappers prevents these products from becoming rancid during the usual sales period. This innovation is expected to increase the consumption of such products as corn meal, nuts, potato chips, etc. Increased consumer confidence in freedom of shelled nuts from rancidity during warm weather will benefit the market for nut crops, which have been a valuable means for increasing crop diversification during recent years.

Research on the effect of light on development of rancidity has shown definitely that light of certain wave lengths retards spoilage by rancidity. It has been found that the peroxide value of a food product is not an unfailing indication of rancidity. Black and green wrappers retard the formation of peroxides and production of rancidity, but when peroxides have eventually been developed in amounts even greater than those found in unprotected products (which will occur even if the food is wrapped so as to exclude light), the protected products will still be free from rancidity. This indicates that a second factor is involved and that its interaction with peroxides in the development of rancidity is inhibited by excluding certain light rays.

FROST DAMAGE

It has been found that variability in the electrical conductivity of the pulp of frozen oranges is an indication of frost damage. It is planned to devise a practical method of detecting frost-damaged fruit before shipment, using the conductivity as a basis. This will enable growers to salvage frozen fruit in byproducts plants, and at the same time eliminate transportation expense on this material and prevent demoralization of the fresh-fruit market.

FOOD PRESERVATION

FRUIT-JUICE INVESTIGATIONS

Last year a critical situation was brought to the attention of the Bureau by the apple growers of central Washington. Cull apples were being sold to driers and vinegar manufacturers at as low as 50 cents per ton. The apple industry was faced by ruin if some method of utilizing surplus apples could not be devised. A temporary field laboratory was established at Wenatchee, and promising juice products were obtained. These included natural and carbonated sweet cider made by clarification and flash pasteurization, and a vacuum concentrate which gave a pleasing beverage on redilution.

CITRUS-FRUIT JUICES

Work was continued on preservation of citrus-fruit juices as a means of utilizing cull and surplus fruit. Previous experiments indicated that complete removal of air and uniform heating during pasteurization are required for satisfactory heat preservation of orange juice. Concentrated and unconcentrated orange juice of satisfactory flavor and promising keeping quality was processed with apparatus that was devised. This work, conducted at the Florida field station, indicates that orange juice, properly deaerated, flash pasteurized at room temperatures between 200° and 210° F., and stored at temperatures not exceeding 50° for 6 months yields a canned product of pleasing odor and flavor.

In general, flash-pasteurized orange juice possesses a flat, but not "cooked", taste, and, to improve the flavor, orange oil from which a greater part of the limonene had been removed was added to the juice. This materially enhanced its flavor, but orange oil containing appreciable quantities of limonene was not suitable because of the "turpentinelike" taste which the juice developed in storage. The addition of orange oil to canned orange juice has been undertaken commercially with encouraging results.

Grapefruit juice properly deaerated and flash pasteurized at 200° to 210° F. yields a product superior to that obtained by present commercial methods. The addition of terpeneless grapefruit oil to packs of grapefruit juice and hearts enhanced the flavor, although this effect was not so marked as in the case of the addition of terpeneless oil to canned orange juice.

PINEAPPLE JUICE

Frozen pineapple juice stored for over a year had lost none of the flavor and aroma of the original juice.

FREEZING PRESERVATION

In response to increasing use of citrus fruits, new citrus-producing areas are expanding, notably in Arizona and Texas, and acreage in California and Florida is increasing. As new groves come into bearing, uses must be found for the increased amounts of culls, many of which are merely off-size or off-shape. Work was continued on the rapid freezing of orange slices and grapefruit hearts. It was found advisable to precool the fruit. Rapid peeling, slicing, trimming, and placing in the containers are desirable in order to shorten contact with air.

The containers should be filled as full as practicable, and should be packed under high vacuum or with an inert gas in the head space. Freezing should begin as soon as the containers are sealed. Valencia orange slices and Marsh grapefruit hearts have been kept for over a year, in both glass and tin, with satisfactory results. The results are not as satisfactory with the Washington Navel orange, which tends to become bitter after defrosting. There is a tendency for both orange and grapefruit products to lose flavor after defrosting. This is retarded by keeping them at ice-box temperature.

Fruit for commercial canning must be harvested at the "hard ripe" stage, and when picked too ripe has been almost a total loss to growers. By means of quick freezing, much of this tree-ripened fruit, which is of superior flavor and nutritive value, can be salvaged so as to yield growers a financial return. Satisfactory frozen products were produced during the past fruit season from some 20 fruits. Some of these products were pulps intended for direct consumption as frozen fruit desserts or for preparation of ice creams, sherbets, and similar products. The remainder consisted of halves or whole fruits frozen for various uses. Successful demonstrations of these products were made in New York, Chicago, San Francisco, Los Angeles, and Seattle. There is a demand for them on the part of ice-cream manufacturers, and as soon as cost and distribution problems are solved the products will be placed on the market.

VEGETABLE COLORING INVESTIGATIONS

In general, color enhances the value of farm products. The most attractively colored fruits and vegetables are the most desirable when sold for immediate consumption or for canning and preserving. Knowledge of the chemistry of coloring matters is yielding information which is important for increasing desir-

able colors and for preventing serious color deterioration in many processed food products. The tomato, in both fresh and canned form, is one of our most important vegetable crops. American tomato growers have been deprived of market outlets valued at thousands of dollars because of foreign competition, due principally to the superior color of imported tomato products. An attempt is being made to improve the color of canned tomato products.

The principal pigments in sweetpotatoes have been shown to be carotene and a small amount of xanthophyll. Owing to the presence of carotene it is logical to assume that those with the deepest color are to be considered the best source of provitamin A. Progress has been made in the isolation and crystallization of the purple pigment of purple-husk maize, one of the many color types in corn with which Prof. R. A. Emerson, one of the leaders in corn breeding, has been working. This work will facilitate the chemical interpretation of genetical factors. Breeding for superior strains of corn and other crops depends ultimately on a better understanding of the laws of heredity, including color factors.

Yellow and red pigments of apples have been isolated and tentative identifications made. Work on the isolation and identification of the coloring matter occurring in Italian and American red and American purple tomatoes, and in the Indian-red pomelo, which is related to the grapefruit of commerce, has demonstrated that the pigment in all cases is lycopin. This pigment was also found to be responsible for the pink color of Marsh and Foster grapefruits. In the Foster grapefruit the pigment is mainly lycopin, whereas in the Marsh variety carotene predominates. This explains why the Foster is a true pink and the Marsh a salmon pink.

ETHYLENE TREATMENT OF FRUITS AND VEGETABLES

In the commercial practice of treating the Japanese persimmon with ethylene, there has been the usual tendency to use fruits which are not sufficiently mature to give the best results. Experiments were conducted which showed that the sugar content of the fruit is not increased by ethylene treatment and that full flavor and color are not developed in the immature persimmon by ethylene treatment. Persimmons should be at least 65 percent colored before harvesting, when full flavor and full color can be obtained by a few days' treatment with ethylene.

Commercial experimenters have been using ethylene as a means of accelerating development of color of tomatoes picked while quite immature. The Bureau's work shows that the sugar-acid ratio is increased by the treatment owing to loss of acid and that, although there is some color stimulation, it is too slow to be of marked commercial advantage. Ethylene treatment cannot be used to advantage on tomatoes that are picked at less than the green-mature stage, which is reached when the tomato has attained full size, but before it has begun to show pink or yellow color.

FERMENTATION PRESERVATION

The feasibility of preparing food products from turnips and similar root crops by fermentation was tested as a possible means of promoting crop diversification. Twenty-five varieties of food vegetables, including some seeds imported from Europe, were grown at Arlington Experiment Farm and fermented in brine. The products were graded according to acidity, color, texture, taste, and odor. The Purple Top Strap Leaf turnip produced a sauerkraut which graded "excellent." The following turnips produced a "good" sauerkraut: Tokyo, Extra Early Purple Top Milan, Purple Top White Globe, Yellow Globe, Extra Early White Milan, and Japanese Shogain. Turnips were the only root vegetables that gave acceptable results.

A study was made of certain factors of quality in cucumbers used for pickles. Cucumbers grown at Arlington Experiment Farm were packed in brine in open jars. Analyses made during the curing process showed that the acidity rises rapidly at first, remains approximately constant for a time, and then gradually diminishes. The loss of sugars roughly parallels the rise in acidity, but the nitrogen content remains unchanged. The cucumbers were packed according to size, and it was found that the smaller or younger the cucumber the longer it resists softening of the tissues. "Soft pickles" contain much less pectin than those of normal texture.

EGGS AND EGG PRODUCTS

It has been shown that carbon dioxide is lost rapidly from shell eggs immediately after laying, and that this loss reduces the acidity of the eggs and leads to breakdown of the egg white, a characteristic of many storage eggs. Coating the eggs with a thin oil reduces markedly the loss of carbon dioxide and saturating the oil with carbon dioxide before coating reduces this loss still further. Eggs so treated, and then held in commercial storage for 8 months, had almost the same pH value as fresh eggs and graded 25 percent higher than did similar eggs oiled on commercial egg-oiling machines. A public service patent covering this process has been granted (U.S. Patent No. 1,888,415).

Preliminary studies on the proteolytic and catalytic enzymes of eggs showed that the activity of these enzymes in the whites and yolks of unoiled eggs is greater than in eggs protected by oil treatment. This is especially true of catalytic enzymes.

INDUSTRIAL FARM-PRODUCTS RESEARCH

FARM FABRICS

The major part of the $70,000,000 worth of cotton duck sold each year for outdoor use is lacking in fire, water, and mildew resistance, fails to afford reasonable protection to goods stored under it, and soon becomes useless. The losses from the use of such inadequate canvas (including tobacco shade cloth, bagging, and that for other farm uses) are estimated at more than $15,000,000 annually.

Investigation was continued for the purpose of devising and improving treatments for canvas, tobacco shade cloth, covers, bagging, and other cotton fabrics, used out of doors on farms and elsewhere, thus making them more serviceable and more durable through increased water repellency and resistance to destructive agents such as light, fire, acids, and mildew, and decreasing losses on farm products stored and protected by such canvas. Fireproofing will increase the use of cotton for awnings which is now curtailed by city fire regulations.

The work on fireproofing indicates that the process for flame-proofing cotton fabrics with stannic oxide may be improved and cheapened by precipitating ferric iron with the tin. The iron salts increase the flame resistance of a given quantity of tin and retard the deterioration of the fabric by light. Chromium, titanium, and some other metallic salts have the same effect as iron, and thus the cost of flame-proofing can be lowered, but there is no indication that tin can be omitted. The year's work has shown, also, the need for better and cheaper glow-proofing agents. Evidence has been obtained that the very destructive effect of chlorinated organic materials on exposed fabrics can be greatly reduced by the use of colored flame-proofing oxides.

In collaboration with the Division of Soil Microbiology it was found that mildewing of leather may occur at 63 percent relative humidity, of fabrics at about 70 percent, and of paper at about 80 percent. A quicker method, using pure cultures of certain molds, has been developed for determining mildew resistance of fabrics. This method gives significant results within 2 weeks. It was found that the zinc borate mildew-proofing treatment can be applied to striped awning material without affecting the colors. Simplified procedures for preparing copper chromate and using copper chromate in mildew-proofing fabrics were devised.

HIDES AND TANNING MATERIALS

Domestic agriculture has a double interest in hides and tanning materials (1) because it supplies $300,000,000 worth of hides and skins and $20,000,000 worth of vegetable-tanning materials required each year, and (2) because those interested in rural pursuits buy about one third of the $1,500,000,000 worth of shoes, harness, belts for machinery, and similar products made and sold annually.

Agriculture is vitally interested in supplying adequate and suitable raw materials and in receiving serviceable and suitable leather goods. At present domestic agriculture supplies only half of these raw materials.

HIDES AND SKINS

Annually, $20,000,000 are lost in the wasteful handling of hides and skins. This means about $80,000,000 worth of leather goods. It is estimated that agriculture bears at least one third of these losses. Material improvement in hides and skins has been effected in combating this loss, particularly in the Southern and Eastern States. Over a large part of these sections producers are getting from one fourth to 1 cent more per pound for hides and skins, primarily because of this work. Improvement in practice has resulted in less damage in skinning, abandonment of vat curing, better built hide packs, improvements in hide-cellar construction, ventilation, and drainage, heavier salting (especially in hot weather), separate packs for skins and for hides, and the use of clean salt in curing.

Two years' research has contributed materially to our knowledge of the cause of reddening of salted hides, a frequent subject of controversy and litigation over claims for damage. This work has shown that all solar-evaporated salts examined, except those subsequently kiln dried, carried hide-reddening organisms. More significant, probably, is the finding that 64 percent of the domestic "G.A." (ground alum) salts examined also carry these organisms. Reddening organisms were not found in any of the mined or vacuum-pan evaporated salts examined.

Serious damage to cured calfskins in the form of numerous deep flesh pits, which frequently cause losses of several hundred dollars per shipment, was found to be due to curing with old, low-grade salt containing large pieces of material nearly insoluble in water. These impurities have practically no preservative action. Partial rotting of the skin immediately beneath them consequently occurs, with the formation of deep pits.

A new study has been undertaken in cooperation with the Tanners' Council of America on the recent increase in abnormally greasy cattle hides. Leather from these hides is discolored and degraded about 5 cents per pound, making a loss on a heavy hide of a dollar or more. The price received by farmers for hides is lowered because of lack of knowledge of the cause, and means for removing the grease. Studies are in progress to determine the connection, if any, between the occurrence of exceedingly greasy hides and the feeding and fattening of cattle. Experiments are also under way on processing to remove the excess grease.

TANNING MATERIALS

The United States now supplies only about half of its requirements for tanning materials for production of leather and the domestic supply of chestnut tannin is rapidly decreasing because of blight which is seriously affecting chestnut trees. A technical and economic study of waste hemlock bark of Washington and Oregon (estimated at more than 350,000 tons annually) as a new commercial source of tannin for leather with a potential annual value of $5,000,000 has been intensively pursued. Extract has been made from 80 tons of this waste bark. Data on yields and on leaching operations have been obtained. Cooperative sole-leather tanning experiments are in progress. The leather in one lot, tanned with liquors containing about 40 percent of hemlock-bark extract, is entirely satisfactory and can hardly be distinguished from the regular tannage without hemlock extract.

The studies in progress indicate that the production of tanning extracts from this bark is commercially feasible, thus adding to domestic supplies, and giving farmers and timber owners of the Northwest another source of income. Additional experiments are under way for comparison of appearance, yield, cutting value, and wearing quality of the specially tanned hemlock leather with regularly tanned leather from the same hides.

Other possible sources of tannin are being investigated as part of a program to provide a more adequate supply of domestic tanning materials. Moisture-free alder wood from Washington was found to contain only 0.4 percent of tannin; the bark contained 12.6 percent of tannin and 17 percent of nontannin substances. The bark compares favorably with eastern hemlock in tannin content. White fir bark from Oregon contained only 6 percent of tannin and 6.5 percent of nontannin substances, too little for utilization under present conditions.

In cooperation with the Bureau of Plant Industry, the tannin content of *Lespedeza sericea* is being studied in the endeavor to propagate plants of low tannin content and thus increase the palatability and digestibility of the plant as a forage crop.

FARM BYPRODUCTS

In the production of the great staple crops, the small grains, cotton, and sugarcane, there necessarily is grown an equal and usually greater tonnage of straws, stalks, and bagasse (sugarcane residue) for which on the whole there is no adequate use. Relatively small amounts are now used as roughage, bedding, or as fuel (sugarcane residue), and in maintaining the fertility of the farm. A comparatively small percentage is sold for industrial uses, such as production of paper and building boards.

A comprehensive investigation of the possibilities of using these various waste materials for a great variety of purposes is being made. Attention is being directed, for instance, to the destructive distillation of these wastes and the production of various products, including activated charcoal, carbon black for painting purposes, oils and tars for waterproofing and roofing materials, fuel gas, so-called "dry ice" and numerous other products. A study is also being made of fermentation products, including fuel gas and the recovery of cellulose, fiber, and other constituents, the thought here being that perhaps small towns, and even individual farm gas plants, may offer a useful outlet for these by-products, especially in those sections of the country where wood, coal, and natural gas are not in plentiful supply locally.

The solution of these various problems of profitable utilization of agricultural wastes involves a subject of great magnitude. The stakes involved are tremendous and a practical solution of the problem may be expected to increase farm income substantially.

DESTRUCTIVE DISTILLATION OF AGRICULTURAL BYPRODUCTS

Industrial scale distillation tests at the Bureau's experimental plant at Ames, Iowa, indicate that corncobs and pecan shells, of the materials tested, give the highest total yields of salable products. The yields compare favorably with those obtained in wood distillation. Yields of 100 pounds of acetic acid per ton from pecan shells, and 130 pounds per ton from corncobs have been obtained. Yields of methyl alcohol from these materials are lower, being about one third those obtained from beech wood. Carbon and tar yields approximate those from wood. The carbon of pecan shells is denser and better adapted for activation than is that from corncob or wood charcoal.

These activated carbons were found to be quite satisfactory in the purification of municipal water supplies, which may prove to be an important outlet for farm waste subjected to destructive distillation. Laboratory work indicates that practically all farm-waste carbons can be activated to some degree. The utility of the tar oils is being investigated, especially with respect to their insecticidal value. Distillation equipment is being studied to develop the most suitable types.

Preliminary experiments have been made to determine the fuel value of wastes, as such, and the production of briquettes for heating purposes. These experiments indicate that a briquette made of carbon and pitch has a performance and heat value comparable to soft coal of good grade. The characteristics of such briquettes can be varied at will. Briquettes for fuel are a possible local outlet for farm wastes in the prairie States and may give the farmers of these States fuel at lower cost.

FERMENTATION OF FARM BYPRODUCTS

Fermentation experiments on waste sugar-beet pulp have shown that over 40 percent of acetic acid can be produced from such pulp. Mixtures of sugar-free beet pulp with added cellulose have produced as much as 60 percent by weight of acetic acid (including small amounts of butyric acid). Fermentation experiments indicate the possible commercial production of a mixture of ethyl, isopropyl, and butyl alcohols, suitable for motor fuel, from waste corn glucose (40 percent sirup), with 15 percent yields of alcohols. The production of lactic acid from such wastes is now approaching the commercial stage.

Experiment showed that under anaerobic conditions prepared lignin is not decomposed to any appreciable extent by bacteria. No carbon dioxide or

methane is produced. Consequently no fuel value is derived from lignin in anaerobic fermentations. Addition of prepared lignin to cornstalk flour or to packing-house waste markedly reduces the fermentability of the material under anaerobic conditions. There is further evidence that this interference is not due to a soluble antiseptic substance, but may be owing to a chemical combination of lignin and protein.

A farm unit pilot plant for study of the working conditions of the production of fuel gas on the farm, from farm wastes and house sewage, is being installed in order to obtain a final solution of this problem.

NAVAL STORES

Naval stores represent an important cash crop of the South and constitute the cheapest suitable raw materials for a number of the country's largest industries. Naval-stores production is the key to longleaf pine reforestation in that it bears much of the expense of bringing the trees to timber size. Naval-stores products are worth from $30,000,000 to $50,000,000 annually, and some 300,000 people make their living from this industry. The program of work on naval stores is directed to saving for the turpentine farmer losses estimated to exceed $6,000,000 annually, on which all costs of production have been incurred; and to developing new, and extending present uses for these farm and forest products.

NAVAL STORES STATION

The naval stores station located in the Osceola National Forest, Lake City, Fla., and cooperating with the Forest Service, began the technological study of naval-stores problems September 18, 1932. For the first time, the American turpentine farmer has an adequate agency for the scientific investigation of the problems of production of naval stores and of their suitability for various uses. Naval-stores production now has an equal footing with other branches of agriculture and forestry, through the operation of an experiment station, designed, located, equipped, and manned for the solution of its problems.

The work of the station is not a program of increased production, but is one of reducing costs, of saving material on which costs have already been incurred, and of expanding uses through better and more suitable products.

The presence of small quantities of water, which may or may not be sufficient to cloud the turpentine and which finally separates when the turpentine is chilled or stands for a long time, is one of the most troublesome problems in handling and storing turpentine and causes losses of more than $100,000 annually. In order to remove this water when the turpentine is made, several types of chemical dehydrators made from turpentine barrels, which the operator can readily make, and using common salt as the drying agent, have been devised. The water is removed from the turpentine, losses are reduced, and a more stable, brighter, cleaner turpentine, more suitable for industrial purposes, is being produced, with increased returns to turpentine operators.

A fire-still plant which incorporates approved features and practices in still-building construction has been designed and erected at the naval stores station. The design is based on the experience gained by the Bureau in its field work on naval stores, and includes such additional features as are necessary in a plant designed for experimental work. This design can be readily modified to meet the needs of the operator, or his preferences for arrangement. Many operators have incorporated features of this plant in remodeling old plants. A number of plants following the general design, with more than 50 still settings worked out by the Bureau, were installed during the past spring.

The South-Eastern Underwriters Association has accepted and is using the Bureau's design, construction, type of materials, and spacing between buildings as a model set-up and gives this setting the minimum rate for fire insurance at an estimated saving of approximately $200 annually per still.

Thirteen hundred cups of 20 kinds of shapes or coatings have been hung, and comparative results are being recorded to determine the optimum shape, size, and material for turpentine cups and accessories, in order to study and prevent losses from changes in gum, and to determine the effects of these factors on properties of products. Nearly all kinds of coated cups show deterioration within 6 months.

Plans and specifications were prepared for special equipment to be used in a new process for filtering and refining crude turpentine gum. In designing this equipment, special consideration was given to the selection of suitable

alloys with a view to using only those that do not impart color to turpentine gum.

Other problems under investigation include: Dip barrels, to determine the most suitable type that will prevent losses and avoid degrading of rosins; gum cleaning, to give the producer and user a more valuable material; barrel gluing, to develop a gluing procedure that will retain turpentine in barrels indefinitely; losses from uncovered dip barrels and separators; better stilling methods to reduce cost and improve products; rosin packages, to improve them, reduce leakage and delay rotting; batting and rosin strainers, to make cleaner and higher grade rosins; recovery of rosin from dross and chips, to save $2 worth of rosin per charge.

Cooperative agents have directed the erection of 40 to 50 turpentine fire stills according to approved plans and recommendations, and additional still settings were made through their efforts. An improvement in grades of rosin amounting in some cases to several hundred dollars annually per still has been effected by using the Bureau method of distillation.

Methods of analysis and testing of turpentine, rosin, and other naval-stores products were devised as an aid in work on composition, properties, and uses, and as a basis for specifications. This work has included determination of the melting point of rosin and preparation of color standards for turpentine in collaboration with the American Society for Testing Materials.

RESIN ACIDS

Work was continued on the composition of pine gums, particularly the nonvolatile part consisting principally of resin acids. It is from this portion that rosin is formed on distilling, and from which rosin derives its properties. The purpose is to acquire basic information for controlling the character and properties of rosin, and for promoting utilization of the natural resin acids. Incidentally, this work will yield data useful in the enforcement of the Naval Stores Act. Two of these acids, alpha- and beta-pimaric acids, were prepared from longleaf-pine gum and their properties determined. There was developed an improved systematic scheme for the separation of sapinic from pimaric, and alpha- and beta-pimaric acid, which yielded these acids in a high state of purity.

Hydrogenated derivatives of these two acids were prepared. These possess much greater stability, especially in resistance to oxidation, than rosin or resin acids. The oxidizability of rosin is objectionable in its uses for making soap, paper size, ester gum, etc. Because of their greater stability, the hydrogenated resin acids should have decided advantages and if they can be economically prepared, they should lead to increased use of naval-stores products. With the object of devising practical means for preventing deterioration of turpentine in tanks and drums, during storage, final tests were made on turpentine that had been kept in experimental storage. The prevention of deterioration of turpentine will yield greater net returns to producers.

OIL, FAT, AND WAX INVESTIGATIONS

Work in this field consists of investigations on the composition and characteristics of agricultural fats and oils with reference to commercial requirements in order to make possible their more profitable production and utilization. Oil-bearing farm products now wasted or inadequately used are studied for the purpose of finding profitable market outlets.

SOYBEAN OIL

The soybean crop has been increasing steadily in recent years and is proving to be a valuable means of crop diversification, particularly in the Middle West and Cotton Belt. It is serving as a means of profitable use of considerable acreage not needed for overproduced staple crops. Utilization of the oil has not kept pace with the demand for the byproduct soybean meal and a stable market for the crop is dependent to a great extent on profitable use of the oil. There is a demand in the paint and other industries for soybean oil of high iodine absorption value to be used as an economical substitute for linseed oil, the bulk of which is now obtained from imported flaxseed.

Examination of over 70 new varieties of soybeans and their oils was made in collaboration with the Bureau of Plant Industry, for the purpose of discovering the oils best suited for technical purposes. Many new varieties from China,

Japan, and Chosen remain to be examined. It is desired to find varieties of soybeans, which yield oils of notably higher iodine absorption than do the oils now produced in this country, as such oils would be of particular interest to the paint, varnish, and linoleum industries. When such desirable varieties are discovered, provided the characteristic properties of their oils remain unchanged after cultivation in this country, it is believed that their introduction will in no small measure assist in the future maintenance of soybeans as an important cash crop, besides materially increasing its annual value.

The insoluble phosphatides of soybeans and soybean oil from North Carolina were studied for the purpose of ascertaining the cause of and means of preventing their troublesome precipitation from the oil which now reduces its marketability.

APRICOT-KERNEL OIL

The composition of apricot-kernel oil has been investigated in view of recent marked interest in the greater domestic utilization of apricot kernels from the pits which are separated at California fruit-drying plants. Between 10,000 and 11,000 tons of these pits are available annually. The kernels, which amount to about one fourth the weight of the pits, contain from 40 to 45 percent of oil. It was found that the oil contained 3.6 percent of saturated acids, consisting chiefly of palmitic and stearic acids.

The unsaturated acids amounted to 90.6 percent of the oil, and consisted of 33 percent of linoleic and 67 percent of oleic acids. The composition and keeping properties of the oil indicate that it is suitable for use as a salad and cooking oil and for roasting shelled nuts, in addition to its customary but rather limited use in the manufacture of certain cosmetics.

PROTEIN AND NUTRITION INVESTIGATIONS

PROTEINS

Chemical and biological investigations of proteins are conducted to develop information which will permit more profitable utilization of foods and feeds, and which will provide fundamental data essential for the solution of problems in human nutrition and in the feeding of farm animals. This field of investigation is of great general importance, but it has a special significance to agriculture because the farmer is vitally concerned both as a consumer and a producer.

Protein is one of the important food elements, and is the constituent that makes muscle. The protein content is a vital factor in the valuation of most agricultural food products. Foods are bought and sold to a great extent on the basis of their protein content. The protein content of wheat is an important factor in determining its price, and a graduated premium is paid for increase in protein content under certain conditions. Practically every State requires that commercial feed be labeled to show the protein content, which must not fall below a given percentage.

The value of protein concentrates used in the United States for livestock feed amounts annually to over 3 billion dollars. The protein value of a feed depends on quality as well as quantity. Not all proteins have the same food value. Some are lacking in certain nutritionally essential amino acids without which animals will not grow. Other proteins contain these same amino acids in abundance.

The effective and profitable utilization of some of our most important feedstuffs depends on a knowledge of how to combine them so that the deficient proteins can be properly supplemented by the adequate ones. Knowledge of the amino acid composition of proteins makes it possible to correct the nutritional deficiencies, for example, of several cereal grains by combining with them in the right proportion other feeds containing proteins of suitable quality. Proper supplementation based on a knowledge of the properties and composition of proteins makes possible an increase of millions of dollars in the annual feeding value of farm crops.

DIGESTIBILITY OF PROTEINS

Food proteins differ greatly in their digestibility. Some are made more digestible by heat, others are not. Certain proteins are not completely digested by the digestive fluids but leave a considerable part of some of the amino acids in the undigested fraction. These amino acids, therefore, cannot be assimilated, and the food value of the protein is correspondingly lowered. Little is known

about the relative ease or order in which the different amino acids are liberated from proteins on digestion. Knowledge of this subject is essential and fundamental for solving many practical problems in nutrition.

Experiments were conducted this year with casein to ascertain the rate of liberation of cystine, an amino acid constituent of protein essential for the growth and health of animals when the casein is digested with pepsin or hydrolyzed with acid. It was found that cystine is early liberated from casein when boiled with acids, but that it is not liberated by digestion with pepsin. Casein, however, is very quickly partially digested by pepsin, yielding peptones and albumoses. Analyses of these partial-digestion products show that they have widely different compositions and have different nutritive properties.

PROTEINS OF YEAST

The use of yeast directly for human consumption has increased tremendously during recent years. In experimental feeding tests also, yeast is generally added to the basal rations to supply vitamins. Dry yeast contains from 40 to 50 percent of protein and nitrogenous compounds. The protein and compounds of unknown character added to experimental rations introduce complicating factors which can well lead to erroneous conclusions in interpreting the results of nutritional studies. These considerations, and the meager information on the proteins of yeast, emphasize the importance of developing more knowledge on the nature of yeast proteins and their amino acid composition.

Proteins representing about 80 percent of the total nitrogen of the yeast have been isolated. These proteins are being studied and analyzed to obtain information relative to their nutritive value, and to their place in human nutrition and in the feeding of farm animals.

SUGARCANE JUICE

The presence of nitrogenous compounds in sugarcane juice presents troublesome problems in the recovery of sugar. In order to determine the effect of the proteins and other nitrogenous compounds of sugarcane juice upon the processes of sugar extraction, the changes in the distribution of ammonia, amide, amino, peptide, and nitrate nitrogen at the various stages of the sulphur-lime process of juice clarification between the original raw cane juice and the final product were determined.

VITAMINS

The tremendous development in the field of vitamins during recent years, the commercial exploitation of vitamins, methods used in the production and transportation of foods which may affect their vitamin values, methods for determining vitamins and their natural distribution, their properties and structure—all these considerations have developed the necessity of producing more information in order to meet and solve the many problems which arise in State and Federal regulatory work, and in practical problems in nutrition of importance not only in animal feeding but also in human welfare.

USE OF SALMON OIL IN FEEDING

Salmon oil can be produced which is fully equal and probably superior to cod-liver oil in the treatment of rickets in infants. This was shown in cooperative studies with the Children's Bureau of the United States Department of Labor. The results were anticipated in view of the fact that this Bureau had previously demonstrated that salmon oils are richer in vitamin D than cod-liver oil. When the value of domestically produced salmon oil in poultry feeding and as a human food is fully appreciated, it will probably replace in a large measure the cod-liver oil which is now imported.

TECHNIC OF VITAMIN ASSAY

A great deal of confusion has arisen in expressing the vitamin content of foods and feeds. With the commercial interest that has been shown in vitamins in the past few years, this confusion has become of considerable importance and serious food-regulatory problems have developed. At a conference held in London 2 years ago, international standards were adopted for four of the vitamins—A, B, C, and D—and units for expressing vitamin potency were

agreed upon. Standard vitamin preparations are issued by the National Institute for Medical Research, England, to a distributing agency in each country. The Protein and Nutrition Division serves in the distribution of the standards in this country. The preparations are issued without cost to laboratories which have legitimate use for them.

THE VITAMIN C CONTENT OF CITRUS-FRUIT JUICES

The present method of determining vitamin C by feeding experiments with animals is expensive, time-consuming, and only approximately accurate. The use of a dye, 2, 6-dichlorophenolindophenol, may prove very helpful in determining the stability of vitamin C in citrus and other fruit juices. In studies on oranges, grapefruit, lemons, and Satsuma oranges, it has been found that vitamin-C content is very closely paralleled by the reducing value of the juice as determined by this dye. With increasing quantities of fruit juices being produced and consumed, this chemical test may serve as a useful guide in eliminating unsatisfactory or undesirable processing methods.

COLOR AND FARM-WASTE INVESTIGATIONS

The color and farm-waste research of the Bureau consists essentially of investigations on the profitable utilization of farm waste and includes, incidentally, some research on colors for agricultural textile materials as follows: (1) The development of color substances which are particularly suitable for American agricultural textile materials, such as cotton, the synthetic cellulose fibers, and wool, thereby widening the market for the corresponding crops; (2) chemical and technological research on the profitable utilization of agricultural wastes; and (3) fundamental and technological research on the utilization of farm products and wastes by mold-fermentation processes.

The work of the Bureau in this field has resulted in the establishment of several industries which have directly stimulated utilization of domestic farm products and have created new market outlets. The American vat-dye industry, made possible by the method developed by the Bureau for the production of phthalic anhydride, has not only broken the foreign monopoly but has effected drastic economies in vat-dye manufacture. By the use of vat colors it is possible to obtain attractive effects more cheaply with domestic textiles such as cotton, rayon, and wool, thereby widening the market for these materials. Since vat colors give attractive shades and as a class are the fastest known to light and washing when applied to cotton, rayon, and wool, effects are obtained comparable to those secured with more expensive imported textiles, such as silk. The result has been the expansion of the use of American textile materials at the expense of other textiles of foreign origin.

The manufacture of furfural has now become an established industry as a result of work of the Bureau. In this industry more than 5,000,000 pounds of oat hulls which would otherwise be wasted are now utilized annually in the production of solvents and synthetic resins.

Work on the industrial utilization of farm products and byproducts by means of mold fermentations has resulted in the development of a number of new materials. Calcium gluconate, a valuable medicinal substance for both human and animal use, has come into industrial production as a result of discovery by the Bureau of a method by which its production cost can be reduced from $150 to 50 cents a pound. A method was devised for economical production of kojic acid, formerly a rare chemical. This substance is now being investigated by several commercial organizations with a view to its utilization. A new fatty material the chemical identity of which has not been thoroughly established and which may possess special properties of value is now being studied. All of these substances are produced by the action of molds on corn sugar. They point the way to greater diversification of the use of corn.

The work on utilization of sugarcane bagasse, which was mentioned in the last annual report, is assuming increased importance with the developments of the past few months. Cotton linters are the principal source of industrial cellulose for manufacture of nitrocellulose for films, explosives, and lacquers; of cellulose acetate for films and textiles; and of rayon. An anticipated shortage of this raw material has led during the past few years to an intensive search for other satisfactory sources of industrial cellulose. The curtailment of the cotton crop and the corresponding decrease in the supply of cotton linters will bring this situation to a climax which will require an immediate solution.

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Tests made by the Bureau have shown that an excellent grade of cellulose can be produced from sugarcane bagasse, thus opening a promising market for the 500,000 tons of waste sugarcane fiber available annually in the continental United States. Industrial experiments based on these results, in which the Bureau has cooperated in an advisory capacity, have indicated that there should be no difficulty in making use of sugarcane fiber to supply needs arising from a shortage of cotton linters.

Experiments have shown the possibility of adding as much as 10 percent of organic nitrogen to the lignin sulphonic acids found in the waste liquor from the sulphite process for paper pulp. The resulting product has been shown to possess marked value as a fertilizer. The industrial utilization of this discovery would not only provide a cheap and valuable fertilizer but would go a long way toward solving the problems of stream pollution arising from the present annual output of approximately 4,500,000,000 gallons of sulphite waste liquor.

INSECTICIDE INVESTIGATIONS

Cheaper insecticides are demanded by farmers seeking lower costs of production. More effective insecticides are desired by fruit growers, truck growers, florists, and nurserymen in order to combat numerous pests which are difficult to control with known materials. Food-law restrictions against the presence of arsenic, lead, and fluorine on sprayed or dusted fruits and vegetables create an urgent demand for new insecticides that are nonpoisonous to man and domestic animals.

Research directed to improving present insecticides and finding new ones has been continued. There is indication that the growing of plants of insecticidal value may provide noncompetitive means of crop diversification which will be of distinct value to domestic agriculture. In addition, intensive efforts have been directed to the problem of the removal of arsenic-, lead-, and fluorine-containing spray residues, the presence of which on foodstuffs constitutes a grave menace to public health.

ROTENONE

Work has continued on the problem of developing from fish-poisoning plants new insecticides that are not poisonous to birds and mammals. In tests against the codling moth, rotenone has given excellent control for a few days, but at the end of a week its efficacy has disappeared because of photochemical decomposition. The use of fish tests in the study of this photochemical decomposition of rotenone and some related compounds which was begun last year was completed. These tests agreed with the entomological tests carried on simultaneously in showing that an easily made derivative of rotenone called dihydrorotenone is inherently more stable than rotenone, and that rotenone can be protected from decomposition by admixture with a light-absorbing material such as lampblack.

As rotenone becomes cheaper it will become competitive with lead arsenate, of which about 30,000,000 pounds are used annually in combating chewing insects. The use of rotenone in place of lead arsenate will eliminate the problem of the removal of lead and arsenic from fruits and vegetables, because rotenone residues are not poisonous to man. The cost of washing apples alone for the removal of poisonous residues is not less than $1,000,000 annually.

Several plant extracts and other materials were tested for toxicity. In a concentration of 200 parts per million (based on weight of original material) the extracts from Huamansana leaves and *Stillingia sylvatica* were quite toxic, and those from huaca leaves, vetiveria roots, and cubé leaves were much less so.

The final experiments relating to the carbon-tetrachloride method of determining rotenone in derris and cubé roots and other plant material were performed and the method published. The use of this method has enabled growers of cubé and derris to select varieties of high rotenone content and, by increasing the production per acre of rotenone, lower its cost.

The development of the Durham qualitative test for rotenone mentioned last year was completed and a description of it was published. It was used throughout the year in testing plants as possible sources of rotenone. Of the 49 samples tested, 32 gave no reaction. The other 17 comprised the following, the figures in parentheses indicating the percentage of rotenone found in those few samples that were analyzed: *Derris uliginosa, D grandifolia* (bark and wood), *Lonchocarpus velutinus*, unknown *Lonchocarpus* sp. (8.9), *Spatholobus roxburghii*

(1.0), *Tephrosia candida* seed, *Polygonum* sp. root, *Mundulea suberosa*, Timbo root (16), Cipo (1.2), Berberra seeds, bejuco de gusano (0.4), barbasco root, Haiari root, Sopilote wood, cubé stems (0.3) and cubé leaves (too little to determine). The bejuco de gusano may be *Lonchocarpus hondurensis*.

The value of 16 percent rotenone obtained in timbo root represents the maximum so far observed in any material. The low values obtained for cubé stems and leaves confirm the assumption that only the roots of this plant are of commercial value. It has been determined that the fine roots of cubé contain a greater percentage by weight of rotenone than do the coarser ones, and that in the coarse roots the rotenone is concentrated in the bark.

A comprehensive study of the relative value of rotenone and the pyrethrins as sprays for house flies has been begun and considerable progress made, the insecticidal tests being conducted by the Bureau of Entomology. So far it has been demonstrated that rotenone, total acetone extracts of derris, and straight kerosene extracts are quite toxic to flies. As the result of this work a number of fly-spray manufacturers, including some of the largest in the country, are now incorporating rotenone or other derris extractives in their products.

CROTON

The complete toxicity-concentration curve for the toxic resin contained in the seeds of *Croton tiglium* was determined with goldfish. The fish survive only 45 minutes in a concentration of 1 part per hundred million. It is even more potent than rotenone, but unfortunately it has a considerable vesicant action which may hinder its use as an insecticide. The chemical investigation is being continued, and insecticidal tests with it are also being made.

SYNTHESIS OF ROTENONE

Partial synthesis of a number of rotenone derivatives have been accomplished. For instance, by starting with derritol, a decomposition product of rotenone, derrisic acid has been synthesized and this in turn, converted into dehydrorotenone. Rotenonone has also been synthesized from derritol. A synthesis of derritol itself would therefore complete the chain of synthesis of dehydrorotenone from the elements. Work on this is in progress.

The parent substances (compounds having the same structure without substituting side groups) of dehydrorotenone, derrisic acid, derritol, and rotenonone have been prepared. The possibility of making synthetic rotenone is considered good.

A practical method for the preparation of dihydrorotenone from rotenone (yield 90 percent) was developed. Application for a patent has been filed. Dihydrorotenone is of value because, while rivaling rotenone in insecticidal potency, it is much more resistant to decomposition by direct sunlight.

ROTENONE IN AN EASTERN WEED

Cracca virginiana, commonly called devil's shoestring, rabbitbean, and goatsrue, has been shown to possess marked insecticidal properties, and because it grows over a large part of the United States, its examination is of considerable significance.

The chemical examination of *Cracca virginiana* resulted in demonstating that the roots of this plant contain four crystalline compounds, namely, rotenone, tephrosin, dehydrorotenone, and an unidentified substance with the empirical formula $C_{22}H_{24}O_4$ and melting point 131° C. The discovery of rotenone in this weed may lead to making the United States independent of foreign sources of this valuable insecticide and at the same time provide an important crop to increase agricultural diversification by growing it on land not needed for overproduced staple crops.

NICOTINE

It has been found that, by the process of base exchange, nicotine may be introduced into bentonite clay, which then functions as an insoluble compound of nicotine capable of acting as a stomach poison with all the desirable emulsifying and spreading properties of the clay. This new product, nicotine-bentonite, may be used as a stomach poison in place of lead arsenate. It is

now being tested against the codling moth. If these tests prove successful, a greatly increased demand for nicotine will arise, and low-grade and off-grade tobaccos as the source of this nicotine may find a better market.

SYNTHETIC ORGANIC INSECTICIDES

Dithiocyanodioxane was synthesized and tested in a preliminary way against fish, to which it is somewhat toxic. Two compounds were made from the thiocyanate by reaction with aniline and with α-naphthylamine, respectively, and will be tested later. Paranitrophenylthiocyanate was also prepared and found to have considerable toxicity. Certain other organic compounds were synthesized and tested.

Previous work has shown that numerous organic compounds containing sulphur are toxic to insects, and the division is testing all easily obtained or easily made aromatic sulphur compounds. In all, 50 compounds were obtained or prepared, and the tests with mosquito larvae performed by the Bureau of Entomology showed two, namely, diphenylene sulphide and 2-phenylbenzothiazole, to be promising enough to warrant more extensive tests.

SPRAY RESIDUES

Because of the establishment of a legal tolerance for lead in foods, the solubility of lead arsenate in many different solutions of acids, alkalies, and salts has been determined to aid in selecting solutions which are capable of removing lead from apples. The determination of lead in residues required a critical consideration of analytical methods capable of estimating the quantities involved. A new procedure was developed which appears promising and which is now being given cooperative trial.

As in previous years, the apples from experimental plots around Yakima and Wenatchee, Wash., were examined for arsenic content. Information concerning arsenical residues on cabbages and tobacco was also obtained. The advantage of using nonarsenicals such as fluorine compounds in the later sprays, as evidenced by smaller arsenic residues, was again demonstrated.

Washing tests were made on various lots of fruit sprayed with various combinations of lead arsenate, mineral oil, fish oil, and cryolite. The fruit had been stored at 50° and 100° F., and washed in either a flood- or brush-type washing machine in one of three solutions, namely, hydrochloric acid, soda ash, or sodium silicate. No difference in the efficacy of the three solutions in removing arsenic could be detected with the fruit that had received cryolite and fish oil in the two final sprays. When mineral oil had been used throughout the season or in the final sprays, best removal was obtained with soda ash and poorest with hydrochloric acid. The arsenic in plain lead arsenate was removed equally well with any of the three washes. In general, fruit held in cold storage was more easily cleaned than that held in common storage. Assistance was given to growers who encountered difficulty in washing apples.

FLUORIDE RESIDUES ON FRUIT

Fluoride-containing insecticides are poisonous to man and animals; hence their use brings up the question of the residue left on food crops. The Bureau is investigating the magnitude of such residues, developing or testing methods for their determination, and devising means for their removal. During last year work on these subjects resulted in the finding of a fairly satisfactory analytical method with which the range of values for residue to be expected was determined. It was demonstrated that the ordinary washing procedures now used will probably suffice to remove fluorine if the legal tolerance is considered to be about that now enforced for arsenic (0.01 grain of As_2O_3 per pound).

FUMIGANTS

Work was done on the development of fumigants, of which those used for grain fumigation are particularly important. A survey made during the past year showed that the most commonly used commercial mixture is ethylene dichloride-carbon tetrachloride previously developed by the Bureau. The possibility of using the similar mixture of propylene dichloride and carbon tetrachloride was studied, but with unfavorable results.

Because of an abundance of fly larvae, favorable conditions with respect to supply of bulbs, additional work, in cooperation with the Bureau of Entomology, was done on the fumigation of *Merodon equestris* and *Eumerus* spp. The lethal limits in concentration and time for the naked larvae (not buried in the bulb) of both species were determined. The greater susceptibility in this case may be illustrated by the statement that, in the case of *Eumerus*, one tenth the dosage for one fourth the time gave 100 percent mortality.

A laboratory study of the effect of sulphur dioxide on the insects and mites found in a mushroom house, including the determination of minimum lethal concentrations for eggs, pupae, larvae, and adults, was completed. These tests have shown that the insects are killed by concentrations which it is possible to produce in mushroom houses. A new and more effective sulphur burner is being constructed for practical tests, and it is expected that recommendations for the guidance of growers can be decided upon before the advent of the next spawning season.

The investigation of the chemical phases of the fumigation of citrus red scale with hydrocyanic acid was continued throughout the year at the Whittier (Calif.) laboratory of the Bureau of Entomology. Numerous laboratory fumigations of scale-infested lemons with hydrocyanic acid were made under controlled conditions of temperature, humidity, and concentration to furnish the entomologists with information concerning the resistance of the scale, to obtain survivors for other experiments, and to determine the relationship between toxicity and the concentration-time integral throughout a range of concentrations and exposures.

During the past year about 220 laboratory fumigations of red scale on citrus were also made under controlled conditions of temperature, humidity, and concentration with over 100 volatile compounds, each used in conjunction with hydrocyanic acid at a concentration of 1.5 mg per liter, which has been adopted as standard for these tests.

ARSENICALS

The arsenical insecticides continue to be the most important means of combating insects; hence it is necessary that they be continuously considered even though great effort is being made to develop substitutes. Work on this project consisted of further experiments with the homologs of paris green. New greens were made with crotonic acid, erucic acid, and the acids from fish oil. The one produced by crotonic acid was well crystallized and agreed fairly well with the theoretical composition.

OIL EMULSIONS

Oil emulsions have been important insecticides for a long time, and their importance will probably increase, now that a renewed effort is being made to eliminate lead arsenate from the sprays used upon fruit and other edible products. Last year's work has shown that efficacy is not greatly dependent upon the proportion of unsulphonatable material in the oil, but is closely connected with viscosity. The oils of higher viscosity make heavier deposits on the foliage and these heavier deposits kill more insects. Confirmation of the idea that emulsions with large oil drops are more toxic than those with small ones was also obtained.

The investigation of the correlation between the properties of an oil and the insecticidal efficacy of emulsions prepared from it was continued throughout the year in cooperation with the entomologists of the Bureau of Entomology at their Gulf Laboratory in New Orleans.

FUNGICIDES

Fungous diseases of agricultural crops are very destructive. The Bureau's work in this field aims to develop new materials effective in controlling such diseases.

The principal activity in this field has been the preparation and testing, in conjunction with the Bureaus of Entomology and Plant Industry, of numerous fungicidal paints as a means of controlling the perennial canker of apple trees in the Northwest. The compounds used included beta-naphthylamine, copper stearoarsenite, copper palmitoarsenite, copper lauroarsenite, nicotine sulphate, anabasine sulphate, cuprous cyanide, paradichlorobenzene, and rotenone.

Aniline compounds with copper chloride, similar to those with copper fluoride and copper sulphate that have already been tested, have been prepared for next season's testing. No copper derivatives of acetoacetic ester, acetyl acetone, and dimethylglyoxime were prepared. They are insoluble in water and will be tested for fungicidal effect.

Building materials such as wall board are at times impregnated with arsenic solutions to protect them from insect damage. Various kinds of fungi have the power of liberating arsenic in volatile form when they grow upon a medium containing it. Analyses of various arsenicals were made, and a method was devised for absorbing and determining the evolved arsenical gases.

MISCELLANEOUS ANALYTICAL WORK

Several hundred samples were analyzed for other Bureaus, including insecticides used experimentally by the Bureau of Entomology, lead arsenate purchased on contract by the Bureau of Plant Quarantine, and bird carcasses from the Bureau of Biological Survey. In addition, many determinations of fluorine, arsenic, and lead in sprayed fruit and vegetables were made for the Bureaus of Entomology and Plant Industry.

FARM-FIRE INVESTIGATIONS

The function of this activity is to conserve invested agricultural capital, such as farm buildings, machinery, and crops by studying the causes of fires on farms and developing practical means to prevent them.

A conservative estimate places the loss from fires on farms in 1932 between $110,000,000 and $120,000,000. This property loss, which was accompanied by a life loss of about 3,500, was practically 25 percent of the fire loss of the entire United States for that year. The Bureau has conducted investigations on the causes and practical means of preventing and controlling fires on farms, which has resulted in an annual saving of millions of dollars of farm capital through reduction in fire losses and which have constituted a safeguard against interruption and possible suspension of individual farming operations.

Information on lightning control, construction of buildings, spontaneous ignition of hay, gasoline, and kerosene, heating equipment, electric wiring and appliances, fire extinguishers, water systems, and rural fire departments has been made available in printed form. This published material has been widely used by farmers, experiment stations, extension workers, insurance companies, underwriters, industry, and in fact all organizations and agencies interested in or concerned with farm-fire prevention and control.

SPONTANEOUS HEATING AND IGNITION OF HAY

Serious deterioration of certain farm crops occurs with considerable regularity after harvesting. In some cases actual destruction results, and in other cases the quality is impaired so as to reduce greatly the market value. This situation is particularly serious because deterioration occurs after the full expense of growing and harvesting the crop has been incurred.

At least one tenth of the value of the harvested hay crop, which was estimated at $632,000,000 in 1931, is lost by spontaneous heating occurring between the time when it is cut and the time when it is consumed. Investigation is being made of the effect of the moisture content, kind and volume of hay, and the effects of methods of curing, storing, and ventilation on spontaneous heating and ignition. A thorough understanding of the causes of spontaneous heating and ignition and development of means of prevention would save American farmers $20,000,000 annually from fires due to spontaneous heating and would reduce the additional loss of some $43,000,000 annually due to deterioration and spoilage resulting from abnormal temperatures and influence of oxidation.

Data compiled from continued surveys show that the leguminous hays are most subject to spontaneous heating and ignition, although fires of this nature also occur in other hays and even in straw. It also appears that barn storage is more conducive to severe self-heating of hay than storage in stacks. Spontaneous ignition occurs in chopped as well as in long hay.

Spontaneous ignition may occur in artificially cured or dehydrated hay if control of the moisture content of the finished product is poor. Cases of excessive heating followed by ignition were investigated where relatively small quantities of chopped hay came from the drier with a high moisture content,

although the remainder of the hay had been well dried. These surveys also have shown that a fire is most likely to occur in heating hay from 2 to 6 weeks after the hay has been placed in storage.

Losses from fire caused by spontaneous ignition of hay as well as losses from hay spoilage resulting from heating can be minimized by the following precautions:

(1) Hay should be sufficiently cured, consistent with the production of good quality, before being placed in mows or stacks. A range of 25 to 30 percent moisture content for long, loose alfalfa and clover hays is suggested. Care should be taken that no batch of hay goes into storage with a moisture content above 30 percent, even though the bulk of the hay falls within the range of safety.

(2) Cured hay upon which rain or dew has fallen should be cured again before being stored.

(3) Wetting of cured hay in storage, as from rain through a leaky roof, should be prevented.

DUST-EXPLOSION INVESTIGATIONS

Research on dust explosions is directly concerned with the protection of human life and property. There are 1,325,000 persons who are normally employed in 28,340 industrial establishments handling products, principally of agricultural origin, where dust explosions constitute a hazard to life and property. The annual value of their products is more than 10 billion dollars. Dust explosions in these plants, which are continually subjected to the dust-explosion hazard and which provide an outlet for farm products such as corn, wheat, oats, etc., result not only in a decrease in local markets for farm products, but also cause unemployment both of workmen in the plants and of men engaged in the handling and shipment of raw materials. There has been a continuous increase in the number of plants handling agricultural products which are subject to the hazard of dust explosions.

During the 16 years, 1917–32, inclusive, the only period for which accurate records have been kept, there have been 324 dust explosions in industrial establishments in the United States. These explosions resulted in the death of 276 persons and the injury of 613. They caused a property loss of $31,263,650, an average loss of $96,500 for each explosion.

The losses of life and property in many of the grain-handling industries as the result of dust explosions have decreased because of the work of the Bureau. The average loss per explosion over a 10-year period has decreased from $520,000 to $28,000, a net average reduction of nearly $500,000. The saving in a single year in the grain-handling industries alone is many times the amount spent during this 10-year period. It is impossible to estimate the saving in human life, but it is evident that from the reduction in dust-explosion losses a large number of workmen have been saved by the application of methods of prevention developed in this work.

One of the greatest unsolved problems in dust-explosion prevention, and one which is of particular economic importance, is that of dust collection and disposal. In many plants which handle agricultural products the dust produced in operating processes is valuable and the proper collection and handling of it constitute an important economic as well as dust-explosion prevention problem. With practically every new development for the utilization of agricultural products, it is necessary to work out new methods of obtaining protection from dust explosions in order to save life and property.

The work on dust explosions during the year included a study of the inflammability of various agricultural dusts and methods of preventing dust ignitions and resulting damage. During the year explosions occurred in the following industries: Grain handling, starch production, fertilizer manufacturing, and plants handling flour and cotton-flock dust. At the request of the Chemical Warfare Service of the War Department an explosion which occurred at Edgewood Arsenal was investigated and recommendations were made for the installation of equipment for the prevention of dust explosions.

Special attention was given to the use of dust-collecting equipment, provisions for venting dust explosions, and spray-drying equipment. Observations were made at a new type elevator employing extremely large bins for the storage of grain, in order to study the dust-explosion hazard due to this new form of grain handling. Many tests were made at the Arlington Testing Station during the year. These tests were in general a continuation of previous researches

dealing with the location and distribution of vents and the determination of venting area necessary to release explosion pressures without structural damage.

Subjects such as outside glazing and the scoring of glass were studied to determine the possibility of providing more effective venting than that provided by fixed glass. The dusts used in these tests included grain dust, cornstarch, wood flour, sugar, and powdered milk. In order to obtain a better standard for the explosibility or relative flammability of dusts, 130 dusts were tested in the laboratory at two concentrations of dust in air, namely, 100 and 500 mg per liter. Nine hundred sixty dust-explosion tests were made and three values were obtained from each test, namely, maximum pressure developed on explosion, maximum rate of pressure rise, and average rate of pressure rise.

The dust explosion hazards committee, under leadership of the Chemical Engineering Division, held its fall meeting in Chicago, and special attention was given to the revision of the Safety Code for the Prevention of Dust Explosions in Flour and Feed Mills. A new dust-explosion prevention code for woodworking industries was prepared. Nine safety codes for the prevention of dust explosions in grain-handling and associated industries have been formulated. These codes are used by insurance underwriters as the basis of rate making, and by State and municipal officials as the basis for inspection, explosion, and fire-prevention standards.

4-H CLUB WORK

Programs of activities for 4-H clubs on farm-fire prevention have been developed in cooperation with the Extension Service. The State of Oregon undertook the first organized 4-H club work in this field, the campaign being initiated by the State fire marshal in cooperation with the Extension Service of the Oregon State Agricultural College, through the medium of the State 4-H club organization. The results of this campaign have been so gratifying that it is being continued in Oregon and plans are under way for similar activity in other States. The enrollment in this farm-fire prevention movement of 4-H club members, who are usually the outstanding boys and girls in their farm community, and the carrying on of well-formulated, intensive campaigns centering on farm properties is bound to result in a greater reduction of farm-fire losses as the movement progresses and spreads.

COOPERATION WITH NATIONAL ORGANIZATIONS

The Bureau continues to have leadership of the farm-fire protection committee of the National Fire Protection Association. This committee issued a comprehensive report, Water Systems for Fire Protection on Farms, which suggests ways and means for the most efficient utilization of available water supplies in extinguishing farm fires and presents certain essential features which should be provided to give reasonably adequate fire protection when new water systems are contemplated.

The Bureau also has leadership in the committee on fire prevention and protection of the American Society of Agricultural Engineers. This committee prepared a complete report on farm-fire prevention and control.

SOIL INVESTIGATIONS UNIT

SOIL SURVEY

During the past fiscal year 27,771 square miles of agricultural lands in 29 States were mapped by the Soil Survey. This brings the total land mapped and classified to date to more than 1,500,000 square miles. The completed soil surveys of this vast area (greater than the combined areas of European Germany, France, and Great Britain) not only provide practical working maps and handbooks to assist farmers to make the best use of their soils, but also afford an inventory of national soil resources of great and immediate value in governmental policy.

Today it is being recognized as never before that land classification, founded on the results of soil surveys (which show the relative productive capacity of soils) combined with economic data, furnishes a sound basis for the development of land-use policies. This fact was emphasized during the past year when the results of previous work of the soil survey were utilized in developing a

basis for land classification in two States, the entire areas of which had been surveyed.

Using the soil survey as the basis for a comprehensive, exhaustive soil classification which has been adopted as the first step in a new land-valuation program, North Dakota has enlisted the aid of the Bureau in its effort to establish a fairer basis of taxation. In connection with the Department's present program of preventing overproduction of staple farm crops by the removal of surplus lands from cultivation, the fundamental necessity for information supplied by the Soil Survey is recognized in connection with land classification, acreage retirements, and readjustments to forestry, grazing, or other nonsurplus crops.

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 farmers to replace advantageously part of their cotton acreage with alfalfa. In the tobacco districts information obtained through the soil survey made it possible for the farmer to select 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 developments of alkali are a menace.

In developing reclamation projects the soil survey has proved to be of fundamental importance, since a knowledge of 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 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 obtained on a soil type in one section 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.

Tables 1 and 2 show the details of the work done during the fiscal year 1933, the areas covered, and their distribution.

TABLE 1.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1933*

State or territory	Area	Area surveyed	
		Square miles	*Acres*
Alabama	Colbert County	286	183,040
	Hale County	322	206,080
	Sumter County	271	173,440
	Winston County	[1] 225	144,000
Arizona	Upper Gila Valley area	138	88,320
California	Barstow area	263	168,320
	Concord area	102	65,280
	Lodi area	[1] 129	82,560
	Napa area	586	375,040
Colorado	Brighton area	[1] 128	81,920
Georgia	Decatur County	[1] 58	37,120
	Hall County	[1] 40	25,600
	Toombs County	68	43,520
Idaho	Bonner County	[1] 171	109,440
Indiana	Cass County	[1] 195	124,800
	LaPorte County	126	80,640
Iowa	Davis County	417	266,880
	Ida County	430	275,200
Kansas	Kingman County	[1] 108	69,120
Michigan	Cheboygan County	[1] 289	184,960
	Oceana County	[1] 289	184,960
	Saginaw County	[1] 340	217,600
	Schoolcraft County	[1] 711	455,040
Minnesota	Kanabec County	165	105,600

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

TABLE 1.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1933*—Continued

State or territory	Area	Area surveyed	
		Square miles	*Acres*
Mississippi	Marion County	[1] 323	206,720
Montana	Lower Yellowstone area	[1] 112	71,680
	Middle Yellowstone area	184	117,760
Nebraska	Boyd County	61	39,040
	Brown County	1,235	790,400
	Keyapaha County	102	65,280
	Holt County	[1] 1,512	967,680
	Rock County	[1] 860	550,400
	Wheeler County	68	43,520
New Mexico	Roswell area	279	178,560
New York	Broome County	[1] 135	86,400
	Chemung County	407	260,480
	Monroe County	[1] 609	389,760
	Otsego County	70	44,800
	Orleans County	[1] 234	149,760
	Rensselaer County	[1] 166	106,240
	Wyoming County	231	147,840
North Carolina	Chatham County	[1] 257	164,480
	Jones County	218	139,520
	Lee County	261	167,040
	Surry County	205	131,200
North Dakota	McKenzie County	[1] 2,302	1,473,280
Ohio	Adams County	[1] 68	43,520
	Athens County	[1] 191	122,240
	Logan County	186	119,040
	Vinton County	412	263,680
Oklahoma	Alfalfa County	[1] 510	326,400
	Carter County	[1] 431	275,840
	McIntosh County	[1] 414	264,960
	Mayes County	[1] 574	367,360
	Washita County	547	350,080
	Woodward County	[1] 532	340,480
Oregon	Umatilla County	[1] 410	262,400
Pennsylvania	Armstrong County	[1] 481	307,840
	Franklin County	[1] 618	395,520
	Huntingdon County	93	59,520
	Wayne County	[1] 518	331,520
Puerto Rico	Soil Survey of	[1] 423	270,720
Rhode Island	Washington County	196	125,440
South Carolina	Edgefield County	[1] 184	117,760
	Sumter County	205	131,200
Texas	Brown County	124	79,360
	Cass County	[1] 662	423,680
	Hardeman County	[1] 231	147,840
	Hunt County	409	261,760
	Williamson County	[1] 527	337,280
	Zavala County	820	524,800
Virginia	Augusta County	[1] 311	199,040
	Halifax County	112	71,680
	Southampton County	583	373,120
West Virginia	Pocahontas County	718	459,520
Wyoming	Fremont County	308	197,120
	Sheridan County	[1] 185	118,400
	Uinta County	100	64,000
Total		27,771	17,773,440

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

TABLE 2.—*Areas surveyed and mapped in the several States during the fiscal year ended June 30, 1933, and the areas previously reported*

DETAILED

State or territory	Work during 1933	Work previously reported	Total	
	Square miles	*Square miles*	*Square miles*	*Acres*
Alabama	1,104	56,902	58,006	37,123,840
Arizona	138	3,945	4,083	2,613,120
Arkansas		15,547	15,547	9,950,080
California	1,080	33,731	34,811	22,279,040
Colorado	128	5,737	5,865	3,753,600

TABLE 2.—*Areas surveyed and mapped in the several States during the fiscal year ended June 30, 1933, and the areas previously reported*—Continued

DETAILED

State or territory	Work during 1933	Work previously reported	Total	
	Square miles	*Square miles*	*Square miles*	*Acres*
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	166	35,696	35,862	22,951,680
Idaho	171	11,832	12,003	7,681,920
Illinois		6,770	6,770	4,332,800
Indiana	321	20,097	20,418	13,067,520
Iowa	847	47,621	48,468	31,019,520
Kansas	108	16,238	16,346	10,461,440
Kentucky		5,542	5,542	3,546,880
Louisiana		17,431	17,431	11,155,840
Maine		2,197	2,197	1,406,080
Maryland		13,959	13,959	8,933,760
Massachusetts		8,811	8,811	5,639,040
Michigan	1,629	29,319	30,948	19,806,720
Minnesota	165	10,920	11,085	7,094,400
Mississippi	323	30,417	30,740	19,673,600
Missouri		37,177	37,177	23,793,280
Montana	296	2,931	3,227	2,065,280
Nebraska	3,838	58,995	62,833	40,213,120
Nevada		652	652	417,280
New Hampshire		1,411	1,411	903,040
New Jersey		9,895	9,895	6,332,800
New Mexico	279	2,286	2,565	1,641,600
New York	1,852	30,233	32,085	20,534,400
North Carolina	941	45,371	46,312	29,639,680
North Dakota	2,302	17,388	19,690	12,601,600
Ohio	857	17,285	18,142	11,610,880
Oklahoma	3,008	17,477	20,485	13,110,400
Oregon	410	15,190	15,600	9,984,000
Pennsylvania	1,710	19,615	21,325	13,648,000
Puerto Rico	423	1,368	1,791	1,146,240
Rhode Island	196	1,085	1,281	819,840
South Carolina	389	25,550	25,939	16,600,960
South Dakota		8,286	8,286	5,303,040
Tennessee		11,198	11,198	7,166,720
Texas	2,773	59,327	62,100	39,744,000
Utah		2,419	2,419	1,548,160
Vermont		1,175	1,175	752,000
Virginia	1,006	12,231	13,237	8,471,680
Washington		10,752	10,752	6,881,280
West Virginia	718	22,779	23,497	15,038,080
Wisconsin		26,659	26,659	17,061,760
Wyoming	593	8,875	9,468	6,059,520
Total	27,771	859,462	887,233	567,829,120

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	1,570	8,510	10,080	6,451,200
Montana	2,495	47,039	49,534	31,701,760
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	4,065	628,354	632,419	404,748,160

PEAT INVESTIGATIONS

The activities of peat investigations during the fiscal year may be divided into two main lines of work.

The first is of a routine nature—answering inquiries and assisting by advice, bulletins, and circulars a variety of correspondents and consultants whose needs are being constantly presented to the Bureau by letter, telephone, personal visits, and by samples submitted for microscopic analysis and identification. The preparation of replies to these requests constitutes a steadily increasing part of the daily work as the American peat deposits and domestic peat products become more widely known and their value as natural resources more fully appreciated.

The second line of work deals with research and cooperation with other bureaus and State agencies in an effort to locate and develop the vast domestic deposits for use in agriculture and industry.

Cooperating with the soil survey, the field work included studies of profile characteristics of peat deposits in Bellefontaine County, Ohio, and the Dismal Swamp Belt in Virginia and North Carolina. The results of this study should prove valuable in pointing out regional contrasts and the need of conserving in its natural condition a type of marginal land such as the Dismal Swamps.

In cooperation with the Bureau of Biological Survey a study was made of profile sections from the Malheur Lake Reservation, Oreg. The study vindicates the position taken by the Bureau of Biological Survey that Malheur Lake is not navigable and that draining the remnant of the shallow lake waters would be detrimental and destroy a great nesting and feeding ground for many kinds of wild fowl.

Tests conducted at Arlington Experiment Farm, Va., in cooperation with the United States Golf Association Green Section, and in nurseries and parks with the Office of Public Buildings and Public Parks, are designed to determine the extent to which mineral soils may be improved by the addition of certain grades of peat and muck. The resulting information gives timeliness to a recently published circular intended to serve the needs of peat producers in 17 States, and to point out to consumers the uses and relative values of different kinds of domestic peat products.

The results of a systematic study of the major groups of peat land, their subdivisions, the distribution of each, and their important relationships has been prepared for publication in book form.

A paper has been prepared dealing with the utilization of peat land for agriculture, industry, and national objectives. It is hoped to ascertain in the near future the distribution of peat land actually used by agriculture and serviceable for industries, the distribution of the principal crops on peat soils, and the specific commercial products manufactured in this country from peat materials.

SOIL EROSION

This Bureau at its 10 regional erosion stations has established facts in regard to the extent and rate of soil erosion and has developed methods of erosion control which are of practical importance to a majority of farmers in the United States and of immediate value to the Government's present program of farm relief.

THE PROBLEM

The Bureau's survey of the extent of soil erosion and its present rate of increase shows that unrestrained soil erosion is rapidly building a domain of worn-out land in the United States—land stripped of its rich surface soil down to poor subsoil and land gullied beyond the possibility of practical reclamation. This wastage of the Nation's most indispensable resource is not merely continuing; it is speeding up with the removal of the absorptive soil down to the less absorptive, more erosive subsoil. The extent of these damages has been revealed by recent erosion surveys of the Bureau, which indicate that land formerly in cultivation to the amount of 35,000,000 acres has been essentially destroyed for crop production and that 225,000,000 acres of land now in crops has lost all or most of its topsoil or is rapidly approaching that condition.

Farmers operating on the denuded land are subsoil farmers. Subsoil farming generally is bankrupt farming on bankrupt land. It means the cultivation of land whose productivity has been reduced by one half to one tenth that of the same land in its virgin condition. While producing a large aggregate of crops,

these farmers have but the slimmest opportunity for making a satisfactory living, whether prices are up or down.

At least three fourths of the farm land of the United States used for clean-tilled crops is subject in varying degrees to the damages of soil erosion. The annual cost of impoverishment of farm lands and damages to roads, reservoirs, irrigation ditches, and valley lands from this cause is estimated at no less than $400,000,000. This does not take into consideration the accumulating damage that cannot be measured until the last inch of topsoil has been swept out of fields.

BASIC FACTS

Now for the first time in history a very considerable amount of quantitative information pertaining to the problem has been acquired—information we should have had 50 years ago.

A number of these important fundamental facts bearing on erosion control which have been obtained since the Bureau began work on this problem are: (1) Erosion varies enormously with soil character, slope, and rainfall. (2) Thick-growing vegetation is the most powerful agency of erosion control. (Erosion of the serious kind is the abnormally speeded-up washing of land following the removal of trees and prairie grasses, and the disruption of the natural porosity of the soil by cultivation and overgrazing. Normal erosion is generally beneficial, not harmful.) (3) Practical measures for erosion control call for extensive use of (*a*) trees and thick-growing vegetation, as grass, clovers, lespedeza, etc., on the steeper slopes and the more erosive soils; (*b*) practice of those rotations which keep the land under the soil-saving crops part of the time (the clean-tilled crops being grown less frequently as the land becomes steeper); (*c*) maintenance in the soil of a good supply of absorptive vegetable matter; (*d*) use of tillage operations that favor increased absorption of rain water, such as contour cultivation, scarification of the land, subsoiling (on some lands), keeping the soil in as coarse physical condition as practicable; and (*e*) use of engineering structures, such as terraces and soil-saving dams.

VEGETATIVE CONTROL MOST EFFECTIVE

In every measurement made throughout the Nation, vegetation has proved itself a most effective agency of erosion control. The powerful effect of vegetation in minimizing erosion and increasing absorption of rainfall is illustrated by comparison of the losses from corn and alfalfa grown on similar soil and slope at the Missouri erosion farm. As against a loss of 105 tons of soil per acre and 28 percent of the year's total precipitation from corn (1931), the corresponding losses from alfalfa were only two fifths of 1 ton of soil per acre and 2 percent of the rainfall.

With respect to the soil-saving types of vegetation, there is no serious limitation to their successful use. They are effectively applicable to all soils, to all slopes, and to all regions having enough rainfall to permit plant growth, even in parts of desert areas.

Next to continuous stands of grass, lespedeza, alfalfa, forests, and other stabilizing types of vegetation, good crop rotations have proved the most effective means of erosion control, at least for numerous extensive types of farm land. At the Bethany, Mo., erosion station the average annual loss of soil under a 3-year rotation of corn, wheat, and clover has been only 13.4 tons per acre, and only 11.6 percent of the rainfall has been lost as run-off on an 8-percent slope; as against an annual average loss of 79 tons of soil per acre and 23 percent of the rainfall under continuous corn.

Strip cropping is a simple measure for controlling erosion, whereby the thick-growing crops are sown in strips along the contours of slopes between the erosion-conducive, clean-tilled crops. Water flowing down slopes is intercepted by the strips and slowed down, causing the deposition of a large proportion of the soil carried by the running water. This Bureau has worked out practical methods for use of this measure, and it is being adopted by many farmers who have seen it in operation.

OTHER MEANS FOR REDUCING EROSION

Terracing as a measure for reducing erosion, developed about 100 years ago in the Southeast, has long been used on many farms in the old Cotton Belt. Some 40 years ago the method was improved by a North Carolina farmer,

Priestly Mangum, by building broader ridges. The Mangum terrace is the type most commonly recommended today.

A properly built terrace on slopes that are not too steep and on soils that are not too erosive is the most effective mechanical means of erosion control now extensively used. On steep slopes or where improperly constructed, terraces often do more harm than good. Owing to limitations with respect to slope and the necessity for careful adjustment of the gradient to soil type, successful use of terraces calls for very discriminating procedure. It can be made (and it has been made, chiefly in the Cotton Belt) an effective implement for reducing erosion.

On the other hand, if these limitations are ignored, terracing on some soils and many slopes will result in speeded-up erosion. If used with discrimination, built correctly, and supported where necessary by good crop rotations, by strip cropping and the seeding of grass along the embankments, as many farmers are now doing on certain sandy soils of Mississippi and Georgia, terracing can be extended over a large area with much benefit in the direction of soil conservation.

The Bureau has developed a water-conserving machine that causes about 2 inches of rainfall to sink into the ground where it falls. This machine digs 10,000 holes an acre, and each hole under ordinary conditions disposes of about 5 gallons of water. It is as cheap to run as any 2-horse corn cultivator and promises to be one of the most effective mechanical means for conserving water and controlling erosion on moderate slopes especially in regions similar to the Great Plains.

SOIL-FERTILITY INVESTIGATIONS

Fertile farm land is still the foundation of national wealth. Fertility must be maintained during the period of adjustment of agricultural production to consumption. To do otherwise is to increase production costs and dissipate invested capital.

In order to evaluate the fertility of prominent soil types on which our major crops are produced and to determine their plant-food requirements, the Bureau is conducting a program of soil-fertility work in cooperation with State agricultural experiment stations. Field headquarters are located in regions where the crops are grown commercially in order to maintain close contact with growers and shippers and to obtain results at first hand. Soil fertility and fertilizer problems relating to important crops, including cotton, potatoes, sugarcane, sugar beets, and truck, citrus, and nut crops, have been solved to an extent which has materially aided farmers to obtain a more economical return from the soil. It is imperative today, with new problems facing the farmers of the United States, that soil fertility be maintained and that the application of methods to this end harmonize with methods of adjusting supply to demand.

Research on fertilizer materials and complete fertilizer mixtures has resulted in knowledge which goes far beyond the stage of 20 years ago. More and more evidence is forthcoming, as the result of soil-fertility studies, that the old assumption that nitrogen, phosphoric acid, and potash are practically the sole dependence of crops for plant food is no longer valid. In the light of modern fertilizer practice, elements such as manganese, magnesium, zinc, copper, and the like are proving to be important additions to the roster of plant-food elements, as is shown by some of the statements which follow.

MAGNESIUM DEFICIENCY IN SOILS

Cooperative field studies are showing that available magnesium, a plant-food element concerned with the development of chlorophyll in plants, may be deficient in different potato soil types to an extent seriously affecting economic production of the crop. Symptoms of magnesium deficiency shown by the potato plant are: Yellowing of the lower leaves, the yellowing progressing from the margin toward the midrib; stunted growth; brittle leaves; and lowered yield. In advanced stages of the disturbance the leaves often develop dead tissue areas. An analysis of potato foliage from affected areas and from those producing normal plants showed that the normal foliage contained from two to three times as much magnesium as the foliage from affected plants.

Magnesium deficiency occurs most generally in soils relatively low in organic matter and highly acid in reaction. The inclusion of different magnesium compounds, such as magnesium sulphate, manure salts, or dolomitic limestone, in fertilizer mixtures has been found to raise the yield level to a point insuring

more economical production. In Virginia, for example, the addition of magnesium sulphate to a regular potato fertilizer increased the acre yield nearly 50 bushels. In Maine, equally good responses have been obtained.

Fertilizer manufacturers are adding magnesium compounds to their fertilizer mixtures to overcome magnesium deficiency, largely as a result of the cooperative work conducted under this project. The field results indicate that the addition of magnesium compounds to potato fertilizer in amounts equivalent to 20 to 25 pounds of magnesium oxide to the ton greatly improves the growth of potato plants and materially increases the yield.

ZINC DEFICIENCY IN SOILS A CAUSE OF PECAN ROSETTE

Through laboratory and field work it has been found that zinc deficiency in soils is an important factor causing rosette, a nutritional disease of pecans, which is responsible for great loss to growers. The addition of small quantities of zinc sulphate to the soil, or applied to the trees as a spray, cures and controls the disease. Commercial growers are using zinc, which is proving of considerable value.

Green-manuring crops for pecan orchards have proved of great value. Aside from making the soil more retentive of moisture in times of drought, a winter green-manure crop turned under in early spring, in decomposing, maintains a satisfactory level of nitrate nitrogen during the summer, thereby eliminating the need of using the higher priced slowly available nitrogenous fertilizers, such as tankage, fish scrap, dried blood, and cottonseed meal.

LESS COMMON ELEMENTS IN FERTILIZERS

Field comparisons of single-, double-, and treble-strength fertilizer mixtures on a number of important soil types in leading potato-producing sections continue to show the economic importance of concentrated fertilizers. Farmers and their organizations and fertilizer manufacturers are showing great interest in the work and are utilizing the results to advantage.

A comparative greenhouse study of continuous soil treatment with fertilizer mixtures containing impurities against pure-salt fertilizer mixtures has furnished indications that the continuous elimination of minor elements exerts a depressing influence on crop growth. This was particularly prominent on radish foliage which displayed distinct symptoms of magnesium deficiency. Field studies made on Caribou loam soil in Aroostook County, Maine with other less common elements of plant food, such as copper, manganese, nickel, and zinc are showing that a soil of such high fertility as Caribou loam does not respond as markedly to these elements as lighter, more readily leached soils in other regions. In fact, the heavier rates of application of these elements on this soil type depressed yields. Field studies on Caribou loam employing lighter rates of application are being conducted to determine whether stimulating effects will result from any of the less common elements.

FERTILIZER TREATMENTS IMPROVE QUALITY

In experimental work in Florida, manganese sulphate, when used in conjunction with fertilizers has proved effective in maintaining the vigor of citrus trees, producing larger yields, better quality, and better color of the fruit. Oranges and tangerines grown where small quantities of manganese have been applied periodically for several years exhibit a desirable, deeper yellow color after being submitted to packing-house coloring processes.

STRAWBERRY SOIL AND FERTILIZER STUDIES

Three years' results with strawberries on the sandy loam soils of the principal strawberry-growing sections of North Carolina, which are typical of strawberry soils of the middle Atlantic Coastal Plains, consistently show that fertilizers containing 6 percent of nitrogen, 8 percent of phosphoric acid, and 6 percent of potash give best results when viability of strawberry plants, yield of strawberries, and quality of fruit are considered. Applications of quickly available nitrogen carriers in early spring proved detrimental to the quality of strawberries as shown in shipping tests, and this practice should be discouraged for commercial plantings, although yields may be increased thereby.

The water-soluble salts in soils, as influenced by added fertilizers, and also the reaction of soils, as influenced by added physiologically acid and physiologically alkaline fertilizers, have proved to be important factors in the viability of strawberry plants. These are important factors in strawberry growing in the coastal plains of the Atlantic seaboard, for great loss is experienced by growers from poor viability of plants and many plantings die in the first and second years during unfavorable weather.

COTTON FERTILIZER STUDIES

Soil fertility and fertilizer investigations with cotton soils embrace field experimental work in Virginia, North Carolina, South Carolina, Georgia, and Texas, on the most extensive soil types devoted to cotton production. Data based on the experimental work of the Bureau point the way for more economical use of fertilizers and lower production cost. In the southeastern Cotton Belt best results have been obtained with fertilizers containing nitrogen approximately 80 percent from inorganic sources and 20 percent from organic sources.

Experiments in cooperation with the Georgia Experiment Station are in progress in Georgia in the principal soil types used for cotton production Some of the upper coastal-plain soils required principally nitrogen and some required both nitrogen and potash to control cotton rust. The Decatur soils of the western part of the State required principally phosphoric acid and a relatively small proportion of nitrogen and potash for best results. On cotton root-rot infested soils of the black-land belt of Texas, readily available nitrogen and phosphate stimulate the growth and fruiting of cotton and tend to check the development of cotton root rot.

Considerable attention is being given to placement of fertilizer in relation to the seed, use of large quantities of fertilizers and chemicals applied in advance of planting, and to deep tillage and subsoiling. Subsoiling in the late summer and fall, in conjunction with the use of quickly available nitrogen and phosphate, is a promising means of profitable growth of cotton in cotton root-rot infested lands. Proper placement of fertilizers is essential for their efficient use in the production of cotton and it has been demonstrated that the preferred placement is to each side of the row, below level of the seed.

FERTILIZER STUDIES WITH SUGAR BEETS

Fertilizer experiments with sugar beets indicate that, due in part to the variation in previous treatment or cropping, no two soils so far tested necessarily respond alike to the same fertilizers; but the response to fertilizers is greater on some types of soil than on others. With proper fertilization certain alkali fields in the irrigated sections of the West can now be made to produce successful crops of sugar beets that otherwise would be a failure. An experiment near Minatare, Nebr., produced on the unfertilized plots an average of less than 3 tons, whereas the fertilized plots produced an average of 12 to 14 tons of sugar beets per acre. In the past this type of land has been avoided for planting to sugar beets, owing to low yields, but with the use of fertilizer—principally phosphate—profitable returns are being obtained from its use, through reduction of cost per ton of beets.

Experiments conducted on other soil types in various localities have shown that fertilizers applied to certain soil types show profitable returns, whereas others produce insignificant increases. Three different fertilizer mixtures—phosphate alone, phosphate and potash, phosphate and nitrogen—produced 15.2, 16.8, and 16.8 tons of beets an acre, respectively. The average of the unfertilized plots was 4.93 tons of beets per acre. The same three fertilizer mixtures applied to Waukesha silt loam produced 10.2, 10.1, and 9.7 tons of beets an acre, respectively, whereas the average of the unfertilized plots of the same field was 9.6 tons of beets. It is the purpose of the soil-fertility studies on sugar beets to determine the soil conditions and soil types on which commercial fertilizer can be used with profit.

SUGARCANE SOIL AND FERTILIZER STUDIES

A complete analysis of four of the more important soil types of the sugarcane belt of Louisiana, including Yazoo very fine sandy loam, Sharkey silty clay, Lintonia silt loam, and Yahola very fine sandy loam, was completed during the

past year. The analysis shows that these soils are adequately supplied with most of the inorganic plant-food materials, but organic matter is rather low in all, except the Sharkey soils.

Two years' results of studies on the composition of sugarcane juice, as influenced by soil types and fertilizer treatment, were completed at the Houma laboratories. The data indicate that the application of nitrogen as fertilizer increases the nitrogen content of the juice to an appreciable degree and also decreases the ash content of the juice, compared with juice from unfertilized cane. These effects seem to be directly proportional to the amount of nitrogen applied as fertilizer. Applications of potash or phosphate fertilizer tend to increase the ash content of the juice over that of unfertilized cane. Application of phosphate apparently does not increase the phosphorus content of the juice.

The highest yield (35.91 tons per acre) of plant cane on Sharkey silty clay was obtained from ammonium sulphate alone. The yield from the unfertilized plots was only 23.28 tons. Phosphate alone produced less than 2 tons over the check, and potash alone approximately 2 tons less than the check. The all-nitrogen and the fertilizer mixtures containing 12 and 16 percent of nitrogen produced an average of approximately 2,000 pounds of sugar an acre more than the unfertilized checks.

FERTILIZER-PLACEMENT STUDIES ON POTATO SOILS

The importance of commercial fertilizer in the production of the potato crop necessitates careful usage. In normal times potato growers use 30 to 40 million dollars worth of commercial fertilizer. Faulty application may easily result in injury to the seed piece and cause poor germination, weak plants, and reduced yield. Field work comparing different methods of fertilizer application or placement on prominent soil types in Maine, New Jersey, Ohio, Michigan, and Virginia has afforded results indicating that placement of fertilizer in narrow bands, about 2 inches away from and either on a level with the seed piece or 1 to 2 inches below, is generally the preferred method of applying fertilizer to potatoes.

VEGETATIVE TESTS WITH AMMONIATED PEAT

The evaluation of ammoniated peat for fertilizer usage and the effectiveness of ammoniated sulphite lignin as a nitrogenous fertilizer material were investigated. More work will be required before final conclusions as to the value of these ammoniated products can be made.

CHEMISTRY OF SOIL ORGANIC MATTER

Work on humus compounds has been confined largely to a continuation of the investigation of uronic acid complexes or uroneides and sterols in soils. Examination of profile samples of virgin soils has given values for the ratio of uronic acid carbon to total carbon which are quite variable, but which are in keeping with those already obtained.

The presence of sterol compounds in soils has been recognized for several years, and is known to be due in part at least to the activity of soil-forming fungi. The biochemical interest in sterols centers around the fact that one sterol (ergosterol) is identical with or closely related to vitamin D. Examination of selected soil samples has shown that sterol compounds are found in all horizons, that several may be present in the same soil, and that the character of the sterols may be quite different in different horizons of the same soil.

CYANURIC ACID

Since the discovery by the Bureau of cyanuric acid in soils, interest in the function of this nitrogenous soil compound has continued, and soils selected for this purpose have been examined for the occurrence of this constituent. It has been shown that in some soils high in nitrogen content, such as peats, this nitrogenous constituent may be absent or present only in very small quantities, but in many soils of the East, containing little nitrogen (0.05 percent or less), cyanuric acid equivalent to half the nitrogen may be obtained.

DEVELOPMENT OF ANALYTICAL METHODS

A large amount of miscellaneous work of a service nature for farmers and other individuals has been done. In connection with the field problems of the Bureau, as well as in investigations conducted by other bureaus, considerable research in developing suitable methods has been necessary. This has been particularly true for iodine, arsenic, and copper determinations, for which satisfactory methods of analysis have been developed.

SOIL AND FERTILIZER INFORMATION SERVICE

In response to the thousands of requests for information the Bureau has sent out information on soil fertility, fertilizers, and manures, composting, home mixing, and soil amendments to inquirers from all sections of the country, and the publications on home mixing and composting have continued to be in active demand. A large number of samples of soils and fertilizers were examined and advice as to their use and value furnished. When necessary, farm and garden problems were studied locally in the field. Due to the economic depression, a great number of unemployed city families have gone to the farm for subsistence and the Bureau has given many of them advice and assistance, both by letter and by personal contacts.

SOIL MICROBIOLOGICAL INVESTIGATIONS

IMPROVED INOCULANTS

Farmers growing legumes have received increasing protection from the Bureau's annual inspection of hundreds of legume and soil inoculants. This inspection is so thorough that the bacteriological examination, greenhouse inoculation of seedlings, and field tests require a period nearly equaling the cropping period on the farm and the results of inspection have not been available in time to remove a worthless product during its first year on the market. Owing to this situation, farmers in certain sections of the South recently suffered losses from poor inoculants for Austrian winter peas. To prevent such losses the inspection is being broadened to include equipment, methods, and personnel of production in order that faulty procedures may be detected and eliminated before the product reaches the market.

The more recent experiments with inoculated legumes have shown that nodule production alone is not a guaranty of the most beneficial activity. After developing and collecting the most effective strains of inoculants, the Bureau is furnishing them to institutions and commercial organizations which supply the farmer.

FOREST SOIL MICROBIOLOGICAL POPULATION

The problems of reforestation and of maintenance of existing forests, which are now increasingly important, involve the necessity of close study of the biological activities which are significant in the return of the litter and waste of these areas to the soil as plant food. The balance between fungi, bacteria, protozoa, worms, insects, etc., presents a complicated series of problems which vary with the climate and soil type and the composition of the forest itself.

Studies and observations of these conditions show a predominance of fungous flora on the forest floor where the soil is very acid, whereas bacteria and earthworms are most in evidence where less acid conditions prevail. Critical and intensive studies are needed to correlate particular forest soil microbiological populations with particular production problems.

ARSENIC POISONING OF SOILS AND DWELLINGS

Arsenical substances totaling 70,000,000 pounds are reported to be used each year in the United States for insecticidal and fungicidal purposes. The larger part of this arsenic eventually reaches the soil as spray residue in one form or another. Arsenic injury to crops is now definitely proved in some of these areas. A survey of the so-called "arsenic fungi", which render compounds of arsenic volatile, has shown that our soils contain abundant molds which are capable of setting arsenic free from the various combinations carried to or formed in the soil. Arsenic has been assumed to be fixed in insoluble or very slightly soluble substances. Molds, however, are known to decompose these

substances so that the arsenic reappears in soluble and volatile forms; hence, it may be toxic, may leach out, or may escape to the air. Under such conditions soil should free itself eventually from arsenic of concentrations toxic to crops.

In the same survey organisms common in the rotting of wood have been found to be tolerant of the concentrations of arsenic used to prevent insect infestation, and hence are capable of producing arsenical odors from wood, fiber board, or other substances so treated. Instead of being few and rare, common and abundantly distributed organisms have been found to act as arsenic fungi. The use of arsenic in situations where such activity can take place and where the poisonous gases may be confined in living quarters, carries with it a menace of poisoning which is not to be ignored.

MICROBIOLOGICAL METHODS FOR TESTING SOIL DEFICIENCIES

Several microbiological methods of testing soil for fertilizer deficiencies have been proposed in recent years. Some of them have been used and good results have been claimed in limited areas, whereas disappointment only developed elsewhere. Two of these methods have been studied during the past year.

On account of the wide-spread interest in the test and the many requests for information, the Winogradsky Azotobacter plaque method for determining phosphorus deficiency of soils has been applied to various eastern soils. The results indicate that this method has no general or practical value when used on eastern soils, although in a few cases it may be modified so that it will indicate deficiencies to some extent.

Another method consists in testing soil by inoculating samples, treated in routine manner, with *Aspergillus niger*. Results obtained by the Bureau indicate that, if the variable factor can be restricted to only one element—that is, nitrogen, phosphorus, or potassium—soil samples can be so treated as to give increasing amounts of mycelium with increasing additions of the element in question up to a maximum beyond which no further increase occurs. From these results a production curve for each soil type can be established for each of the three elements, nitrogen, phosphorus, and potassium. New samples of the same soil can then be tested in routine fashion and the needs calculated from the points where they fall upon the curve.

These results indicate that the method is feasible where the resources of a well-equipped laboratory are available. Tests with three different soil types have shown that the method must be calibrated for any one or probably for a group of soil types similar in such factors as origin, reaction, fertility, and texture. Laboratory results have correlated closely with those from plots of one type of soil under rigorous control in the greenhouse.

CELLULOSE DECOMPOSITION

Studies of cellulose decomposition have taken two forms. (1) Certain bacteria known as Cytophaga, which are of world-wide distribution and which are reported to be active in cellulose decomposition, have been investigated. Laboratory studies, however, indicate that this activity is limited by temperatures and moisture requirements which greatly reduce their probable significance in the field. Surveys of their occurrence are in progress.

(2) Another type of cellulose destroyer has been found in the genus *Chaetomium*, a group of molds cosmopolitan in occurrence and familiar in the laboratory, but whose vegetative mycelia have not previously been studied. When tested on fiber materials in the laboratory, these organisms proved to be very active destroyers of cellulose and related substances. They were tolerant of quite varied temperatures and were active within a wide range of moisture conditions. These characteristics have resulted in the use of *Chaetomium* in testing the mildew resistance of cotton textiles used as canvas, tobacco shade cloth, bagging, and for other farm purposes.

SOIL CHEMISTRY AND PHYSICS

During the past year the major interest of the Division of Soil Chemistry and Physics has been centered upon the study of soil colloids. Previous study has shown that the colloid, which makes up the fine material in the soil, has a profound effect upon both the chemical and physical behavior of the soil. The particular soil properties depend upon both the nature and the quantity of colloid present. A thorough knowledge of the amount and quality of the col-

loids in a given soil should enable one not only to understand and predict the probable effect of additions of fertilizers and manures but also to trace the origin and subsequent development of the soils of the various soil groups. The colloids exert a dominant influence upon the capacity of the soil for retention and distribution of soil moisture. Much additional information has been gained by recent investigations along these lines.

It has been made increasingly evident that blanket specifications for agriculture are not practicable over other than limited areas, and that agricultural practice must be based upon soil classification. The colloid studies have shown that plant-food storage is a function of the colloid content. It has been found that the sandy soils, especially where rainfall is heavy, are not only poor in colloid but that present is likely to have low plant-food capacity and that in wet and hot climates the colloid is in general of a type which cannot store up plant food. It is therefore hopeless to attempt to build up such soils to a state of so-called permanent fertility. Even large increase of organic matter is impractical since the climatic conditions which produce colloids of low fertility also tend to destroy organic matter. Such soils must be handled differently from those containing other types of colloid. They must be supplied with plant-food material in small quantities at frequent intervals.

In the case of soils developed under cooler climate and higher rainfall the colloid, when depleted, may be built up in plant food, and added fertilizers are not necessarily exhausted in a single season. Organic colloids may be accumulated by the use of green and other manures. In the case of soils developed under low rainfall but yet sufficient for crops, the plant-food supplies are likely to be abundant and no need for fertilizers is felt except under special circumstances and for special purposes. It must not be inferred that such soils are immune to injury from improper handling. They may be greatly damaged by erosion, by wind or water, and in many cases this has occurred even to the complete removal of the true soil. Soils have been permanently impoverished by the leaching of their plant food by smelter fumes, or other acid additions, to an extent which renders their reclamation economically impossible. In irrigated areas improper soil management may produce injury by bringing up from lower levels soluble materials of such character and quantity that their removal at reasonable cost is impossible.

Recent and very difficult investigations of the organic matter of the soil have revealed a number of new facts about the organic colloid. Thus it was found that the organic colloid, like the inorganic, is amphoteric; that is, it may function at the same time as an acid and as a base. Furthermore, the organic matter of the soil varies in composition in different areas and the nitrogen content is highly variable in different areas and at different depths, particularly with respect to the carbon-nitrogen ratio.

Studies of the behavior of the soil with water have developed two new relations: The maximum volume of soil in equilibrium with water is variable in soils of divergent types, and distribution of water within the soil also is varied by the character as well as by the quantity of colloid.

There have been developed a number of new or improved methods of soil examination. Among these is one for the estimation of selenium in soils and another for vanadium. Still another is an improved process of determining the available bases in a soil and of the total base-holding capacity.

FERTILIZER INVESTIGATIONS UNIT

The activities in the field of fertilizer investigations are of practical importance to the farmer through the development of methods for the most economical production and use of the various fertilizer ingredients. This involves studies of the chemistry and economics of the manufacture of various compounds of nitrogen, phosphorus, and potash from the many sources, followed by the determination of the properties of these and how they may best be utilized in the final mixed product. Since the fertilizer industry is well established, many of the activities involve improvements and assist in meeting new conditions that constantly arise. A few figures will serve to emphasize the present importance of fertilizers to the farmer and the changes that are taking place.

The consumption of commercial fertilizers in the United States during 1932 amounted to 4,361,795 tons, as compared with 6,293,041 tons in 1931, and an average of 7,689,422 tons for the preceding 5 years. The fertilizers used in 1932 contained 215,730 tons of nitrogen, 431,250 tons of phosphoric acid (P_2O_5), and

164,945 tons of potash (K_2O). The average analysis formula of the fertilizers consumed during the year is therefore 5-10-4, showing an increased use of nitrogen relative to both phosphoric acid and potash.

Although the consumption of fertilizers is largely centered in the southern and eastern sections of the country, the expenditures for this item by the farmers of the country as a whole for crop production is only exceeded by that for labor, feed, and farm equipment. During the past 2 years the expenditures for fertilizers decreased less than for any of the other three items mentioned. This relatively smaller decrease in the use of fertilizers at a time of such low prices for farm products, poor markets, and depressed conditions in general indicates the basic importance and absolute necessity of fertilizers in maintaining the productivity of the soil, the quality of farm products, and lower costs of production.

Previous to the World War the United States possessed a plentiful supply of only one of the fertilizer ingredients, phosphoric acid. A large part of the nitrogen was imported and practically all of the potash. Since that time researches on our natural resources have resulted in making the country independent in regard to the nitrogen supply and potentially so in regard to potash.

The mixed fertilizers now on the market differ radically in composition from those in use before the war. The use of organic nitrogen, for example, has decreased from 57 percent of the total in 1913 to 19 percent at the present time. Ammonia nitrogen increased on the other hand during the same period from 24 percent to over 60 percent. Nitrate nitrogen has decreased from 20 percent to 11 percent, whereas the use of many synthetic materials, such as urea, has greatly increased. These and other changes in the sources of materials used have changed the chemical, physical, and physiological properties of fertilizer mixtures with the result that the investigation of these properties is more necessary than ever before. The success attained in further reducing the cost and increasing the efficiency of fertilizers depends in large measure on the solution of the problems that thus arise in connection with their changing composition.

NITROGEN

CATALYSTS IN NITROGEN FIXATION

The early activities of this project were largely responsible for the introduction of a suitable catalyst for use in the direct synthetic ammonia process under manufacturing conditions. The methods then used were of necessity empirical, due to limitations of time; the present work is more concerned with the nature of catalytic action.

One important conclusion to be drawn from this year's work is that the rate at which ammonia is formed on a catalyst depends on the rate at which nitrogen is adsorbed by or reacts with the surface atoms of the iron catalyst. Incidental to measurements of equilibrium over catalysts (data used in connection with the preparation and purification process in the synthesis of ammonia), the discovery was made that practically all previous similar measurements were in error. This discovery will permit a more accurate calculation of the maximum efficiency of the various processes involved.

PHYSICAL CONSTANTS OF GASES AND FERTILIZER SALTS

Since the synthesis of ammonia was the first high-pressure process utilized commercially on a large scale, none or only inadequate physical data were available. After measuring the compressibilities of hydrogen, nitrogen, and mixtures of hydrogen and nitrogen over a wide range of pressure and temperature, it was found necessary to include carbon monoxide, methane, and helium. The compressibility of helium is of particular interest in the study of the mechanism of synthetic ammonia catalysts and incidentally of others too. The knowledge of the solubility of the various gases in water is of importance in the gas-purification process which precedes the catalytic conversion to ammonia and byproducts.

The solubility of hydrogen in water has been determined over a temperature range from 0°–100° C. and up to 1,000 atmospheres, and similar measurements on nitrogen have been made from 25° to 100°. Mathematical treatment has given added importance to the above-mentioned compressibility data by developing precise methods for calculating quantities such as high-pressure specific heats, entropies, coefficients of expansion, and similar data not only for the

measured range, but also for higher temperatures and pressures. These calculations have been in great demand.

The photoelectric, spectroscopic, thermionic, and X-ray investigations have added greatly to our present understanding of the synthetic ammonia catalyst and of the mechanism of reactions involving nitrogen fixation. The application of X-rays to biology has presented many interesting aspects and is being actively prosecuted in cooperation with the Bureau of Plant Industry. X-ray analyses are also of great aid in analyzing complex fertilizer salts, and checking and following various processes in fertilizer technology.

UREA SYNTHESIS

Since the production of ammonia by synthetic processes has attained large proportions not only in this country but throughout the world, the use as fertilizer materials of conversion products from this source has increased rapidly. Some of these products, as well as the ammonium sulphate from by product sources, give a decided acid reaction in the soil. The desire for a conversion product less acid in its reaction has been met in part by the development of a process by the Bureau for the synthesis of urea. The process employs only the two products from the direct synthetic ammonia process, namely, ammonia and carbon dioxide. By heating a mixture of these two compounds in an autoclave at 150° C., a partial conversion to urea takes place. This process has been put into commercial operation at one plant in this country and the product is being employed in the preparation of mixed fertilizers. As a result of this synthetic production of urea, it is now obtainable for fertilizer purposes for about 4 cents a pound, whereas previously it was far too expensive a chemical to be considered for this purpose.

Laboratory investigations on the conversion products obtained in the synthesis of urea have furnished data, from the determination of a melting-point diagram, of solubilities and of vapor pressures, indicating the conditions necessary for the separation of urea from the unconverted ammonia, carbon dioxide, and other products. The relatively low vapor pressures of the mixtures with excess ammonia present and the low freezing point indicated the possibility of transporting the liquid for use in the preparation of mixed fertilizers. A solution of this character modified by the addition of water, thus further reducing the vapor pressure and freezing point, is being produced commercially for the direct ammoniation of superphosphates. In this way there is obtained a product with higher nitrogen content than is otherwise possible by direct ammoniation.

PEAT AS A NITROGEN CARRIER

A recent development in the utilization of ammonia for the production of a fertilizer material is the treatment of peat with ammonia to form a product with a nitrogen content in some cases as high as 20 percent, part of which is in the form of water-soluble, and part in the form of water-insoluble, nitrogen compounds. Experiments have been conducted by heating peat at temperatures from 30° to 300° C. with ammonia in a closed vessel, and the effect of moisture present, of pressures, and time of treatment have been studied. With the types of peat investigated the increase in temperature had a marked effect in increasing the nitrogen content of the product. A maximum nitrogen content was obtained with peat containing about 10 percent of moisture, but heating beyond 20 hours had little effect in adding more nitrogen.

The product obtained possesses general physical characteristics which indicate that it would be a valuable conditioner in mixed fertilizers, and as such would prevent caking of mixtures on storage and would cause maintenance of a condition suitable for easy distribution in the field. The portion of nitrogen insoluble in water should be retained in the soil for some time and should supplement the more readily soluble materials. This would tend to lessen the loss of nitrogen through drainage or leaching from certain soils where heavy applications of fertilizers are employed.

General considerations of the abundance and cheapness of both peat and ammonia give promise of its commercial production at a price comparable to that of inorganic nitrogen carriers. Since organic nitrogen generally sells at a premium and the price in some cases amounts to three times that paid for

nitrogen as ammonium sulphate, this development would result in a large annual saving and at the same time release for feeding purposes some of the high protein materials such as cottonseed meal and blood.

BIOCHEMICAL AND ORGANIC INVESTIGATIONS

Much progress has been made during the past year in ascertaining the properties of the nitrogen-fixing enzyme, present in *Azotobacter*, which has been termed "azotase". It has been shown that it is active only at a pH above about 6.0. The variations in the rate of fixation with nitrogen pressure have been shown to be independent of temperature, pH, and calcium, strontium, or oxalate concentration. The optimum oxidation-reduction potential of the medium must be somewhat lower for nitrogen fixation than for nitrate reduction or growth.

Other studies with *Azotobacter* have shown that, contrary to reports in the literature, these organisms can live and grow at a pH of less than 6.0, provided they have a supply of fixed nitrogen available. This explains why they may sometimes be found in acid soils.

The influence of carbon dioxide upon *Azotobacter* has been studied and quantitative methods developed which should be useful in studying various organisms of interest in soil, dairy, medical, and even industrial processes. A carbon dioxide requirement by *Azotobacter* which is clearly distinguishable from simple stimulation or utilization as a source of carbon has been shown to exist. The maximum effect on growth and nitrogen fixation is attained at a pressure of carbon dioxide approximating that in air.

Previous work with humates prepared from soil had shown that the stimulating effect of these on nitrogen-fixing bacteria, as well as on the growth of higher plants, is due to the mineral elements, principally iron, held in a readily available form. During the past year, new methods have been devised for the preparation of synthetic and natural humates containing various metals, the inorganic salts of which are ordinarily insoluble in culture media. The efficiency of the process of adding these elements to humate has been increased to nearly 100 percent as compared to 1 or 2 percent formerly obtained. The method of preparing synthetic humate from carbohydrates, such as glucose, starch, molasses, cellulose, or sawdust, has likewise been greatly improved. A number of samples have been prepared for various investigators at their request.

A study of the cause of decreased nodule formation on legumes supplied with combined nitrogen has shown beyond a reasonable degree of doubt that the effect is due to inadequate carbohydrate supply. In the presence of an abundance of nitrogen the photosynthetic carbohydrate is used almost entirely for top growth, thus greatly reducing the supply that reaches the roots. This lack of energy materials in the presence of nitrogenous compounds prevents the roots from growing rapidly. Under the same conditions nodules either fail to develop or grow to only a limited extent for the same reason. Experimentally, it was observed that the addition of sucrose to the roots of alfalfa seedlings, supplied with nitrates, tended to counteract the harmful effect of the nitrates on nodule formation. The nodule bacteria play a very secondary role in the phenomenon.

In the study of the nitrogenous compounds present in *Azotobacter*, nucleic acid, consisting of nitrogenous bases, sugar, phosphoric acid, and some iron, has been separated. It differs from the nucleic acids found in other kinds of living matter, principally in the fact that the nitrogen content of the nitrogenous bases is lower.

Considerable progress has been made in the investigations on the direct combination of nitrogen and organic compounds. Nitrogen in an activated form was found to combine with certain types of substances to yield a variety of highly nitrogenous bases.

POTASH

Particular attention has been devoted to that phase of the potash problem designed to provide cheap potash for the Middle West and Northwest from the abundant volcanic lavas of Wyoming. These deposits are fortunately situated closely contiguous to the world's greatest known phosphate deposits located in Wyoming, Utah, Idaho, and Montana, and contiguous to cheap coal and other

raw materials, thus affording very advantageous conditions for the low-cost production of both potash and phosphates. Methods under development provide means for their combination as potassium phosphate in a form which carries a low distribution charge because of its high plant-food concentration. The territory to be served is now lacking in adequate quantities of both of these essential plant foods. These investigations therefore involve not only the establishment of new, noncompetitive industries, with opportunities for employment, but relate to an essential aspect of profitable agriculture and land utilization.

Toward the close of the year, attention was concentrated on those aspects of the potash problem which have particular pertinence to the Muscle Shoals fertilizer program in order to provide information concerning the production of diversified, high-analysis potash salts, such as the sulphate, phosphate, and nitrate, from the purchasable domestic muriate, or from the naturally occurring potash raw materials in the vicinity of the Tennessee Valley, notably the potash shales.

The application of the various commercial acids, such as nitric, hydrochloric, sulphuric, and hydrofluoric, to the more abundant potash materials, such as Wyoming leucite, Utah alunite, Georgia shale, and New Jersey greensand, has been studied during the year, and substantial contributions have been made to the pertinent fundamental data and technology. Emphasis is placed on byproducts to share production costs and on high plant-food concentration of the fertilizers produced, to reduce delivery charges.

Smelting methods, particularly when applied to a mutually fluxing mixture of potash and phosphate rocks, offer the unusual advantage of yielding two fertilizer essentials in one operation and are especially applicable in Wyoming and Tennessee where the two raw materials can be economically assembled with accompanying low-cost fuel. The potentialities of this proposal have been greatly enhanced by tests which demonstrate that coke is not an essential fuel, but that local coals can be substituted. The low-temperature carbonization of these coals as a preliminary to their use as blast-furnace fuel greatly enhances the economy attained.

Recent advances in the technology of potash recovery as a byproduct of cement manufacture bring to the fore the importance of conserving the very considerable tonnage of potash now allowed to go to waste in this industry. This amounts to approximately 85,000 tons (K_2O) annually in normal years and is subject to a marked increase through slight modification in process. Such potash has the dual advantage of being a byproduct of present wide distribution, and of being of sufficiently small unit output to find ready local markets.

Attention has been given to the utilization of the high-grade potassium chloride produced as a domestic industrial chemical for use in various industries. Consideration has been given to its conversion into other fertilizer salts such as the sulphate, phosphate, and nitrate, in order to enlarge its market and provide a greater variety of potash fertilizers of domestic origin for domestic use.

PHOSPHATES

An extensive study of the occurrence, production, reserves, and chemical composition of phosphate rock in the United States was completed, and the results of this investigation have been reported in a technical bulletin. Aside from its scientific value, this work will serve as a fundamental basis for the more rational utilization of the domestic phosphate deposits.

A study of the action of phosphoric acid on phosphate rock was made. It was shown that the best conversion of the phosphate rock into available forms is obtained with acid containing approximately 50 to 65 percent H_3PO_4. This work is being continued to determine whether the reaction can be accelerated to such an extent that it will be possible to produce concentrated superphosphates and complete fertilizer mixtures in a continuous operation. The treatment of phosphate rock with phosphoric acid seems to offer the best means for the utilization of phosphoric acid produced by acid-decomposition and furnace processes.

Investigations on the removal of fluorine from phosphate rock showed that the fluorine can be completely eliminated by heating the rock at approximately 1,400° C. in an atmosphere of steam in the presence of small quantities of silica.

The important feature of the process is the fact that removal of the fluorine results in the conversion of the phosphate into citrate-soluble (available) forms. The process offers promise as a means for the economical production of phosphate fertilizers similar in properties to basic slag. Also, the product could probably be used as an economical source of phosphate for animal feeding. Nearly all of the fluorine in the phosphate rock can be recovered as a byproduct of the process.

A study is being made of the determination and distribution of water in superphosphates and other phosphate fertilizers. Information on this subject is of fundamental importance in the preparation of fertilizers of good mechanical condition and drilling qualities. A study is also being made of the preparation, properties, and chemical composition and constitution of the complex calcium phosphates. In cooperation with the Arkansas Agricultural Experiment Station, a study was made of the effect on plant growth of calcium and potassium metaphosphates and pyrophosphates and of certain iron and aluminum phosphates.

Improvements in blast-furnace methods of phosphate smelting during the year consisted of an increase in the temperature of the hot blast of about 500° F., which resulted in a saving of fuel and reduced the cost of phosphoric acid. Advances have also been made in the method of cooling the exit gases and of precipitating and collecting the elementary phosphorus therefrom. Special attention is being given to this project in connection with the possible utilization of the Tennessee phosphate-rock deposits by the Tennessee Valley Authority.

MIXED-FERTILIZER TECHNOLOGY

Reference was made in last year's report to the increasing use of the cheaper synthetic materials in mixed fertilizers. Many of these materials differ greatly in their chemical and physical properties from those which they are supplementing or replacing. It thus happens that the mixtures that are now placed on the market show a much wider range of physical properties and of plant-food content than those formerly used. Some of these mixtures have the disadvantages that (1) they undergo leaching or localized concentration in the soil, (2) they cake or become sticky under humid conditions, (3) they contain an unbalanced proportion of the essential plant-food elements, (4) they are acid forming in their influence on soil reactions, and (5) they tend to burn plants unless care is taken to prevent it.

These undesirable properties affect the efficiency of fertilizers by impairing their quality and by interfering with their uniform distribution in the field. The work on mixed fertilizers during the past year has been largely directed toward methods of improving the quality and mechanical properties of fertilizers, particularly those of higher analysis.

Inasmuch as many of the undesirable properties of fertilizers are associated with the soluble components of the mixture, a study has been made of methods for reducing the soluble-salt content of mixed fertilizers. It has been found that the addition of dolomite to a fertilizer mixture not only conditions the mixture and reduces its acid-forming tendency, but also decreases its solubility by forming the available, but slowly soluble substance, magnesium ammonium phosphate.

The quality as well as the physical properties of a fertilizer mixture may change on storage as a result of chemical reactions which take place between some of the newer materials now used in fertilizers and the other components of the mixture. It has been found, for example, that urea reacts with gypsum and monocalcium phosphate, the principal components of superphosphate, to set free water of crystallization and form the complex compounds, calcium sulphate-urea and urea phosphate. The monocalcium phosphate and urea also dissolve in the water set free to form a saturated solution of very low vapor pressure.

The resulting mixture is therefore very hygroscopic and of exceptionally poor drillability. The conditions are very different if the superphosphate is ammoniated before the addition of the urea, or if the urea is added in the form of urea-ammonia liquor. The monocalcium phosphate is then changed into dicalcium phosphate and monoammonium phosphate. Neither of these compounds increases the hygroscopicity of urea or reacts with it to any appreciable extent.

The mechanical properties of a superphosphate that has been treated with urea-ammonia liquor are therefore superior to one that has been mixed with the corresponding quantity of solid urea.

The ammonia-nitrogen content of the mixed fertilizers of this country has increased 155 percent since 1913, whereas that of nitrate nitrogen has decreased 40 percent. The former is acid forming in its influence on the soil reaction and the latter is basic. Most of the fertilizers in use at present are therefore more acid forming than formerly. With a view to the preparation of nonacid-forming fertilizers, a study was made of the reactions which take place when such basic materials as calcium carbonate, limestone, and dolomite are included in fertilizer mixtures of different types. The reactions were found to vary according to whether the phosphatic component of the mixture was superphosphate or ammonium phosphate. All three liming materials react with superphosphate to evolve carbon dioxide. The first two also react to reduce the availability of the superphosphate, but the action of the dolomite in this respect is slight.

Carbon dioxide is also set free when calcium carbonate or limestone is included in fertilizer mixtures containing monoammonium phosphate. As the reaction proceeds the mixture becomes alkaline in reaction and, if the carbonate present is sufficient to give a nonacid-forming mixture, loss of ammonia also takes place. There is little or no loss of ammonia, however, when the limestone or carbonate is replaced with dolomite.

Superphosphate and double superphosphate are examples of fertilizer materials that differ only in the content of one inert component. The first, having a plant-food content of 16–20 percent, is classed as an ordinary or low-analysis material, whereas the second, having a plant-food content of 45–48 percent, is a concentrated or high-analysis product. The use of double superphosphate thus affords a means of preparing a series of concentrated fertilizer mixtures that have the same plant-food elements in the same proportions and combinations as do the ordinary mixtures made from superphosphate. Fertilizer formulas have been developed for the preparation of concentrated mixtures of this type that are greatly superior in quality and drillability to many of the concentrated mixtures now on the market. A study has also been made of the reactions involved and the best technic to be followed in the ammoniation of double superphosphate.

Statistics have been compiled which show that the average mixed fertilizer sold in the United States in 1913 contained 2.2 percent N, 8.9 percent P_2O_5, and 3.9 percent K_2O, or a total of 15.0 percent of plant food. In 1931 the concentration of mixed fertilizers had increased, so that the average analysis formula was 3.3–9.5–5.1, making a total of 17.9 percent of plant food. If no filler had been used in making these mixtures they would have contained an average of 16.6 percent of plant food in 1913 and 21.1 percent in 1931. The data compiled also show the kinds of fertilizers used in each State over the last 50 years. In most States the concentration of the fertilizers consumed has increased as the materials available permitted but, in a few, more and more filler has been used so as to continue to provide the farmer with the same grade of goods he has been accustomed to buying.

The field tests on the effect of particle size on the efficiency of fertilizers are being continued. They indicate greater leaching of nitrogen and reversion of phosphate from the smaller-sized particles. On the other hand, under certain conditions of rainfall, the smaller-sized particles proved more efficient because of greater availability to the plant.

INFORMATION AND EDITORIAL SERVICE

In addition to the technical bulletins, soil surveys, circulars, and other official publications listed below, more than 150 articles on various phases of the Bureau's work have been published in outside journals and periodicals during the past fiscal year. These articles have, for the most part, supplied technical information of value to scientists and, in other cases, have interpreted to farmers and the general public important phases of the Bureau's work. In cooperation with the press service of the Department, the Bureau has furnished newspapers with timely information on practical problems of agriculture and utilization of farm products.

PUBLICATIONS OF THE BUREAU OF CHEMISTRY AND SOILS ISSUED DURING THE YEAR JULY 1, 1932, TO JUNE 30, 1933

TECHNICAL BULLETINS

No. 315. Soil Survey (Reconnaissance) of St. Croix Island, Virgin Islands.

No. 334. The Effect of Inorganic Acids on the Physical Properties of Waterleaf Rag Bond Paper.

No. 335. Fertilizers for Sweetpotatoes Based on Investigations in North Carolina.

No. 344. Petrographic Methods for Soil Laboratories.

CIRCULAR

No. 264. Mechanical Application of Fertilizers to Cotton in South Carolina, 1931. (Joint publication with Bureau of Agricultural Engineering and National Fertilizer Association.)

JOURNAL OF AGRICULTURAL RESEARCH ARTICLES

Differences in the Amino Acid Content of the Chief Protein (Glycinin) from Seeds of Several Varieties of Soybean.

Oil Content of Nine Varieties of Soybean and the Characteristics of the Extracted Oils.

A Method for Determining the Quantity of Mineral Oil Retained by Leaf Surfaces after Spraying. (With the assistance of the Bureau of Entomology.)

Base-Exchange Modifications of a Leonardtown Silt Loam Under Fertilizer and Crop Control.

Progressive Changes in the Cuticle of Apples During Growth and Storage. (Joint Publication with Bureau of Plant Industry.)

The Possible Effect of Hydrogen-ion Concentration on the Absorption of Potassium and Phosphorus by Wheat Plants under Field Conditions.

Chemical Composition of Native Alaskan Hays Harvested at Different Periods of Growth.

SOIL SURVEYS

Basin area, Wyo.
Branch County, Mich.
Calhoun County, Iowa.
Caroline County, Md.
Chippewa County, Mich.
Fort Sumner area. N.Mex.
Franklin County, Mass.
Gooding area, Idaho.
Greeley area, Colo.
Hampden and Hampshire Counties, Mass.
Hancock County, Miss.
Hart County, Ga.
Kent County, Md.
McIntosh County, Ga.
Milk River area, Mont.
Mille Lacs County, Minn.
Ottawa County, Ohio.
Polk County, Fla.
Rincon area, N.Mex.
Sac County, Iowa.
San Luis Obispo area, Calif.
Shoshone area, Wyo.
Suffolk and Nassau Counties, N.Y.

YEARBOOK ARTICLES

Fertilizer Composition and Placement Play Big Part in Cotton Growing.
Wheat Does Best in Well-Drained, Fertile Loams; Responds to Fertilizer.
Utilization of Fruits and Vegetables Aided by Chemical Discoveries.

U.S. GOVERNMENT PRINTING OFFICE: 1933

For sale by the Superintendent of Documents, Washington, D.C. - - - - - - Price 5 cents