REPORT OF THE CHIEF OF THE BUREAU OF CHEMISTRY AND SOILS

United States Department of Agriculture,
Bureau of Chemistry and Soils,
Washington, D. C., August 31, 1931.

Sir: I present herewith the report of the Bureau of Chemistry and Soils for the fiscal year ended June 30, 1931.

Respectfully,

Henry G. Knight,
Chief of Bureau.

Hon. Arthur M. Hyde,
Secretary of Agriculture.

INTRODUCTION

The Bureau of Chemistry and Soils is engaged in perfecting a nation-wide inventory of the soil-fertility resources of the United States to serve as the basis for a land classification whereby the Nation, the States, and individual farmers will be enabled to develop more efficient and profitable agriculture by the proper adaptation of crops to soils. With the object of assisting American farmers to more economical and profitable crop production, the bureau is constantly seeking new and cheaper sources of fertilizer and is continuously engaged in perfecting and cheapening methods of fertilizer manufacture and fertilizer application. The bureau is working steadily on the problem of profitable utilization of farm by-products and farm refuse, and the object of much of its research work is the widening and improvement of markets for farm by-products, surpluses, and refuse, by demonstrating their value as sources of raw material for industry and consequently as sources of increased income for the farmer.

The research and fact finding of the bureau, as they relate to the plant-food resources of the Nation, the economic utilization of soils, the development and effective use of our fertilizer resources, and the utilization of crop wastes and surpluses by manufacturing industries, are of the utmost importance to producers and consumers of farm crops and the manufacturers who convert these crops into commercial products.

Under the 131 major lines of inquiry recognized as projects, the Bureau of Chemistry and Soils is actively prosecuting investigations on 559 subprojects. The major lines of inquiry are continuous, or at least cover a period of years, whereas the subprojects, which represent the detailed activities of the bureau at any given period, have

time limits placed on them, and when completed they are succeeded by others usually along the same line of inquiry. Within this organization are the soil survey, which is mapping soil areas and laying the foundation for the study of the Nation's soil resources; soil-erosion studies, which aid in reducing losses from soil washing and in controlling flood water; soil-fertility studies, having for their purpose a better utilization of the soil; and finally the application of engineering and chemical technology to the study of fertilizer resources and the more economical and diversified utilization of the products of the soil.

The research work now in progress includes investigations in soil chemistry, soil physics, soil erosion, soil microbiology, soil fertility, nitrogen fixation, potash and phosphate resources, crop chemistry, fruit and vegetable chemistry, fermentation methods for the production of organic acids, the utilization of farm and industrial wastes, food microbiology, food deterioration and spoilage, dust explosions and farm fires, and improvements in the technic of producing sirups, sugars, vegetable oils, proteins, insecticides, fungicides, tanning materials, and a variety of other products.

For the purpose of administration three large units are recognized within the bureau—(1) chemical and technological research, (2) soil investigations, and (3) fertilizer and fixed-nitrogen investigations. Each of the three units is under a chief scientist, who not only directs the work of his unit but also serves as a member of an informal coordinating board within the bureau. By virtue of its broad field of activities and the coordinated effort within the bureau, the organization is given the opportunity to attack problems along very broad lines.

In the main, appropriations are made to the bureau for the purpose of attacking specific problems, the solution of which is of benefit to the business of agriculture and has, therefore, a utilitarian objective. Direct attack upon some of these problems, however, in the absence of essential fundamental knowledge, would be wasteful of funds and energy. Search for the fundamental knowledge is therefore often necessary, and it may lead the investigator into the realms of pure science, where a foundation is laid for the logical attack and final solution of the problem under consideration. Such a method of attack requires careful, thoughtful planning, the development of skilled technic, intelligent and discriminating analysis of results, and ability of a high order to make the necessary practical applications.

Although the bureau encourages the development of more research in the realm of pure science, it is always with the definite object of solving some practical problem. The results of such research may have a very wide application in fields far removed from agriculture or industries based on agriculture, so that in such cases the bureau contributes materially to the advance of science in general. Research for research's sake without regard to practical applications in the fields assigned to the bureau has no place in this organization.

To an increasing extent the work of the bureau is carried on in cooperation with the States, and its cooperation with industrial groups is also increasing. For a period of more than 30 years the soil survey has been conducted on a national scale in cooperation

with the several States which have usually shared expenses equally with the bureau. Soil-erosion work is now conducted in cooperation with seven States. Much of the soil-fertility work is in cooperation with the agricultural experiment stations of the several States, and wherever it seems practical and desirable other research is carried on cooperatively. The bureau makes very close contacts with industrial groups utilizing agricultural materials or manufacturing the finished products primarily for use on the farm.

It is estimated that in gross tonnage farm by-products constitute more than 60 per cent of the materials that are removed from the land. It is estimated that there is a total of 260,570,000 tons of agricultural materials for which the farmer now fails to get a return at all commensurate with the cost of soil fertility and labor expended in their production. These materials have in them part of the farmer's assets—that is, the fertility of his land, the advantage of his climate, and the fruits of his labor—but they bring an insignificant return. Because so much of the costs of agriculture is tied up in farm products it is evident that their profitable utilization will result in a greater return and is of greater economic importance to the farmer, under present conditions, than increased production, because these products are at hand and ready for use, whereas increased crop production requires further expenditure of soil fertility and of the time, energy, and money of the farmer. With these facts in view the bureau is constantly engaged in research, seeking a more economical utilization of farm products in the manufacture of articles of commerce and the production of more uniform final products, which will benefit the farmer and the ultimate consumer.

This widening of markets for farm products through the development of new channels for their industrial utilization is one of the most important functions of the bureau. Painstaking research and the application of the results to the problems of industry are the only way that this may be brought about. New industries have arisen during the last few years which use as their raw materials the products of agriculture. Numerous examples may be cited where waste has been converted into valuable commodities, but the greatest agricultural waste, the crop residues, consisting of stalks, straw, hulls, etc., are still awaiting wide industrial uses. If the history of the past is to be repeated such waste of to-day will become important raw material for the use of industry to-morrow, and the Bureau of Chemistry and Soils is working constantly toward that objective.

The detailed mapping and description of 28,530 square miles of soils in 30 States and in Porto Rico and the Virgin Islands during the past year, and reconnaissance surveys covering 14,014 square miles in Montana, Minnesota, Oklahoma, and Vermont, bring the entire area of soils which the bureau has mapped to date to a total of 1,449,792 square miles, or 927,866,880 acres. The extent of the work which the soil survey has accomplished can be judged from the fact that this total area is nearly three times as great as the combined (European) areas of France, Germany, and Great Britain. Impressive as these figures are, their size alone does not convey an idea of the great importance of this inventory of the resources of American farmers and its relation to the agriculture of the United States.

While the growing demands of farmers for the soil survey indicate its increasing value to farm producers in every State in the Union, it has very special importance at the present time as a guide in regional and national problems of agriculture because of the present readjustments in farm practice. Obviously the soil survey furnishes the information upon which the future inevitable land classification of this country must be based. In fact no land classification based on the natural productive capacity and the natural adaptability of soils to crops is possible without the facts supplied by the soil survey.

By the use of the soil survey and in cooperation with the soil fertility division of the Bureau of Chemistry and Soils, entire regions and States have been enabled to add many millions of dollars to their farm income in recent years. One such example is furnished by the growth of the tobacco industry in Georgia; another is afforded by the benefits derived from the use of phosphatic fertilizers on western sugar-beet soils as recommended by soil fertility specialists of the bureau. Within the past year a reconnaissance survey of the principal sugarcane areas of Louisiana was completed, and specialists from the bureau, in cooperation with State workers, by means of fertilizer experiments, demonstrated the kinds and amounts of fertilizer most effective on the dominant sugarcane soils. Such assistance will undoubtedly prove of timely benefit in helping the sugarcane planters to adopt more economical methods of production, thereby increasing their margin of profit at a period of peculiar economic depression. Similarly within the past fiscal year farmers of one of the most important strawberry-growing districts of the South have been enabled to increase their receipts by approximately $75 an acre by adopting new fertilizer practices recommended by the bureau. The bureau has also assisted in laying the foundation for the solution of certain agricultural problems in Porto Rico and the Virgin Islands where it has completed the field work for detailed surveys during the past year.

New developments in fertilizer manufacture during recent years are changing the entire fertilizer industry. At no time in its history has this industry depended to such an extent on research for its prosperity and its economy of operation as to-day. The research of the bureau in this field has been very effective in aiding economy of production which continues to reflect direct benefit to agriculture in the form of cheaper and more satisfactory sources of plant-food materials. Such researches, directed to the development of a more advanced national agricultural program, have become recognized as primary functions of the Federal Government.

During recent years the farmers of the United States have spent about $250,000,000 annually for commercial fertilizer. The amount has been somewhat less during the past year, but it offers ample proof of the necessity for commercial fertilizer in American farming and justifies the efforts that are being made to bring about improvements that will result in the farmers getting more for the money invested in this material. During the past year progress was made in improving methods of converting nitrogen, phosphoric acid, potash, and other materials into fertilizers and of making them of greater benefit to farmers by lowering the cost, by increasing the plant-food content, by improving the drillability, and by developing

more advanced methods of applying them to crops. Imports are still the source of 80 per cent of the potash used by American farmers, but American production is on the increase and is now supplying more than 100,000 tons of fertilizer salts. Investigations are being made by the fertilizer and fixed nitrogen investigations unit of the bureau to find commercially feasible methods for the production of suitable potash materials from the various potash minerals that are known to exist in great quantities in various parts of the United States. It is anticipated that the bureau's researches on the blast furnace will result in the more economical production of potash and phosphoric acid fertilizer in various regions of the United States.

The nitrogen-fixation industry, to which this bureau has given assistance through a comprehensive research program covering a period of years, is now a thoroughly established and functioning producer of cheap nitrogen. An important new development in which the bureau has assisted to make this cheap nitrogen still more useful has been demonstrated to affect also the supply of phosphates. Probably the most interesting and important of the recent developments in fertilizer manufacture is the direct use of synthetic ammonia in fertilizer mixtures containing superphosphates, and recent studies by the bureau indicate that it should be possible at least to double the quantity of free ammonia now used in fertilizer mixtures without decreasing appreciably the value of phosphoric acid in the mixture. Steps are accordingly being taken by the official organization of the State control chemists which will allow an increase of about 100 per cent in the use of free ammonia in fertilizer mixtures. This will provide for an increase in the use of synthetic ammonia in this country of at least 80,000 tons annually, having a wholesale value of about $8,000,000.

The bureau has recently demonstrated, in cooperation with one of the State experiment stations, that at least a 10 per cent saving in fertilizer can be realized by uniform distribution in the field. The bureau has also been instrumental in fostering a program for increased plant-food content in fertilizers, which means a proportional saving in freight, handling, and sacking costs. The average plant-food content has increased from about 15 per cent in 1920 to about 18 per cent in 1930, with every indication that the increase will continue. The bureau has cooperated in the past with as many as 25 State experiment stations at one time in testing out new fertilizer salts and fertilizer mixtures with a view to determining their suitability for plant growth on the respective soils.

During the past year the output of information from this bureau, both in the form of official publications printed by the department and articles by scientific workers published in technical and scientific journals, has greatly increased. Seventy-four new publications from this bureau, exclusive of Yearbook articles and the annual report of the chief of the bureau, were printed by the department. These included 52 soil-survey reports, 7 technical bulletins, 3 circulars, 3 leaflets, 1 farmers' bulletin, and 8 articles in the Journal of Agricultural Research. The number of soil-survey reports published in 1930–31 is the largest in any one year since the organization of the bureau and brings the reports much closer to date than has been the case for a number of years. The technical bulletins and

circulars present valuable findings of the bureau on soils and chemical and technological research. The 139 articles by scientific workers of the bureau, which have appeared in technical and scientific journals and other publications, have furnished other scientists and the public the latest information on the progress of research carried on by the three units of the bureau.

From its editorial office the bureau has continued to increase its output of information to the press and has sent out a large number of news releases of timely interest on the varied work of its units. It is constantly cooperating with the press service and the radio service of the department's office of information in furnishing information to the public and to the special or regional groups which it can serve best.

CHEMICAL AND TECHNOLOGICAL RESEARCH

The work of the unit of chemical and technological research includes primarily investigations which relate to the study of the carbohydrates, fats, proteins, vitamins, essential oils, organic acids, tannins, lignin, and other constituents of agricultural produce; to the improvement of methods for their determination, separation, and purification; and to the discovery of new processes for their industrial utilization.

The conversion of the surpluses and wastes of agriculture into products of commercial value is a general project of outstanding importance. It has been estimated that the straw, stalks, hulls, and other residues of several leading crops of the United States constitute an aggregate of more than 260,000,000 tons with a calculated content of approximately 115,000,000 tons of cellulose, 66,000,000 tons of pentosans, and 53,000,000 tons of lignin. The development of processes for the industrial utilization of these vast untapped reserves of potential wealth will add many millions to the value of our agricultural products.

In addition to the studies relating to the proximate organic constituents of crops, the unit of chemical and technological research conducts another important class of researches which have for their object the discovery and improvement of methods for protecting foods and other farm products against the destructive action of insects; molds, bacteria, and other microorganisms; enzymes; atmospheric influences, such as light, heat, humidity, and deleterious gases; explosions and fires; and miscellaneous chemical changes, such as oxidation and reduction. The loss to American agriculture from these various causes amounts each year to more than $1,000,000,000, and the reduction or prevention of this great drain on our agricultural prosperity is another leading purpose of the research work of this unit.

The varied researches of this unit during the present and preceding years have been conducted with constant attention to the correlation of the theoretical and practical phases of the work. This has involved, first of all, fundamental researches on the chemical nature of the numerous organic and inorganic constituents of our agricultural products and of their mutual relationships to one another, and secondly, thorough technological applications of the fundamental knowl-

edge thus acquired to the practical problems of nutrition, food preservation, and the manufacture of leather, paper, naval stores, dyestuffs, sugar, starch, fats and oils, insecticides, and other industrial products.

A close correlation between the work of the chemical and technological research unit and that of other governmental and State institutions is also maintained, and, as a result of this, many collaborative investigations have been conducted by the scientists of this unit with those of other bureaus. Such cooperation has resulted in a more comprehensive understanding of the highly complex factors which characterize so many phases of agricultural research and also in a strengthening of the esprit de corps of the department as a whole.

CARBOHYDRATE INVESTIGATIONS

CANE SIRUP

Important progress was made on the problem of producing sirup of higher quality and more uniform grade on individual farms. Cane sirup is an important cash crop on more than 270,000 farms in the South, about 2,000,000 tons of sugarcane with a value of $12,000,000 having been grown for sirup production in 1930. On account of the great variation in the quality of cane sirup made on different farms, producers are greatly handicapped in marketing their product for direct consumption, and an increasing proportion is going through the hands of commercial blenders. This has tended to reduce farm-made cane sirup to the status of a raw material in another industry, thus degrading the price.

Experiments were conducted on the possible use of various decolorizing carbons for treating sugarcane juice to improve the quality of the sirup. Juice from selected lots of sugarcane representing as definite cultural and varietal conditions as possible was used for sirup making, a careful record being kept of all data available relative to variety, fertilizer, soil, and conditions of growth. The results of the work to date indicate that activated decolorizing carbons may be used to advantage by small-scale sirup producers. It is believed that a comparatively simple procedure for use on the farm can be developed after further study has been made of the use of carbons in typical farm-sirup evaporators.

CANE SUGAR

Investigation of the composition of cane juice and the influence thereon of various cultural and varietal factors was continued, attention being given also to investigation of the basic principles of clarification of cane juice. In many cases ineffective clarification is the result of "refractory" juices which reflect the influence of adverse cultural conditions.

The juice of sugarcane grown on soil of certain types was found to be deficient in phosphate, and the addition of commercial phosphoric acid improved the clarification and resulted in the production of raw sugar of greatly improved quality. In general, the filterability of sirups and sugars obtained from the clarified juice of cane from various areas correlated well with the phosphate content of the juice,

but a number of exceptions indicate that in many cases the phosphate present is not in available form for reaction with lime and precipitation as calcium phosphate. A method was devised whereby it is possible to determine the proportion of the phosphorus compounds in the juice which are available for clarification reactions.

Studies were made of the deterioration of sugarcane in Louisiana as a result of freezes at harvesting time, and it was found that the juice of such cane contained unusually large quantities of d-mannitol and the gum dextran. Mannitol was present in such quantities as to crystallize from molasses.

The composition of various fractions of sugar juice was investigated with reference to clarification of the juice and its suitability for production of different grades of sugar, sirup, and molasses. The possibility of employing different methods and degrees of clarification to partly eliminate characteristic differences in juice composition was further investigated. This work is intended to furnish chemical and chemical-technological information, which will be useful for supplementing the data customarily employed for selection of the most suitable varieties of sugarcane for general cultivation in continental United States. The work has also yielded considerable chemical data on improved clarification methods for production of raw sugar of better quality and production of white sugar on the plantation without oversupplying the market with edible molasses as a by-product.

In studying the variable composition of sugarcane juice, considerable information was gained relative to the elimination of gums, iron, ash, phosphates, sulphates, colloidal matter, and coloring substances by different methods of juice clarification. A study was also made of the extent to which colloidal substances are eliminated from cane juice by different clarification procedures.

BEET SUGAR

Investigation of various nonsugar constituents of sugar-beet juice, which have an adverse effect on yield and quality of sugar, was continued, attention being given to possible correlations between the amounts of these nonsugar substances and various factors, such as kind of soil, fertilizer, weather conditions, and storage. Methods were improved or devised for the determination of the following nonsugar compounds in the presence of a considerable excess of sucrose in sugar-beet juice and products derived therefrom: Inorganic and organic phosphorus compounds, labile organic sulphur, sulphates, sulphites and aldehyde-sulphites, and various nitrogenous compounds.

A large number of samples of beet sugar and other products from sugar-beet juice representing beets grown under a great variety of cultural conditions were investigated. The examination of these samples has not yet been completed, but it is anticipated that the data will indicate some correlation between cultural factors such as kind of soil and fertilizer on the one hand, and content of various nonsugar compounds, such as phosphates, organic phosphorus compounds, and inorganic and organic nitrogen compounds, on the other hand. In general, the samples of beet sugar collected during the

season of 1930 were of better quality than those of the preceding season. This improvement is attributed, to a considerable degree, to improvements in juice clarification resulting from suggestions derived from this investigation.

MAPLE SIRUP

In cooperation with a commercial manufacturer, semipermanent liquid maple-sirup color standards were developed and have been placed on the market. Another manufacturer, to whom cooperation has been furnished, is developing a set of permanent glass color standards for maple sirup. These color standards will be of great value to maple-sirup producers by enabling them to produce maple sirup of higher grade and greater uniformity of quality and thereby to obtain an increased financial return.

Although the production of maple sugar and maple sirup is not an extensive industry, it is an important one in the producing sections, particularly as it provides a cash crop. Almost 4,000,000 gallons of maple sirup and 2,600,000 pounds of maple sugar were produced in the United States in 1930.

HONEY

During the past year attention was directed principally to investigation of the colloids of honey from the standpoint of their influence on quality. It was found that these colloidal substances possess a positive electric charge. A method based on this fact was devised whereby the colloids of honey may be flocculated by means of the colloidal clay bentonite possessing a negative electric charge. This method of clarification yields honeys of brilliantly clear appearance and apparently with diminished tendency to undergo granulation. The procedure has not yet been developed on a suitable commercial basis, and the investigation is being continued with that end in view.

A study was made of the quantity and composition of the colloidal constituents present in honey and their influence on such properties of honey as caramelization temperature, color, granulation, viscosity, and tendency to foam. These data have been obtained in the case of honeys from a great variety of floral sources. The colloidal material consists, for the most part, of nitrogenous compounds, highly emulsified wax particles, gums, and inorganic substances, such as calcium, iron, and silicon compounds.

UTILIZATION OF CULL AND SURPLUS SWEETPOTATOES

Investigation of the possibility of utilizing cull and surplus sweetpotatoes for production of starch was continued. One of the principal difficulties in obtaining starch of suitable quality from sweetpotatoes was solved in the course of the past year's work. By the use of a process in which sulphur dioxide is applied during the process of grinding the sweetpotatoes and a very dilute solution of sodium hydroxide is used at a later stage in the purification of the starch it has been found possible to produce starch of prime quality and fine white color, regardless of the variety of the potatoes and whether or not they have been stored. This increases the probability of develop-

ing a profitable means of utilization of cull sweetpotatoes on a commercially practical basis.

Investigation was also made of various possibilities of utilizing the residual pulp and the more concentrated portions of the waste water as by-products. A satisfactory basis for cattle feed may be obtained by concentrating the portions of waste water of higher density to a sirupy consistence, mixing with the residual pulp, and drying. This product is somewhat deficient in protein, but when mixed with a product such as peanut, soybean, or cottonseed meal a palatable cattle feed of good quality and satisfactory composition is obtained.

CARBOHYDRATES IN WILD DOMESTIC PLANTS

In carrying out a systematic investigation of the latent and potential plant resources of the country, about 60 native uncultivated plants were analyzed for carbohydrates and incidentally for other compounds. Inulin in considerable quantities was found in several plants which have been widely used for food by the Indians of the United States. Very little inulin is contained in the present diet in the United States, although inclusion of this substance in our diet has been repeatedly advocated by investigators in nutrition, particularly with respect to prevention and treatment of diabetes. Knowledge of the chemical and physiological properties of inulin is, however, still very meager. Supplies of pure inulin from various plant sources have been prepared for the purpose of studying its chemical and other properties.

FOOD RESEARCH INVESTIGATIONS

PRESERVATION OF FRUIT JUICES AND PULPS

The importance of the fruit-juice industry is increasing rapidly from year to year. More than 5,000 gallons a day of orange juice is being frozen in one plant in Florida, and carload shipments are being sent from California. Greater knowledge is needed of the limitations of preservation by freezing, especially of the causes of deterioration during prolonged storage.

During the past year the bureau has endeavored to reveal some of the causes of deterioration of frozen fruit juices. More than 900 containers, consisting of different types of bottles, jars, and cans filled with different fruit juices, fruit hearts, and slices, with and without sugar sirup, packed under atmospheric pressure and under 26 inches of vacuum, have been frozen at various temperatures and kept in cold storage. Results have shown that, when carefully prepared, orange juice and slices and grapefruit juice and hearts can be preserved in this way for a year with little loss of flavor, and pineapple juice and slices retain the natural flavor of the fruit to a high degree.

An important development, which bears directly on the distribution of frozen products, is that when juices and fruit products are defrosted after a long period of storage and placed in the ordinary ice box without opening the package, they will keep for more than 60 days with little loss of flavor. The samples packed under 26 inches of vacuum retained from 22 to 23 inches.

In addition to the investigation of freezing fruits and juices, the subject of preservation by other means has been studied. At the present time a series of tests using helium gas is under way, and others using oxygen, nitrogen, and carbon dioxide are planned.

GRAPEFRUIT BY-PRODUCTS

A continuation of the study of utilization of waste from grapefruit canneries was carried on during the year, and methods devised for use on oranges were modified to fit conditions found in grapefruit cannery waste. Studies on the production of naringin, the glucoside present in the fruit, were made, and methods are now available for producing naringin in considerable quantities at low cost. The question of turning the waste of grapefruit canneries and juice factories into acceptable cattle or chicken food has also been studied, and arrangements are being made for actual drying experiments.

SPOILAGE OF FROZEN VEGETABLES

Studies on the possibility of botulinus poisoning arising from the consumption of spoiled defrosted vegetables have been carried on both from the cultural standpoint and from the standpoint of commercial practice. Experiments with spores of *Clostridium botulinum* prepared in dry form, which most closely resembles their natural condition in the soil, suspended in solution simulating the effect found in vegetables and frozen by different methods, show that neither the rapid nor the slow freeze kills the spores or liberates toxin from them. This is very important, for, interpreted in commercial practice, it means that defrosted vegetables will have just as many living spores as were present originally when the material was prepared. These tests have been run on widely different strains of the *C. botulinum* with exactly duplicate results. Similar experiments, in which the spore suspensions have remained frozen for varying periods of time, have shown that long-freezing storage does not kill the spores or release toxin.

The possible significance of the spores in the spoilage of frozen vegetables is being studied also by the preparation of fresh peas, as follows: Inoculation with the botulinus spores, freezing, defrosting, and holding under various conditions. Samples were prepared containing a heavy inoculation, light inoculation, and no inoculation, and four different types of containers have been included. Several containers have been found to be toxic, and the toxin has been identified. Many containers, both inoculated and not inoculated, have yielded botulinus organisms, and botulinus toxin has been found and identified in uninoculated containers.

PRESERVATION OF FOOD PRODUCTS

Further studies on the production of sauerkraut from surplus turnips have been made with special reference, (1) to the most suitable methods of cutting and packing in order to obtain the best fermentation, and (2) to the use of different turnip varieties for this fermentation. Repeated experiments have shown that either grind-

ing or shredding the turnips promotes lactic fermentation, whereas slicing markedly interferes with it. The results of the variety tests are not yet available.

RANCIDITY IN FOOD PRODUCTS

Experiments on the delay or prevention of rancidity in rice mill and other products seem to show that light plays a most important rôle in influencing the keeping quality of foods. A new field of research is thus indicated.

BAKING INVESTIGATIONS

A new series of investigations in cake making was conducted, using wheat germ as a part substitute for wheat flour. It was found that cake of very good appearance and of excellent flavor resulted from the use of 25 to 30 per cent of wheat germ. Wheat germ is rich in vitamins A, B, G, and E, and can be successfully used in all baked products and especially in the making of cake where egg whites instead of the whole egg or egg yolk are used.

In collaboration with the Bureau of Fisheries, very successful experiments have been carried on in the use of 10 to 15 per cent of fish flour, a specially prepared and biologically pure product, in making cookies flavored so highly with ginger or cinnamon that the taste of the fish is practically hidden. This fish flour contains 20 to 30 per cent of easily assimilated calcium phosphate.

Experiments in baking by using so-called water-retaining and stale-retarding agents indicate that these substances have but little effect in retarding staling. Experiments in keeping bread at comparatively high and at very low temperatures for three or four days seem to indicate some delay in staling.

PRESERVATION OF EGGS

Studies on the preservation of shell eggs by oiling have led to the development of a new method of treating eggs under a vacuum. Fresh graded eggs treated by various methods were placed in commercial cold storage for 11 months and then regraded. The vacuum-oiled eggs retained their original high quality far better than did any of the other lots.

Studies have also been made of the amount of oil taken up by the eggs under different methods of treatment. Although in the vacuum method the oil is carried through the shell pores, microscopic examinations show that the oil does not penetrate the egg membrane but remains between the membrane and the shell.

PLANT PIGMENTS

Investigations of naturally occurring vegetable coloring matters were directed particularly to a study of the pigments of tomatoes and apples.

Tomatoes constitute an important truck crop both in the fresh state and in canned form, the estimated acreage in 1929 being about 450,000 acres which yielded a total of 1,900,000 tons of tomatoes. In recent years there has been a very great increase in imports of tomato

products, the value of such imports in 1929 being more than $10,000,000, and this increase is largely attributable to the superior color of the imported products. Studies on tomato pigments have been started with the view of determining the factors influencing color formation in fresh tomatoes and deterioration of color in canned and preserved products. During the past year raw materials, consisting of various foreign and domestic tomato pastes, were collected, and considerable quantities of red coloring matter were isolated, which will be further purified and thoroughly investigated chemically and physically. Crystalline carotin has also been obtained from tomatoes.

One of the important problems confronting apple growers is the production of highly colored fruit. In 1930 the production of apples in the United States amounted to 163,543,000 bushels, having a total estimated farm price value of $152,546,000. A pleasing color appearance not only has an appreciable effect on the market value but also is responsible for an enhanced value from a nutritive standpoint. Preliminary investigations of the chemical nature of the coloring matters and of the factors influencing their formation have shown that flavonol or yellow pigments are the mother substances of red or anthocyanin pigments. A flavonol has been isolated and identified from red apples, and the presence of a similar substance has been shown in yellow apples. Further work will be carried out on these types of pigments and the investigations extended to the corresponding red coloring matters.

VEGETABLE SURFACE COVERING

Knowledge of the composition, quantities, and functions of the waxy coating and cutin of fruits and vegetables is very meager, in spite of the commercial and agricultural importance of the botanical entity known as plant cuticle. This covering plays a most important rôle in the application and subsequent removal of sprays, resistance to injury by fungi, bacteria, and insects, and in the keeping qualities of fruits on the market and in storage. During the past year quantitative determinations were made of the various constituents of the waxy coating of 17 varieties of apples from the States of Washington and New York. Determinations were also made of the permeability of the skins as measured by evaporation losses. A satisfactory method for determining the quantity of cutin in apples was developed, and investigation of the chemical composition of cutin in tomatoes and apples has been started.

ACIDS OF GREEN VEGETABLES

An investigation was made of the organic acids of broccoli, cabbage, lettuce, and spinach. As no analyses of broccoli were found in the literature, the examination of this vegetable was made rather complete and showed that the leaves and buds have materially the same composition and nutritive value. Both buds and leaves contain proteins somewhat in excess of that reported in spinach. The predominating organic acid in broccoli is citric acid. It also contains *l*-malic acid and small amounts of oxalic and succinic acids.

The organic acids of lettuce were found to be *l*-malic acid, citric acid, and oxalic acid. The percentage of oxalic acid was found to be 0.011.

Fresh spinach was found to contain 0.31 per cent of oxalic acid. Citric acid and a small amount of *l*-malic acid were isolated.

The study of the acids of wheat seedlings was extended to include barley, corn, oats, and rye plants. All these plants were found to contain aconitic, malic, citric, and oxalic acids. The occurrence of aconitic acid in all plants of the Gramineae, or grass family, so far examined, including sugarcane and sorghum, is noteworthy. A paper embodying the results of this work has been submitted for publication in the Journal of the American Chemical Society.

INDUSTRIAL FARM PRODUCTS DIVISION

HIDES AND SKINS

Hides and skins are the base goods of all leather. Every pound of hide substance lost through spoilage and waste is a complete loss of its equivalent yield of leather. It is estimated that our annual loss from poor handling of hides and skins is at least $20,000,000. The bureau's work on hides and skins bears directly and indirectly on reducing this waste.

Field work of the bureau among butchers and dealers on correcting poor practices in skinning and curing is gaining in favor among the trade, and in spite of the many difficulties, economic and otherwise, progress is being made. During the year more than 700 personal calls on butchers, dealers, and tanners have been made by the bureau's hide specialists. On repeat calls it has been found that corrections have often been adopted and have resulted not only in better hides and skins but also in greater financial returns to the producers.

Study of the reddening of salt-cured hides has been intensively pursued during the year and some progress has been made. This reddening is recognized by the trade as an abnormal condition and is consequently looked on by the buyer with suspicion and some concern as to the effect that might develop therefrom later in the tanning. More than 200 samples of salt have been examined for their ability to develop red growth on laboratory media. Of 36 samples of solar salt, 34 developed a red growth, as did also 25 out of 39 samples of open-pan evaporated salts. Of the 62 samples of mined salt and the 17 samples of vacuum-pan evaporated salts examined none showed red growth.

TANNING MATERIALS

This country imports about one-third of the $25,000,000 worth of tanning materials used each year. Furthermore, more than half of the domestic supply of tannin is now being obtained from only one source, the wood of the American chestnut tree, which, it is realized, is doomed by the chestnut blight. In recognition of this the work on tanning materials is mainly directed toward the discovery and development of possible new sources of tannin and the conservation of established sources through better methods of produc-

ing and handling and more economic and efficient processes of tanning.

Because of the important international trade in tanning materials, the bureau is actively cooperating with the American Leather Chemists' Association in the recently revived movement to set up international methods of tanning analysis. In collaboration with a committee of that association an elaborate comparative study has been made of several procedures to determine the insolubles in tanning extracts, a determination that is now one of the moot questions in the proposed international methods.

In connection with the possible exploitation and development of Florida mangrove bark, a recently submitted sample of this material was examined. Analysis showed it to contain, on the moisture-free basis, 26 per cent tannin and 13.5 per cent nontannins. Although this would place the bark among those rich in tannin, the content is about 10 per cent less than that of the imported mangrove bark at present competing.

The utilization of pine bark in the South as a source of tannin in connection with the simultaneous use of the wood as a source of fiber is receiving attention. Analyses of a few preliminary samples have indicated, in some cases, an encouraging tannin content.

Active cooperation has been continued with the Bureau of Plant Industry, in examining for tannin many foreign barks and woods which that bureau is collecting in connection with its work on discovering and introducing into this country substitutes or replacements for the American chestnut tree. During the year about 100 analyses were made of additional specimens from Japan, Taiwan (Formosa), and China. Those which from their tannin content deserve especial attention are the bark of *Quercus dentata*, *Q. sessilifolia*, *Castanopsis subacuminate*, *Myrica adenaphora kusanoi*, and both the bark and wood of *Lithocarpus konishii*.

The results of an examination of young Chinese chestnut trees grown at Bell, Md., are being assembled for publication. Probably the most interesting point brought out by the data is that the tannin content of the bark and wood of these trees is practically the same as that of near-by second-growth American chestnut trees of the same age. Data are also given on the vertical distribution of the tannin and nontannins from the roots to branch tips, showing a gradual decrease of tannin toward the top of the tree.

The study of ferrochrome as a tanning material has been practically completed on a laboratory scale, as a result of which work public-service Patent No. 1,757,040 on ferrochrome tanning preparation and process has been issued.

LEATHER

Every year in this country shoes and other leather goods having a retail value of approximately $2,000,000,000 are made. Values of such magnitude involving daily necessities of such widespread use provide a fertile field for scientific studies and for the application of technical knowledge directed toward the production of finished articles of greater serviceability and better workmanship; more efficient and less costly methods of production; judicious selection of

goods for the service intended; and their protective treatment and proper use for the longest service.

Assistance has been given several manufacturers of shoes and leather goods in indicating and eliminating the causes of defective products.

The results of an elaborate study of the density of leather have been published in Industrial and Engineering Chemistry.

Cooperation has been continued with the Government Printing Office in helping that office to select bookbinding leathers for public binding work. In this connection 47 leathers have been tested and analyzed during the year.

The last part of an 8-year natural aging experiment on the deterioration of leather is being completed. This experiment involves a comparison physically and chemically of the leathers before and after aging and will provide much original data that should be of intense interest and value regarding the deterioration of leather, and especially in establishing beyond question the extent of the absorption of acid from naturally polluted air.

FARM FABRICS

During the past year service tests were continued on hay caps made of lightweight fabrics and subjected to various waterproofing treatments. As a result, definite recommendations regarding materials and treatments suitable for this purpose can now be made.

Experiments were conducted to show the waterproofing value of new products, including chlorine derivatives of diphenyl and two water-insoluble and water-repellent substances extracted from apple peels by the food research division. One of the latter, ursolic acid, gave canvas very high water resistance, but was found to be subject to mildew under the conditions of the test. New commercial antiseptics were tested for their mildew-proofing value. Precipitation of salicylanilide and aluminum stearate together on the fabric offers considerable promise as a water-repellent and mildew-resistant treatment where it is desired to leave the appearance of the fabric unchanged.

From the studies conducted to determine the cause of the flame-proofing action of tin oxide it was found that certain other metallic oxides, including those of copper and manganese, are as effective as tin oxide and probably more so. Data bearing on the theory of the flame-proofing action of certain metallic oxides were obtained and are being prepared for publication.

Farmers' Bulletin 1157, entitled "Waterproofing and Mildew-proofing of Cotton Duck," was published in revised form. This bulletin tells how to select canvas for various uses on the farm and elsewhere, and gives formulas for waterproofing canvas with easily procurable materials.

PAPER

Work on paper testing and paper specifications, in collaboration with Government agencies and scientific societies, and work on the deterioration of paper has long engaged the attention of this bureau and was actively continued during the past year.

The United States Government uses paper in very large quantities, and the preparation of specifications for the various kinds of paper

needed, which was initiated by the Bureau of Chemistry more than 20 years ago and in which the Department of Agriculture has taken a leading part ever since, has resulted in estimated annual savings ranging from $50,000 to $500,000. Publishers of periodicals, by adopting similar specifications, have effected savings estimated at more than $500,000 annually.

The paper technical committee of the Federal Specifications Board and the paper specifications committee of the Congressional Joint Committee on Printing have revised old and prepared new specifications for the purchase of paper by the General Supply Committee and the Government Printing Office. The American Chemical Society has also been given advice regarding the suitability of papers for their regular publications and also for the proposed library editions of their journals.

During the past year, in the studies of the causes of deterioration of paper, attention has been given to the improvement of methods of analysis, the development of an accelerated-aging test, the examination of old papers, and determining the effects of small quantities of aluminum sulphate, sulphuric acid, and hydrochloric acid on papers.

Previous work in this bureau had shown that there is a progressive loss of folding endurance with continued heating of papers. Continued work along this line during the past year showed that heating accelerates the injurious action of certain constituents of the paper, thus developing in a short time what might be the action of these constituents over a long period of time under normal conditions of room temperature. Such a test offers the best and simplest means now known for predetermining the intrinsic merits of papers from the standpoint of durability.

About 20 samples of old papers of different kinds were subjected to chemical and physical tests in an effort to determine the causes for different degrees of deterioration. The results showed very clearly that those papers having relatively high acidity also showed great deterioration.

The effects of aluminum sulphate, sulphuric acid, and hydrochloric acid were studied also by applying the heating test to samples of all-rag waterleaf paper of high strength, which had been treated with solution of these chemicals in various concentrations. The results so far obtained indicate that small quantities of the chemicals cause great deterioration of paper as measured by this test. The untreated sample showed no decrease in strength after heating for 72 hours at 100° C.

UTILIZATION OF CORNSTALKS

The purpose of the studies on the utilization of cornstalks is to determine the practicability of various suggested uses and to promote such uses as will aid in the control of the European corn borer. Particular attention was given to the utilization of cornstalks and other crop by-products by destructive distillation. Experimental runs were made on cornstalks, cottonseed hulls, and rice hulls in a wood distillation plant and also in a plant that had been used for the destructive distillation of straw but had been tentatively remodeled for use with other farm wastes. Valuable information was

acquired on the changes in design and equipment necessary for satisfactory results with cornstalks. The products obtained were also studied in the laboratory as an index to plant-operation factors and from the standpoint of possible commercial applications.

Samples of cornstalk flour and bagasse flour were prepared and furnished to a manufacturer for experimental use in plastics.

NAVAL STORES

Turpentine and rosin, the principal products of the naval-stores industry, are essential raw materials of many manufactures. They are produced at more than 1,400 plants scattered over the Southern States from North Carolina to Texas, and the annual production has a value at the stills of about $60,000,000. The bureau's work on naval stores includes development and demonstration of improved practices, processes, and equipment so as to prevent waste, reduce cost of production, and yield products of better quality, and research on the composition and properties of naval stores to promote wider and more profitable means of utilization.

FIELD SERVICE

During the year the naval-stores technologist visited 34 plants, where he gave instructions and demonstrations to proprietors and a large number of visitors on improved methods of turpentine distillation, still setting, barrel gluing, rosin straining, and handling of products. The erection of 12 turpentine stills was supervised by the field representative. It was not possible to comply with all the requests for personal supervision in the erection of stills, and 32 persons were given advice through correspondence on still erection.

GUM CLEANING

Improvements were made in the experimental gum-cleaning equipment at Arlington Experiment Farm which allowed the filtration of turpentine gum on a practical scale. Two hundred and fifty gallons of crude gum were passed through a special type of filter, having but 1¼ square feet of filtration surface, in about four hours. Rosin made in the laboratory from the filtered gum was perfectly clean and brilliant. However, in the experimental work at Tallahassee, Fla., the rosin made contained small reddish-brown particles, even though the gum was filtered perfectly clean. It was found that these were caused by dissolved or dispersed matter in the water which is always present as an emulsion in crude gum. This dissolved matter separates in solid form and contaminates the rosin when the turpentine and water are distilled off. Various means of demulsification and separation of the water were studied, and a process was developed in the laboratory that gives promise of producing a filtered gum entirely water free, which, on distillation, will yield a brilliant dirt-free rosin. Special equipment will be necessary for the practical application of this process, and on the design of this equipment will depend the success of the process.

In connection with the gum-cleaning experiments at Tallahassee, considerable experimental work was done on the operation of a commercial still. In previous work with the steam still it had been ob-

served that the charge may be scorched by allowing the coils to become exposed. This was verified, but it was found that, with the use of superheated steam in coils kept under regulated temperature and pressure, the introduction of superheated steam mixed with moist steam into the charge as required, and having the charge cover the coils at all times, rosin could be obtained entirely free from scorching and burning. It was found possible to control the temperature of the charge within very narrow limits and to turn out the rosin at any temperature desired.

COMPOSITION OF OLEORESIN

In connection with the study of the composition of oleoresin, a substantial quantity of white crystalline mixed resin acids was prepared from a sample of scrape, and a quantity of mixed-resin acids was prepared from gum. A partial separation was made of pimaric and sapinic acids. Numerous experiments were made with fractional crystallization of these acids in an attempt to isolate the pure component acids of the two classes. So far only preparations with an increased concentration of one or another of the various acids in the respective classes have been made.

COMPOSITION OF TURPENTINE

Considerable attention was given to the design, construction, and installation of laboratory-fractionating apparatus for use in separating the constituents of turpentine. Six fractionating columns of various types were installed. Five of these columns and accessory apparatus, including pressure regulators and dephlegmators, particularly for vacuum fractionation, were made in the bureau. Numerous experiments were performed with turpentine and other liquids to determine the relative merits of the various fractionating columns. Fractionations were made of a number of turpentines from authentic and commercial sources, and their composition in terms of alpha and beta pinene and tailings was determined. Two papers bearing on this work were presented before the spring meeting of the American Chemical Society.

Further work was done on a method for determining small quantities of sulphur and chlorine in turpentines, particularly sulphate wood turpentine, and a paper describing the method and giving results from its use was prepared for publication. In cooperation with the carbohydrate division a polariscope equipped with a monochrometer was set up, and optical rotation measurements on turpentines and other liquids can now be made at different wave lengths.

In cooperation with naval-stores producers and users, examinations and tests were made on 11 samples of turpentine to verify the accuracy of the hydrometers being used.

DETERIORATION OF TURPENTINE

The effect of continued storage of turpentine was studied in collaboration with a manufacturer of shoe polishes. The turpentine examined had been kept for about two and one-half years in large storage tanks under conditions suggested by this bureau, which included almost complete exclusion of air and frequent withdrawal of

separated water. At the end of this time the bulk of the turpentine was used in regular shoe-polish production and was considered satisfactory. Some of the turpentine from the large storage tanks was transferred to clean steel drums which had been shellacked on the inside. The storage of the water-free turpentine in these drums was continued for another year under conditions duplicating as nearly as possible those under which the turpentine was previously stored. Periodic laboratory tests indicated little change during the storage in tanks, but appreciable change on additional aging for one year in drums, which was probably caused by contact with air during the transfer. The turpentine was still considered satisfactory for use in shoe polish after the storage in drums.

Laboratory work was carried on to determine the effect on turpentine of shipment and storage in galvanized steel drums and in steel drums coated on the inside with various kinds of varnish and lacquer. Turpentine has a slow corrosive effect on galvanized sheet steel and becomes contaminated with zinc and iron. The only coating which has thus far been found to prevent satisfactorily an interreaction between iron and turpentine containing water is a special lacquer baked on the surface of the metal.

GLUING TURPENTINE BARRELS

Previous work having failed to develop an effective and economical substitute for glue, work during the past year consisted largely in encouraging the more general adoption of the improved gluing practice whereby freshly glued barrels are exposed to the action of formaldehyde vapors for 36 to 48 hours. The use of formaldehyde vapor was found to be more practical than rinsing out the glued barrels with 10 per cent formaldehyde solution, which is likely to leave water in the barrels.

TURPENTINE IN FRESH GUM

In order to acquire information on variations during the chipping season in the quantity and properties of turpentine in fresh gum from different varieties of pine and from trees of different ages and types of growth, experiments were conducted in cooperation with the Forest Service on 12 trees in the vicinity of Starke, Fla. These included six slash pines and six longleaf pines, representatives of the two varieties being paired as closely as possible with regard to size, condition, and exposure. Collections of gum were made at 2-week intervals and the samples of gum were analyzed and the typical constants determined immediately after each collection.

OIL, FAT, AND WAX INVESTIGATIONS

PALM OIL

In view of the rapid expansion of the palm-oil industry, a more intimate knowledge of the properties and composition of this oil has become desirable in connection with its utilization. Previous investigations have shown that differences exist in the composition of various commercial palm oils, and studies have been under way to determine the characteristics and the composition of samples of oil from the important producing localities. During the past year such

studies were made on palm oil from Nigeria. The Nigerian oil showed a higher saponification value than the oils from Sumatra and the Belgian Congo previously investigated. The determination of the proportions of the individual fatty acids in each sample closely agreed with the differences observed in saponification values and the quantity of saturated and unsaturated fatty acids.

SAPOTE-SEED OIL

An examination was made of the oil expressed from the fruit of the sapote, a member of the Sapotaceæ family grown in Honduras. This tree is commonly found in southern Mexico, Central America, Ecuador, Colombia, and other American tropical regions. In some localities considerable quantities of the seed are said to be available for the production of oil and cake. The oil can be used either for edible or technical purposes. An analysis of the seed showed that it contained 57 per cent of oil, and the oil was found to contain about 21 per cent of stearic acid. Since in the majority of the vegetable oils palmitic acid predominates in the saturated acid fraction, it has been suggested that sapote-seed oil could be used to advantage for obtaining stearic acid in quantity, the use of which is annually increasing at a rapid rate.

CHERRY OIL

Owing to the rapid expansion of the sour-cherry canning industry in this country in recent years attention is being given to the utilization of the separated pits. An investigation was made of the oil expressed from the pits, and it was concluded that this oil is well adapted for use as an edible oil, as well as for the manufacture of cosmetic preparations. Manufacturers of the oil have found that it is particularly suitable for use in the oil roasting of nuts to be salted.

WHEAT OIL

The study of the oil from wheat germs, concerning which there is little reliable information, has been undertaken in view of the fact that such information would be of much value to the packing industry and to those engaged in certain types of nutritional studies involving the use of wheat oil. The oil under investigation was obtained by extraction from an exceptionally good preparation of germ material prepared by a flour mill, especially for a study of the proteins. To date it has been possible only to determine its characteristics. As the keeping quality and stability of the oil are of interest also to the baking industry, it is proposed, from time to time, to examine reserve samples of the oil from this standpoint.

ANALYTICAL METHODS

Further study has been made on methods of analysis for the evaluation of cottonseed in connection with the department's committee on sampling and grading of commercial cottonseed, and several changes in procedure have been recommended. As the seeds, which are to be graded or evaluated on their chemical analysis, aggregate a total between 4,000,000 and 5,000,000 tons a year, the great importance, both

to the farmers and to the manufacturers of the products, of having an accurate analysis of the seed is obvious.

A preliminary study has been made of the preparation and physical properties of certain esters of the higher fatty acids to determine whether any of these derivatives could be used for the separation of one fatty acid from another.

Considerable work was done in attempting to convert quantitatively ordinary oleic acid, which is found in a great number of fats and oils, into the solid isomeric form, known as elaidic acid, by means of various catalysts, but so far it has only been possible, under the more favorable experimental conditions, to obtain a conversion of 80 per cent of the original oleic acid. Quantitative conversion would provide a much-needed method for the direct determination of oleic acid not only in various fats and oils but also in various manufactured products.

NUTRITIONAL INVESTIGATIONS

CHEMICAL INVESTIGATIONS ON PROTEINS

Because of the predominant and indispensable place proteins occupy not only in the group of proximate principles of foodstuffs but also in the life processes of every living cell, renewed interest and attention are being given to problems of chemical and nutritional significance that center in the knowledge of the proteins. The chemical structure and nature of proteins still remain largely unknown. Many unsolved problems of great importance depend for their solution on a more complete knowledge of protein chemistry.

PROTEINS OF CEREALS

Investigations on glutelins, a class of proteins, have been continued. The glutelins of wheat, rice, oats, corn, rye, and barley have previously been investigated in this bureau, and during the past year the glutelin of buckwheat was studied. Only one glutelin was found, which is characterized by having a high content of the nutritionally essential amino acids, arginine and lysine. It is apparently devoid of proline, an amino acid which has been found in practically all seed proteins. Its isoelectric point is characteristic of glutelins as a group.

SWEETPOTATOES

The proteins of sweetpotatoes are valuable supplements to the proteins of cereals and legume seed in that they contain nutritionally essential amino acids which are deficient in the proteins of cereals. During the past year studies have been made of the nature of the changes that take place in the proteins when sweetpotatoes are allowed to remain in storage under different conditions. Most of the protein in freshly dug sweetpotatoes, or in those that have been stored in a cool place, consists of a globulin to which the name ipomoein has been given. However, if sweetpotatoes are allowed to remain improperly stored in a warm place it has been found that the quantity of ipomoein gradually decreases, and there appears another protein which increases in quantity with the time of storage up to a certain limit. Ultimately both proteins gradually disappear with a corresponding increase in nonprotein nitrogen.

ALCOHOL-SOLUBLE MILK PROTEIN

Chemical studies were made on the alcohol-soluble protein from milk. This protein is unique in that it is the only protein obtained from an animal source which is soluble in alcohol, all alcohol-soluble proteins heretofore known having been obtained exclusively from cereals and grain. Quantities of this milk protein are available in a crude form in the alcoholic extract of casein obtained during the preparation of vitamin-free casein used in connection with nutritional feeding experiments. The product has been purified, and the percentages of some amino acids, not heretofore determined, have been established.

SOYBEANS

Work has been started to ascertain possible differences in the nature and chemical composition of the proteins of several widely different varieties of soybeans. Knowledge of any differences, for example, in the percentages of the nutritionally essential amino acids would have an important bearing in connection with the selection of the right varieties of soybeans for cultivation from the standpoint of their nutritive value.

SUGARCANE JUICE

An investigation is in progress to obtain more information regarding the character of the nitrogenous compounds in sugarcane juice by applying new methods of analyses which have recently been developed. This work should be of interest in connection with problems relating to the sugar-refining industry.

BIOLOGICAL INVESTIGATIONS OF PROTEINS AND VITAMINS

POTATO PROTEIN

With the object of ascertaining the nutritive value of potato protein, a preparation containing all the constituents of the potato except most of the starch and one-half of the washed pulp was fed to rats. When this preparation furnished the sole source of nitrogen in diet adequate with respect to the essential dietary factors other than protein, only maintenance resulted. Addition to the diet of as much as 20 per cent gelatin, either alone or together with a mixture of cystine, tyrosine, and tryptophane caused no improvement in the rate of growth. On the other hand, addition of 10 per cent casein or lactalbumin enabled the animals to grow at a normal rate. It is concluded that casein and lactalbumin contain some essential dietary factor which is lacking in the potato preparation and in gelatin, and which is not one of the known essential amino acids.

COTTONSEED MEAL

The investigations conducted on the nutritive value of cottonseed meal during the last few years have definitely established that the value of the meal for animal feeding is influenced by the method of manufacture. These investigations are being continued in order to determine which factors are operative and which factors must be carefully controlled to insure meals of the highest quality.

Information of importance in the interpretation of investigations concerning cottonseed-meal injury has been obtained during the past year. Gossypol, the recognized toxic principle occurring in the raw seed to which cottonseed-meal injury has been attributed, produces injury symptoms in the animal that are influenced to a marked degree by the quality and quantity of several essential components of the diet. If the level of gossypol fed to experimental animals is kept constant, the toxic response is greatly modified by varying the quality of the diet with respect to protein, fat, iron, and reaction of the inorganic residue. This is observed with rations which are adequate with respect to every known essential. In addition, certain products, such as yeast, have an apparent specific effect that can not be attributed to the quantity of protein, fat, or minerals carried by the yeast. It has been found possible to detoxify raw cottonseed containing an abundance of free gossypol by mere contact with certain solvents.

FISH OILS

The cooperative work with the Bureau of Fisheries on the nutritive value of fishery-food products and by-products has been confined largely to obtaining more complete information with respect to the vitamin content of fish oils. It has been shown that menhaden oil, which ordinarily is about three-fourths as potent in vitamin D as cod-liver oil, can be made fully as potent as that oil in vitamin D if the heat treatment in the preparation of the oil is properly controlled. Salmon oil, prepared from the waste that results in canning, can be made twice as potent as cod-liver oil in vitamin D and equal to high-grade medicinal cod-liver oil in vitamin A. While the present domestic output of salmon oil is not large, by using waste that is now discarded it can be made three times as large as the present domestic output of cod-liver oil. Canned salmon is an important source of vitamin D in the American diet. Statistics show that the canned salmon sold annually in this country contains more oil than the cod-liver oil used for both human and animal feeding. Tests conducted during the past year show that the oil from canned salmon is fully equal to cod-liver oil in vitamin D.

VITAMINS IN SULPHURED APRICOTS AND IN FROZEN ORANGE JUICE

Studies of the effect on vitamin C of sulphur dioxide used in the manufacture of dried apricots have shown that sulphured apricots retain their original vitamin C content remarkably well through commercial processing and subsequent storage, whereas dried unsulphured apricots are devoid of this vitamin. However, ordinary methods of cooking destroy the vitamin completely, and if the practice of sulphuring is to be of any practical significance in the preservation of vitamin C it will be necessary to devise other methods of preparing the fruit for the table.

Frozen orange juice has recently come on the market in large quantities. Orange juice is recognized as an important source of vitamin C, and there is at present no available data on the effect of different methods of freezing and storage of frozen juice on its vitamin content. Studies have been undertaken in cooperation with the food research division to obtain the desired information. Feeding tests

are now in progress on orange juice frozen under conditions simulating those used in the industry, and some of the material is being kept at a low temperature to determine the effect of storage.

COLOR AND FARM WASTE INVESTIGATIONS

DYE INTERMEDIATES

Vat dyes continue to be the most important factor in the domestic dye industry. Ranking first in order of production, they constituted 35 per cent of this country's total output of dyes in 1929. Though there was a marked decrease in importations of dyes in 1930, the total amount imported was still large, aggregating more than 1,700,000 pounds. The work of the bureau has an important influence in the field of vat-dye production, and the results of the studies of the various problems are looked forward to by the industries concerned. As carried on, these studies include determinations of physical constants of dye intermediates, a study of fundamental details of synthesis, improvement of existing methods, and the preparation of new vat-dye intermediates. This work points the way to new fields for the production of dyes to compete with those which are still imported.

The preparation of di-chloroanthraquinones from o-dichlorobenzene is being given active consideration. Combined with phthalic anhydride this material gives a mixture of two isomeric di-chloroanthraquinones, but unfortunately the more valuable of the two is present only in comparatively small amounts. Attempts to change this ratio have been unsuccessful, but as a result of the work done by the bureau much misinformation on the subject of these intermediates has been cleared up. The physical constituents of new compounds have been established, and general information of a practical character has been made available for future investigations. Work on the synthesis of 2-amino-anthraquinone from phthalic anhydride and bromo-benzene has been completed, and much information of a fundamental nature as well as of potential practical value is included in a report on this synthesis which has been prepared for publication.

BIOLOGICAL APPLICATION OF DYES

Stains bear somewhat the same relation to many biological researches that dyes bear to the textile industry. They have a wide application in the examination and differentiation of the various constituents of animal and plant life and are of utmost importance both for the advancement of pure science and for the application of science in matters of vital practical importance. The outstanding achievement of the research on stains during the past year has been the synthesis, in cooperation with the Garvan Cancer Research, of a new stain for cancer tissue, which is the best that has yet been devised for this purpose, and which has greatly simplified the work of the cancer diagnosticians.

A comprehensive study of the preparation of seven basic magentas by two methods has been practically completed. This work will be of great assistance to the stain technologists, who have been uncertain as to which one of the several dyes contained in the commercial mixture known as basic fuchsin was responsible for the results obtained

in their technics. These dyes have been carefully synthesized, and their identity is being proved by analyses and spectro-photometric tests. Samples will be forwarded to leading stain technicians for tests and reports on their relative values.

Various methods of preparation of auramine have been studied with a view to obtaining good yields and a pure material. This dye has a very strong antiseptic value and is used very extensively in bactericidal work.

Fifty-one samples of stains have been identified and analyzed during the past year from the commission on standardization of biological stains. The Garvan Cancer Research was supplied with a considerable number of special dye preparations. The Cancer Research of Philadelphia was supplied with several special neutral stains, with a number of preparations of fluorescent character, and with two antiseptic preparations of the addition-product type. Further absorption measurements were undertaken for the Rockefeller Institute, and considerable progress was made in preparing for the institute a reliable supply of cresyl blue.

INDUSTRIAL FERMENTATIONS

The chemical action of microorganisms is receiving attention both from a fundamental and a practical standpoint. Since work was started in the bureau on industrial fermentations some five years ago, the bureau has become recognized as one of the leading authorities on the subject and bureau contributions to the literature are being quoted in Japanese, German, and English journals.

A survey of the action of molds on xylose prepared from farm wastes has been practically completed for the genera Aspergillus and Penicillium. In all, 164 strains of these fungi have been investigated. While practically all these organisms utilize the xylose well for growth, very few produce compounds which might have industrial significance.

The great difficulty in the utilization of the metabolic activities of molds on an industrial scale is that, in fermentations involving oxidation reactions, the organisms must be grown on the surface of the solution. This requires the use of expensive shallow pans and gives rise to serious engineering problems. Any means that will allow such fermentations to be carried out in deep vats would be a very valuable contribution. This problem has been investigated, using the kojic acid fermentation because of its standard yields. Under ordinary cultural conditions submerged growth of the organisms gives very low yields of acid. This may be due to a number of causes, chief among which is the diminished available supply of oxygen.

To overcome this, experiments have been conducted in which the fermentation is carried on under increased air pressures. Thus far experiments at 5 and 10 pounds pressure have been completed. At 10 pounds the yield of kojic acid has been double that obtained at atmospheric pressure. It is planned to carry pressures up to 100 pounds, which would be entirely feasible in an industrial process, but before this is attempted additional details must be worked out.

The action of certain organisms on dextrose was investigated, using commercial corn sugar as the source of dextrose. The most

important finding was the ability of a strain of *Aspergillus flavus* to produce much higher yields of kojic acid than have hitherto been reported. A yield as high as 48 per cent of theory has been obtained. This yield makes the production of this material by fermentation feasible if sufficient demand for the product develops. About 50 samples of kojic acid have been distributed to those interested.

The stimulating effects of more than 30 organic compounds on mold metabolism have been investigated. One compound, ethylene chlorhydrin, has been found to be decidedly effective in increasing yields of kojic acid by about 25 per cent.

BAGASSE CELLULOSE

The work on bagasse cellulose during the past year has been devoted to taking up the final phases of the investigation and the preparation of a report on the work. Cellulose has been produced which is in many ways superior to some of the alpha cellulose produced from wood pulp. Although it is not so good as the cellulose produced from cotton linters, it would be acceptable in many cases in which the latter is now the sole raw material.

LIGNIN

Lignin is an important component of farm wastes and is also an industrial waste as part of the sulphite waste liquor of paper mills. There is no definite information available on the chemical composition of this material, and very few of its physical properties are known. These facts must be cleared up before any satisfactory procedure for its utilization can be contemplated. During the past year definite progress has been made in this respect, and certain compounds have been obtained which aid in a reasonable speculation as to the nature of the lignin molecule.

Studies have been made on the possible empirical industrial utilization of lignin. A number of resins have been formed by the combination of lignin with other materials, and a patent has been issued covering these products. Some work has also been started on the production of tanninlike materials from lignin sulphonic acid.

INSECTICIDE INVESTIGATIONS

INSECTICIDAL PLANTS

In the study of insecticidal plants with the object of developing new insecticides which can be substituted for lead arsenate, the compound rotenone has continued to claim the greatest share of attention, as it is still the most important and promising material in this connection.

Rotenone has been subjected to intensive study from four angles—structure, methods of application, toxicity to insects, and possible toxicity to humans and animals. Information has been obtained concerning the solubility in various liquids as a guide to the analysis of the roots of the tropical plants supplying rotenone and their commercial extraction; methods of preparing dusting and spraying mixtures containing rotenone have been studied, and important data

concerning its decomposition in solution discovered; its toxicity to many insects, such as aphids, caterpillars, codling-moth larvae, clothes moths, fleas, lice, and mites, has been investigated by collaborating entomologists; and a thorough study of its possible toxic effects to man and animals has been made by means of careful and numerous experiments on guinea pigs, rabbits, and dogs, to which it was administered intravenously, subcutaneously, and orally. As a short summary of the findings it may be said that rotenone has now proved itself superior to nicotine against many aphids, at least comparable with lead arsenate against some chewing insects, and practically nontoxic to man and animals when taken orally.

The other crystalline materials, toxicarol, deguelin, and tephrosin, that have been isolated from certain tropical plants, have also been intensively studied and their toxicities to numerous insects have been determined. Certain relationships which have been established between these materials are expected to prove a great aid in the final interpretation of the structure of this whole group of fish-poisoning materials.

An investigation of more than 50 other plants reputed to have insecticidal value, many of them native to the United States, is also under way.

SYNTHETIC ORGANIC INSECTICIDES

The results of insecticidal tests with 25 dipyridyl derivatives and related compounds, carried out in conjunction with the Bureau of Entomology, were published. This work brought out important information on the correlation between chemical structure and toxicity. New methods for the synthesis of nicotine isomers starting with gamma gamma dipyridyl have been worked out.

Certain organic thiocyanates and isothiocyanates were prepared, and their toxicity to fish was determined. The results indicate that these classes of compounds are promising sources of new insecticides, and tests of their toxicity to insects will be made.

SPRAY RESIDUES

The quantity of arsenic left on apples by various spray treatments and the efficacy of numerous washing solutions in removing it under different conditions were determined. The effect of sprinkler irrigation on the amount of arsenic residue was also studied, and it was found that low sprinklers have no effect, but that high ones playing on the foliage have a tendency to reduce it.

In continuing the work on arsenic residues on tobacco several hundred analyses were made and the residue per leaf was found to range from 0.12 to 3.52 milligrams of arsenic. The arsenic present at the time the leaves are picked persists through the sweating and curing processes. In the course of this work it was discovered that nicotine and certain other materials seriously interfere with the standard Gutzeit method of estimating arsenical residues.

FUMIGANTS

The use of hydrocyanic acid generated from sodium or calcium cyanide was studied in relation to the fumigation of narcissus bulbs. Certain relationships between dosage, hydrocyanic acid concentra-

tion, and degree of control were determined. The effect of absorption of hydrocyanic acid by the bulbs was very marked. A fundamental study of the reaction of the citrus red scale to fumigation with liquid hydrocyanic acid has been started in an effort to overcome the resistance to hydrocyanic acid that the red scale has developed during the long period in which fumigation of citrus trees has been practiced.

HOMOLOGUES OF PARIS GREEN

The study of the compounds that copper arsenite forms with the copper salts of the fatty acids has been continued in an effort to develop a material that is equal to Paris green in its toxicity and superior to it in other respects.

The lower members of the series, containing formic, propionic, and valeric acids, on some of which other investigators have worked, were first studied, and then some of the higher members containing oleic, lauric, palmitic, and stearic acids were prepared. For these combinations of which the copper salt of the fatty acid is insoluble a new method of analysis was developed for determining definitely whether the combinations formed are true double compounds or only mixtures of the fundamental components.

Stearic "green" was proved to be a definite substance, and the preparation of about 25 pounds of it was begun in order that both laboratory and field tests might be made during the coming season.

OIL EMULSIONS

Chemical work on oil emulsions was started at the New Orleans laboratory of the Bureau of Entomology to assist the entomologists in a fundamental study of the reaction of insects to oil emulsions.

A new method for the practically instantaneous preparation of soap-oil emulsions in the cold and without agitation was developed, and a manuscript describing it was submitted for publication.

Investigations were started on the use of copper oleate and the fatty acid salts of other toxic metals, such as mercury and zinc, in emulsions to increase their insecticidal action or confer on them fungicidal properties, and considerable work was done along this line. A definite procedure for the preparation of such emulsions was worked out for copper oleate and will be applied to salts of the other metals.

FLUORINE INSECTICIDES

The study of all compounds containing fluorine that have any significance as insecticides was continued. Results of tests against the codling moth in the Northwest were so favorable that a bulletin recommending the use of certain fluorine compounds for the control of this insect has been prepared by the entomologist in charge of these tests and the fluorine expert of this bureau.

DUST-EXPLOSION INVESTIGATIONS

The dust-explosion hazard exists in 28,000 industrial plants employing almost 1,500,000 persons and manufacturing products having an annual value of $10,000,000,000. The Bureau of Chemistry and

Soils is the only governmental agency studying dust explosions in industrial plants and in agricultural operations, and it is looked to in both the United States and in foreign countries for technical information on the subject. The investigations relate directly to the development of methods and appliances for the saving of life, property, and foodstuffs. During the past year 18 dust explosions, which resulted in the death of 17 persons, injury to 53 others, and property damage amounting to $562,750, were investigated. These explosions occurred in grain elevators, wood-working establishments, and plants manufacturing cattle feed, starch, linseed meal, tobacco by-products, and wood flour.

INERT GAS

In certain plants flue gas used to create an inert atmosphere has proved injurious either to the product or to the equipment in which it is used. During the past year conferences were held in Washington and in Chicago on the development of suitable gas-washing and gas-conditioning equipment. As a result of these conferences and previous tests of gas-conditioning equipment the wooden grid type scrubber is being recommended as the most economical and practical piece of equipment for the purpose.

Following an explosion of tobacco dust at a tobacco by-products plant the company officials asked for a survey and inspection of the plant for the purpose of eliminating dust-explosion hazards. The inspection indicated the practicability of using inert gas, and on the bureau's recommendation an inert-gas system has been designed and installed by the company.

VENTING AREA TESTS

Work has been under way at the Arlington Experiment Farm to determine the ratio between dust-explosion pressures and venting areas. In a heavily reinforced compartment or room with a volume of 100 cubic feet, explosions are produced with starch, flour, grain dust, cork, or other powdered combustible material, and observations are made to determine the value of vents of different types and sizes. Swinging iron vent doors of various sizes and hinged plain glass windows are provided to release explosion pressures and thus prevent the destruction of the chamber. By leaving vents of various sizes open, the effect of pressures within the box can be observed. These tests have attracted considerable attention and have been given publicity by newspaper writers, photographers, and motion-picture producers. A number of demonstrations have been given for officers of the Baltimore and Washington fire departments and for operators of industrial plants. Additional demonstrations are being scheduled.

SERVICE TESTING

Samples of dust submitted by firms in various sections of the country were tested for explosibility, and reports were prepared giving the information desired by the companies to allow them to take the necessary precautions against the dust-explosion hazard. The samples included wood flour, tobacco, processed tankage, wood, soap, resins, linseed-oil cake, and other dusts.

DUST-EXPLOSION HAZARDS COMMITTEE

In order to provide for the prompt application of the control and preventive methods developed by the bureau engineers, close cooperation has been maintained with industries, insurance organizations, State commissions, safety organizations, and numerous fire-fighting and fire-protection units.

At the annual meeting of the National Fire Protection Association at Toronto in May, 1931, the dust-explosion hazards committee, which is under the leadership of the chemical engineering division of the bureau, presented for adoption regulations for the prevention of dust explosions in wood-flour manufacturing establishments, in spice-grinding plants, terminal grain elevators, and starch factories; regulations for pulverizing systems for sugar and cocoa; and regulations for the use of inert gas for fire and explosion prevention.

STATE FIRE SCHOOLS

The chemical engineering division cooperated during the year with the national fire waste council of the United States Chamber of Commerce and with a number of State colleges and firemen's organizations in conducting short-course fire schools for the instruction of firemen. These schools were well attended, and considerable interest was manifested by the firemen in dust-explosion prevention. At these meetings addresses were given on suitable subjects, and dust-explosion demonstrations were produced in the miniature elevator. Requests have been received from a number of States for assistance during the coming year in conducting similar schools.

SPONTANEOUS IGNITION OF HAY

During the year experimental work on spontaneous heating of hay was continued in the specially-constructed barn on the Animal Husbandry Experiment Farm at Beltsville, Md.

The plan to use 25 or 30 tons of loose, undercured alfalfa could not be carried out because of the severe drought. It was therefore necessary to utilize baled alfalfa, shipped in from other sections. In July, 28 tons of alfalfa were placed in the barn after the bales had been opened. As the loose hay was thrown into the mow it was sprinkled with water, approximately 20 tons of water being added in this manner. Samples of hay and gases were collected at desired points during the progress of the experiment.

It was indicated in a general way in this experiment that the admission of measured quantities of air and of oxygen directly to heating areas (during certain stages, at least) did not produce a further rise in temperature, but that the indirect admission of air to such areas, infiltration through near-by vertical holes cut in the hay, was conducive to a rise in temperature. Although efforts to produce the advanced stages of heating were unsuccessful, the experiment was of value in yielding information on such factors as compactness and wetness of hay, indirect ventilation, effect of the injection of oxygen, and in perfecting technic and apparatus. The amount and nature of acids found in the samples of hay col-

lected during the progress of the experiment was determined by analysis. The samples of gases were also analyzed.

Apparatus designed for laboratory investigation of the oxygen-absorbing properties of various types of hay, before and after subjection to spontaneous heating, has been constructed.

COOPERATION WITH NATIONAL ORGANIZATIONS

The Bureau of Chemistry and Soils has leadership of the farm fire protection committee of the National Fire Protection Association. This committee includes 4 members from the Department of Agriculture, 1 member from the Department of Commerce, and 13 representatives of national organizations. At the request and under the supervision of this committee a farm-fire survey covering one county in each of the States of Iowa, Wisconsin, and Indiana was made during the summer of 1930, and a report of the survey has been published by the association.

Final editing and revision of the handbook, Prevention and Control of Farm Fires, has practically been completed. The preparation of this material was in the hands of a joint committee, comprised of members of the farm fire protection committee and of the agricultural committee of the national fire waste council.

The spontaneous heating and ignition committee of the National Fire Protection Association, which includes 3 representatives from the Department of Agriculture, 2 from the Department of Commerce, and 12 from national organizations, is preparing a national program of research and also a brochure on the spontaneous heating and ignition of agricultural and industrial products.

On the request of this committee questionnaires for reporting cases of spontaneous heating and ignition of agricultural products were sent out to all State fire marshals, directors of experiment stations, and directors of extension workers. The response as well as the interest shown has been gratifying, and a great deal of general information was forthcoming. This contact also provided a medium for further bringing the importance of the subject to the attention of these officials.

EXHIBITS

Exhibits to show the results of the bureau's research work, including subjects on food research, vitamins, farm wastes, dust explosions, and fertilizers, were prepared and displayed at State fairs, industrial expositions, and conventions.

Three exhibits were prepared and shipped to France for the International Exposition of Colonial and Overseas Possessions at Paris. One of these exhibits relates to the subject of bagasse, the second is made up of citrus by-products, and the third deals with the utilization of sweetpotatoes.

ENGINEERING DESIGN AND DEVELOPMENT SERVICE

The chemical engineering division renders special service to the various divisions in the bureau in the design, installation, and operation of mechanical equipment for the commercial application of scientific discoveries for the utilization of agricultural resources. The division cooperated with the industrial farm products division

in the development of a commercial process for filtering crude turpentine gum. A semicommercial plant was designed and constructed at Tallahassee, Fla., for the purpose of obtaining experimental data on the practicability of a turpentine gum-filtration process developed during the past year.

Plans and specifications were prepared on the design of a naval stores field laboratory. Economic engineering studies were made on the various processes proposed for the utilization of farm products.

EXPLOSION AND FIRE HAZARD OF INSECTICIDES

Considerable experimental work was carried on by the chemical engineering division in cooperation with the insecticide division to determine the explosion and fire hazards of insecticides. A series of explosibility tests were made with the vapors from liquid ethylene oxide mixed with liquid carbon dioxide; also liquid ethylene oxide and solid carbon dioxide. Similar tests were made with mixtures of carbon bisulphide and carbon tetrachloride saturated with sulphur dioxide and with mixtures of ethylene dichloride and carbon tetrachloride saturated with sulphur dioxide. Large-scale tests were conducted at the Norfolk, Va., grain elevator operated by the Norfolk & Western Railway Co. during the fumigation of wheat with ethylene oxide and solid carbon dioxide. The tests at this elevator and previous tests at the Canadian Pacific Railway grain elevator at Port McNicoll, Ontario, indicated that there is no apparent explosion or fire hazard in the storage bins after the grain has been treated with a fumigant consisting of 10 parts of solid carbon dioxide to 1 part of ethylene oxide.

The Bureau of Chemistry and Soils is cooperating with the National Fire Protection Association in the work of the fumigation hazards committee, which includes two representatives from the bureau. This committee is developing practical safety standards for application in the use of insecticides.

SOIL INVESTIGATIONS

SOIL SURVEY

The practical importance of the soil-survey work is not merely expressed in its value to the individual farmer but it constitutes the study of the most important of the natural resources of the United States and is not duplicated in any sense whatever by any other studies carried on by any other agency in the United States. It is a work that is exclusive, unique, and peculiar to itself.

The work of the soil survey is primarily directed to the investigations of soils in the field, their natural geographic environment as related to agriculture, identification of the various kinds or types of soil, and the preparation of reports in the form of descriptive material and maps on their character and distribution. During the fiscal year of 1931 work was done in 85 areas distributed over 30 States, Porto Rico, and the Virgin Islands.

Thirty-nine of these areas were completed during the year. Some of these projects were begun in the preceding year, and some were begun during the fiscal year of 1931 but have not been completed.

Most of this work was done in detail, the soil types being differentiated in as great detail as was possible so that they might be shown on a map with the scale of 1 inch to the mile. A relatively small area, however, was surveyed by the reconnaissance method, the most important project being a survey of practically the entire State of Vermont. Tables 1 and 2 show the details of areas covered and their distribution.

TABLE 1.—*Individual areas surveyed and mapped during the fiscal year ended June 30, 1931*

State or territory	Area	Area surveyed	
		Square miles	*Acres*
Alabama	Dallas County	[1] 451	288,640
	Lauderdale County	150	96,000
	Mobile County	[1] 117	74,880
	Wilcox County	330	211,200
	Winston County	56	35,840
Arizona	Tucson area	408	261,120
California	Alturas area	174	111,360
	Dixon area	435	278,400
	Suisun area	[1] 244	156,160
Colorado	Longmont area	[1] 500	320,000
Georgia	Decatur County	211	135,040
	Hall County	114	72,960
	McDuffie County	[1] 46	29,440
Idaho	Benewah County	[1] 425	272,000
Indiana	Jennings County	[1] 33	21,120
	Knox County	368	235,520
	Vermillion County	254	162,560
	Washington County	[1] 458	293,120
Iowa	Franklin County	157	100,480
	Hancock County	[1] 164	104,960
	Monroe County	371	237,440
	Washington County	[1] 69	44,160
Kansas	Bourbon County	486	311,040
	Kingman County	179	114,560
	Marion County	[1] 418	267,520
Kentucky	Fayette County	27	17,280
	Mercer County	[1] 127	81,280
Louisiana	Livingston Parish	[1] 474	303,360
Maryland	Kent County	[1] 227	145,280
	Queen Annes County	49	31,360
Michigan	Bay County	246	157,440
	Eaton County	[1] 202	129,280
	Iron County	[1] 679	434,560
	Montmorency County	[1] 386	247,040
	Oscoda County	153	97,920
Minnesota	Hubbard County	[1] 579	370,560
Mississippi	Greene County	332	212,480
	Marion County	104	66,560
Montana	Gallatin Valley area	507	324,480
Nebraska	Dundy County	263	168,320
	Furnas County	[1] 629	402,560
	Harlan County	[1] 518	331,520
	Hitchcock County	724	463,360
	Knox County	[1] 175	112,000
	Sherman County	135	86,400
New Mexico	Lovington area	354	226,560
New York	Delaware County	[1] 1,084	693,760
	Orleans County	27	17,280
	Rensselaer County	77	49,280
	Steuben County	[1] 420	268,800
North Carolina	Brunswick County	[1] 341	218,240
	Chatham County	203	129,920
	Franklin County	[1] 418	267,520
	Surry County	33	21,120
Ohio	Adams County	185	118,400
	Athens County	100	64,000
	Licking County	[1] 153	97,920
	Putnam County	[1] 169	108,160
Oklahoma	Craig County	[1] 282	180,480
	Grant County	[1] 440	281,600
	Kiowa County	1,062	679,680
	Pittsburg County	[1] 955	611,200
	Tillman County	[1] 298	190,720
	Woodward County	73	46,720

[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, 1931*—Continued

State or territory	Area	Area surveyed	
		Square miles	*Acres*
Oregon	Umatilla County	[1] 422	270,080
Pennsylvania	Indiana County	439	280,960
Porto Rico	Soil survey of island	[1] 289	184,960
South Carolina	Abbeville County	284	181,760
	Dillon County	[1] 169	108,160
Texas	Bee County	293	187,520
	Collin County	[1] 294	188,160
	Falls County	455	291,200
	Polk County	[1] 149	95,360
	Scurry County	[1] 795	508,800
	Wheeler County	417	266,880
Virginia	Grayson County	425	272,000
	Nansemond County	271	173,440
	Rockbridge County	[1] 414	264,960
West Virginia	Pendleton County	[1] 408	261,120
	Randolph County	215	137,600
Wisconsin	Barron County	[1] 340	217,600
	Crawford County	[1] 320	204,800
Wyoming	Johnson County	[1] 1,241	794,240
	Sheridan County	[1] 1,062	679,680
Total		28,530	18,259,200

[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, 1931, and areas previously reported*

DETAILED

State or Territory	Work during 1931	Work previously reported	Total	
	Square miles	*Square miles*	*Square miles*	*Acres*
Alabama	1,104	54,036	55,140	35 289,600
Arizona	408	3,537	3,945	2,524 800
Arkansas		15,547	15,547	9,950,080
California	853	31,666	32,519	20,812,160
Colorado	500	4,905	5,405	3,459,200
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	371	34,866	35,237	22,551,680
Idaho	425	11,075	11,500	7,360,000
Illinois		6,770	6,770	4,332,800
Indiana	1,113	18,174	19,287	12,343,680
Iowa	761	45,815	46,576	29,808,640
Kansas	1,083	13,902	14,985	9,590,400
Kentucky	154	5,146	5,300	3,392,000
Louisiana	474	16,957	17,431	11,155,840
Maine		2,197	2,197	1,406,080
Maryland	276	13,367	13,643	8,731,520
Massachusetts		8,811	8,811	5,639,040
Michigan	1,666	26,030	27,696	17,725,440
Minnesota	579	[1] 10,341	10,920	6,988,800
Mississippi	436	29,495	29,931	19,155,840
Missouri		37,177	37,177	23,793,280
Montana	507	2,013	2,520	1,612,800
Nebraska	2,444	53,849	56,293	36,027,520
Nevada		652	652	417,280
New Hampshire		1,411	1,411	903,040
New Jersey		9,895	9,895	6,332,800
New Mexico	354	1,084	1,438	920,320
New York	1,608	26,572	28,180	18,035,200
North Carolina	995	43,379	44,374	28,399,360
North Dakota		16,878	16,878	10,801,920

[1] Kittson, Norman, and Wilkin Counties, Minn., were included in the detailed work and recorded in the report for 1930. In this report and hereafter they will be included in the reconnaissance work of the Red River Valley.

TABLE B.—*Areas surveyed and mapped in the several States during the fiscal year ended June 30, 1931, and areas previously reported*—Continued

DETAILED—Continued

State or Territory	Work during 1931	Work previously reported	Total	
	Square miles	*Square miles*	*Square miles*	*Acres*
Ohio	607	16,189	16,796	10,749,440
Oklahoma	3,110	7,758	10,868	6,955,520
Oregon	422	14,579	15,001	9,600,640
Pennsylvania	439	18,260	18,699	11,967,360
Porto Rico	289	860	1,149	735,360
Rhode Island	----------	1,085	1,085	694,400
South Carolina	453	24,764	25,217	16,138,880
South Dakota	----------	8,286	8,286	5,303,040
Tennessee	----------	11,198	11,198	7,166,720
Texas	2,403	54,527	56,930	36,435,200
Utah	----------	2,419	2,419	1,548,160
Vermont	----------	1,175	1,175	752,000
Virginia	1,110	10,125	11,235	7,190,400
Washington	----------	10,752	10,752	6,881,280
West Virginia	623	21,335	21,958	14,053,120
Wisconsin	660	25,867	26,527	16,977,280
Wyoming	2,203	2,818	5,121	3,277,440
Total	28,530	796,684	825,214	528,136,960

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	1,960	3,877	5,837	3,735,680
Montana	3,730	38,527	42,257	27,044,480
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
Oklahoma	2,515	1,164	3,679	2,354,560
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	5,809	3,315	9,124	5,839,360
Washington	----------	16,540	16,540	10,585,600
Wisconsin	----------	14,425	14,425	9,232,000
Total	14,014	610,564	624,578	399,729,920

During the past year a soil survey was made on the island of St. Croix (Virgin Islands). This will be published as a separate report, and the soil types will probably not be included in the list of types covering regular detailed surveys.

The number of soil-survey reports sent to the printer during the past year was greater than for many years. Notwithstanding the depression in agriculture, the results of the soil survey are much more in demand than ever before.

One of the important results of the agricultural crisis now prevailing in the United States will doubtless be increasing demand for land classification. Without discussing the meaning or method of land classification, it should be mentioned here that the soil survey furnishes the only logical foundation on which a land classification for agricultural purposes can be based.

A classification of land on the basis of the soil is far more complete for agricultural purposes than a classification on any other possible

basis, because the soil is the one factor involved in agriculture that expresses the combined results of all factors of geographic environment on which agriculture is dependent.

The agricultural crisis will make necessary a final adjustment of agriculture to the best lands. The knowledge being accumulated by the soil survey will be of the greatest possible assistance in making these adjustments that are so important and essential to the future development of our agricultural industry.

EXTENSION OF SOIL SURVEY TO FOREST LANDS

Up to the present time the soil survey has been concerned with agricultural lands whose characteristics made cultivation possible. The increasing adjustment of agriculture to the more productive agricultural lands and the inevitable future use of much land which has previously been in cultivation for the growth of forests and grass, not merely because of the necessity for timber and grass products but also for the purpose of conserving water and protecting the soil from erosion, makes it desirable to know the character of all the soils, and whether they can best be cultivated or devoted to forestry and pasturage. During the past year the bureau has extended its work into mountainous areas and into the areas of the national forests to a greater extent than ever before. It does not undertake to study the character of the soils in these areas in detail, but every soil map that covers the national forests will in the future cover the general character of the soils within the forests and mountainous areas not within national forests. By this method can be determined the distribution of the areas where different kinds of timber or different species of grasses may be grown most successfully.

PEAT INVESTIGATIONS

Closely allied to the work of the soil survey is that of peat investigations. The object of peat investigations is to study the origin, development, and characteristics of peat and muck land in order to determine the relative value of these resources for different uses and to apply the information gathered in the classification and mapping of these organic materials.

During the course of the last fiscal year a detailed survey and classification of peat soils in the Erie-Ontario Basin and other areas of New York State was carried out in cooperation with the agricultural experiment station of Cornell University. As a result of this field work, 3 principal series of organic soils and 12 type profiles have been established and described. The report discusses certain ecological and morphological interrelations existing between structural profile features and factors of climate, edaphic conditions, and the succession of vegetation stages in the past that brought about a peat deposit. The study of these peat areas provides not only a basis for uniformity and completeness of profile studies and for further special investigations of physical properties, chemical organic compounds, and crop responses, but it also suggests means of turning unprofitable, submarginal peat land to commercial uses other than farming.

Further progress in coordinating the research of the bureau on the physical and chemical character of organic soils has been facilitated by recently developed field methods establishing type-profile units. The investigation of complete type profiles, obtained from different geographic sections of this country, with attention to botanical composition, sequence, thickness, and characteristic features of different layers of parent material in the entire cross section, is especially important. The full utilization of results of such work aids in establishing the geographic relationships of these units.

Much progress has been made in the comparison and correlation of profile data, but the information is still far from being complete. The United States, together with Alaska and other territorial possessions, affords striking examples of natural regions of peat land. The major divisions recently established are receiving further study in order to establish the principal subdivisions and their respective units. A characterization of the subgroups and units furnishes an opportunity for verifying their relationships to Eurasian peat lands.

The work in peat investigations and its service is steadily expanding. Experimental work on uses of peat is now being developed at the Arlington Experiment Farm in cooperation with the greens section of the United States Golf Association and the Bureau of Plant Industry. A circular has recently been prepared giving information as to the character of moss peat, its characteristic properties, relative merits for different uses, and distribution in this country.

The peat deposits of the United States are assuming industrial and commercial importance sufficient to warrant the collection and the publication of information as to the occurrence and geographic distribution of commercially important areas of peat, methods in the preparation of satisfactory peat composts, and the steps necessary to be taken in the development of an American peat industry that would yield products of commercial value comparable to peat products imported from other countries.

SUPPLEMENTARY WORK BY THE SOIL SURVEY

In addition to the work of field investigations of soils and the preparation of maps and reports, the soil survey undertakes other work based mainly on the accumulated results of the previous work. During the fiscal year 1931 a number of these supplementary or subordinate projects have been carried out to successful conclusion.

THE ATLAS OF AMERICAN AGRICULTURE

One of the most important activities consisted in the preparation for publication of the soils number of the Agricultural Atlas of the United States, data for which has been in the course of preparation for publication for several years past by the various bureaus of the department under the editorship of O. E. Baker, of the Bureau of Agricultural Economics. This material has now been assembled, the maps and illustrations have been prepared for the engraver, and a report is being prepared for publication. This number of the atlas will include a generalized soil map of the United States on the scale of 40 miles to the inch, covering 12 sheets. It will include various

colored and other illustrations and will be accompanied by a report describing the predominant soils of the United States and containing a discussion of their chemical composition based on the complete ultimate chemical analyses of the soil types.

LOCATION OF HOSPITAL FARMS

During the past year the Public Health Service has been engaged in the work of locating a number of sites for the establishment of hospitals to care for narcotic addicts. Because the hospitals are to be established on farms, the soil survey was called on to assist in their location. In deciding on the sites for two of these farms that have already been located, the character of the soil has been a factor of major importance.

LAND CLASSIFICATION IN THE LOWER MISSISSIPPI REGION

The War Department during the past year called on the Department of Agriculture for assistance in determining the character of the land in the lower Mississippi alluvial plain, on which it is designed to establish certain outlet channels for flood waters. The character of the soil was recognized as an important factor in the determination of the value of these lands. Employees of the soil survey assigned to this work have recently completed their first assignment, and a report has been submitted to the War Department. Work on additional areas is still in progress.

The results of this work and supplementary studies on the character of this region based on accumulated knowledge have emphasized the great fundamental value of lands in this region and the fact that the lower Mississippi flood plain of alluvial land constitutes one of the unique regions of the world, since there is no other region of similar character, size, and relative importance known. It is much larger than the alluvial land of the Nile, of the Amazon, of the Euphrates, and apparently than the alluvial area formed by any other large river, with the possible exception of the Ganges. It differs from the latter, however, in that it is a region which requires no irrigation. The Mississippi soils have been derived to a great extent from materials washed from the Great Plains of the West, where the soils have not only not been leached but where they also contain high percentages of organic matter, a considerable part of which has been deposited in the alluvium now accumulated in the Mississippi River bottoms. The region also is important because its climate makes possible the growth of almost any of the staple crops which man requires in large quantities. A still more important characteristic of the region is its contrast with the surrounding uplands, since it constitutes a very large area of extremely fertile soil in the midst of an area in which the upland soils are very poor. It constitutes, therefore, a tremendous reserve for the growth of grain for a large region where cheap grain production is not yet feasible. The recognition of the character, relationships, and importance of this region is regarded as one of the important results obtained in the work of the soil survey during the past year.

LAND CLASSIFICATION FOR THE INDIAN SERVICE

During the past year studies of the character of soils on the Pima Indian Reservation of Arizona were undertaken at the request of the Bureau of Indian Affairs. A considerable area of land of this reservation was found to be highly charged with alkali, and on the basis of this finding the projected utilization of the land has been decidedly modified.

PIPE CORROSION STUDIES

The Bureau of Standards is engaged in a study of the corrosion of iron pipes buried in the soil, and has asked assistance from the soil survey in studies of the character of soils in which pipes have been buried for experimental purposes and those in which commercial pipe lines have suffered severe corrosion. During the last year studies have been made in various places, chiefly in Oklahoma. This work consists of the identification of the soil in the spots where the pipes have been buried and a study of the particular horizon in which the pipes are embedded.

BOTTOM-LAND INVESTIGATIONS

During the past year considerable interest has been aroused, chiefly through the efforts of the Missouri Agricultural College, in the study of the characteristics and possible utilization of the alluvial land in various parts of the United States. This work has begun with compilation by the bureau of the areas and a study of the general character of the alluvial lands in the United States as shown in the reports of the soil survey. The study has also included an estimate of the area and character of the alluvial land in areas not yet covered by the soil survey based on the alluvial land in the near-by areas that have been surveyed. This compilation has reached an advanced stage, and very little additional work is required for its completion. It will furnish the basis for working out the details of a project or series of projects under the general direction of an interbureau committee recently appointed to give consideration to this matter.

THE NATIONAL MONUMENT AT YORKTOWN, VA.

At the request of the Interior Department the bureau has made a study of the character of the soils on the area of the National Monument Park at Yorktown, Va. A soil survey was made of the area of the park, and a report has been prepared for the use of the national park officials.

THE NATIONAL TRAINING SCHOOL FOR BOYS

The National Training School for Boys, situated in the vicinity of Washington, recently requested the bureau to make a soil survey of its farm area and give advice regarding the extension of agriculture and protection from erosion. The field work for this has been completed, and a report is now in the course of preparation.

VIRGIN ISLANDS

The decrease in the price of sugar and of bay rum has brought a crisis to the agricultural industry of the Virgin Islands. On the transfer of the administration of the islands from the Navy Department to the Department of the Interior, a request was made for a study of the natural conditions of the islands with a view to a readjustment of its agriculture. There are no mineral deposits on the islands, and the population is rather dense, so that their livelihood must necessarily be based mainly on agriculture. At the request of the Office of Experiment Stations a representative of the soil survey was detailed to make a general study of the soils of the islands. During the summer a representative of this bureau spent some time on the island of St. Croix, that part of the islands which was once important agriculturally and on which the present agricultural opportunities seem greatest. The results of this study have been prepared in the form of a soil map and a report describing the characteristics of the soils which show that the soils of the island are, in general, highly productive and that the readjustment of agriculture is a matter that concerns the willingness of the people rather than any limitation placed on readjustment by nature. A report on this work is being prepared for publication as a contribution from the soil survey.

MISCELLANEOUS

A large amount of miscellaneous correspondence has been carried on by the various employees of the soil survey during the past year, chiefly in answering questions concerning the character of soils in various parts of the United States and their utilization for special purposes.

SOIL-EROSION INVESTIGATIONS

During the fiscal year the work of the Bureau of Chemistry and Soils in connection with soil-erosion and moisture-conservation investigations was expanded by the establishment of three additional experiment stations. These new stations have been located in three major soil regions where erosion is a very serious agricultural problem, as follows: One near Pullman, Wash., in the Washington-Oregon-Idaho wheat belt; one 10 miles west of Statesville, N. C., in the middle Piedmont region, representative of upper South Carolina, middle North Carolina, and southern Virginia; and the third between Clarinda and Shenandoah, Iowa, representative of the rich loessial soil region of the Missouri River Valley. This expansion conforms to the provisions of the national program for erosion control and moisture conservation, as presented to Congress in November, 1928.

The work at the five previously established stations (at Guthrie, Okla.; Temple, Tex.; Hays, Kans.; Tyler, Tex.; and Bethany, Mo.) has proceeded with very gratifying results. Additional experiments have been installed and others planned, as funds have become available. Invaluable data, based on quantitative measurements of soil and water losses under various controlled conditions, relating to soil type, slope, character of rainfall, etc., are being accumulated. This fun-

damental information, now being obtained for the first time in history, is making it possible to interpret the basic principles of erosion, run-off, and water penetration with sufficient clearness for practical application of the results in connection with intelligent planning, installing, and perfecting erosion-control and water-conservation methods of both the engineering and agronomic types. It has been learned, for example, that the rate of soil removal on some types of land, occupying moderately steep slopes, is so rapid that there seems, at the present stage of the investigations, little possibility of saving such land where used for clean-tilled crops, except under systems of strip farming, supplemented by terracing, or terracing supplemented by soil-saving crops grown in rotation with the clean-tilled crops. These methods are now under experimentation. It is believed that these methods applied to erosion control will not only prove effective for the important soils in question and probably others, but that they will also be so practical and obviously sensible that farmers will readily adopt them. Strip subsoiling, also under experimentation, is a promising means of soil and water conservation; but this method will need to be subjected to several years' trial, under varying rainfall and soil conditions before it can be advocated as a practical farm method. The indications are that the system may work best on soils in comparatively dry climates. Subsoiling of entire fields is under way and may prove effective both as a practical means for reducing erosion and for increasing water storage in those soils having subsoils which fracture readily and do not run together again with saturating rains. Additional time will be required to test the practical efficacy of this method.

At the Guthrie erosion station the effectiveness of substantially built graded terraces has been demonstrated on the rolling parts of the red plains of Oklahoma not only in markedly slowing down erosion but in rehabilitating erosion-denuded land. In 1930 fairly good crops, considering the drought, were grown on terraced land which, before the time this farm was taken over for an erosion experiment station, had been cultivated and then abandoned because of excessive erosion. On the other hand, indications from experiments thus far carried out point to the impracticability of employing closed, level terraces on the Vernon fine sandy soil as far east as Guthrie, Okla. With this means of erosion control, under central Oklahoma conditions, strips of the ordinary farm crops are drowned out in the terrace channels. Open, level terraces, however, have held well and are very promising in connection with erosion control and the storage of rainfall in regions corresponding to central Oklahoma.

A very valuable experiment in connection with the renewal of fertility in severely eroded fields, which, though abandoned, have not yet been destroyed, is now under way at the Bethany (Mo.) erosion station on the important Shelby loam soil. A field of formerly good soil, which had suffered so much from sheet erosion and shallow gullying that it was considered of little value for crop production, has been overhauled at very low cost by constructing a series of small dams in the gullies by the use of old fertilizer sacks filled with soil and bluegrass roots, plowing in the gullies between the dams, and then seeding the area to wheat. The bluegrass roots went through

the bags, promptly took hold of the ground, and quickly established firm "living" dams, and these quickly silted in from above with the first rains. The wheat developed splendidly, and it is believed that with the rotation planned for the area erosion can be largely or entirely controlled on such areas by this comparatively inexpensive method. This experiment is so practical and cheap that it has attracted much attention of the farmers of the region, some of whom already are applying the experiment-station method to their fields. Another experiment of the same type, supplemented by terraces, is under way at the Tyler (Tex.) station and is being planned for installation at some of the other stations.

The effect of erosion on cotton has brought out some valuable information at the Guthrie erosion station. Here eroded land, having no topsoil, not only is losing its exposed subsoil material twice as fast as uneroded land of the same original type (having the same slope and rainfall and receiving precisely the same treatment), but it has thus far produced less than half as much cotton. Moreover, the staple of cotton from the eroded land is shorter than of that from the uneroded area, and the content of oil in the seed is considerably less. The acreage rate of cottonseed-oil production has been 38 pounds from eroded soil as compared with 98 pounds from uneroded soil of precisely the same original type.

A very important study at the Guthrie station has thrown new light on the function and importance of forest litter and leaf mold. Two adjoining plots of virgin post oak-blackjack woodland were put under control, both having the same soil, slope, and vegetative cover. One was left as nature established it; the other was burned over. During the nine months since this experiment was started the unburned land has lost water by run-off (rains have been infrequent thus far) at the rate of 338 gallons an acre, as against 28,250 gallons an acre lost from the burned plot. Only a trace of soil was washed off the area still having its cover of forest litter and leaf mold, whereas a considerable amount was lost from the burned-over ground. In other words, the burned-over land has lost water by run-off during the life of the experiment at the rate of nearly 100 tons an acre in excess of the run-off from the unburned land plus the water-holding capacity of its unburned litter and forest-mold cover. This would indicate that when the forest ground cover is burned muddy water is allowed to enter and clog up the pore spaces of the soil, thus enormously reducing the water-absorbing capacity of the ground.

These results are of the utmost importance in that they furnish a much clearer understanding of the function of forest litter, forest mold, grass litter, or any similar material of a protective-cover character. The discovery points to a number of possibilities for vegetative erosion control.

At the Kansas station an experiment to determine the possibilities of growing alfalfa in the uplands of western Kansas and Nebraska through the increased storage of rain water in the soil, with the assistance of closed terraces, is indicative of successful results. Further trials will be necessary, however, in order to cover the necessary annual variations of rainfall before final conclusions are reached.

RECONNAISSANCE EROSION SURVEYS

A reconnaissance erosion survey of the Brazos River, Tex., drainage basin, carried on in cooperation with the Brazos River Conservation and Reclamation Commission and the Texas Agricultural Experiment Station, was completed during the field season of 1930, and a report covering this survey is awaiting publication of the latest census data pertaining to Texas agriculture, in order to correlate the latest crop statistics with the areas of the various types of erosion found. This survey covered all or parts of 70 counties, embracing a watershed area of 27,114,240 acres. Of a cultivated area within the boundaries of the watershed, amounting to 9,483,807 acres, 8,175,328 acres were found to be suffering from sheet erosion and gullying. Of the latter class, there were 1,894,951 acres, with 40,490 acres abandoned largely because of gullying. In addition, there are 17,630,433 acres of uncultivated land, of which about 4,712,654 acres are gullied and 741,893 acres consist of rough broken land and rough stony land. A considerable part of this gullied area represents land which has been severely eroded by reason of overgrazing. Some of it consists of formerly cultivated land abandoned because of erosion.

The results of this survey indicate that floods in the Brazos River probably can never be adequately controlled until a far-reaching, effective system of soil and water conservation is put into operation over the drainage basin. More than this, the survey shows the distribution of the critically suffering areas and defines the type of erosion going on under each classification. Such information is vitally necessary for a comprehensive analysis of the needs of the area and its various component parts in connection with the problems of flood control, irrigation, and soil conservation.

The measurements of the annual losses of soil by erosion are showing that the more productive part of the land, the humus-charged topsoil, is being washed off at a rate which is rapidly lowering the crop-producing capacity of numerous important farm soils, thus adding to the area of marginal and submarginal land. Moreover, the information being obtained is bringing about a better understanding of the durability or lack of durability of our important farming soils. This knowledge will unquestionably serve to bring the users of land to a realization of the absolute necessity for better protection of all erosive cultivated areas. This new conception of the vital importance of the topsoil is based on the fact that within periods ranging from 30 to 75 years unless better protection against erosion is provided, the entire depth of the more fertile top layer of many exceedingly important types of farm land will be washed off down to the subsoil, which is not only much less productive (in many instances practically valueless), but which is much more difficult to till and much more susceptible to destructive gully washing.

Extensive field work by the bureau has clearly demonstrated that the topsoil of most farm lands is not nearly so deep as generally has been supposed. Of 172 soil samples, representing 115 important types of farm land (nearly all of them erosive uplands), collected from 34 States, only 7 samples were as thick as 16 inches. The average depth of the topsoil represented by the 172 samples was only 9 inches. Some of these soils are being washed away at the rate of 7

inches—which in some instances exceeds the total depth of the topsoil—in about 30 years, and others at the rate of 7 inches in 35, 40, or 50 years, and so on. In losing this important layer, which not only contains the bulk of the soil humus and beneficial organisms but, undoubtedly, a considerably larger amount of available plant food than the unweathered, raw subsoil, it is obvious that the farmer on this land is losing his principal capital.

This is a new conception of land value, and it is being rapidly brought to the attention of the American farmer as the result of the experiments now being made to solve the fundamental principles pertaining to erosion processes and to ascertain practical methods for erosion control. The measurements of the rates of run-off and erosion, as well as the rates of fertility losses, for various slopes undergoing various cultural and cropping systems, on different soils, are supplying indispensable data for measuring the effectiveness of terraces on various slopes and soils. The results are providing data, for example, which determine the rate of soil loss between the various obstructions employed to control erosion, as terraces, crop strips, etc. With this information it will be possible to fix definitely the degree of slope for different soil types at which cultivation must cease and the land be turned over to forestry or a permanent grass cover.

SOIL-SAVING CULTIVATOR

At the Hays (Kans.) erosion station, the representative of the Bureau of Chemistry and Soils, with the cooperation of the Fort Hays substation, has built a cultural implement which promises to prove effective in that region and possibly in other regions by causing more of the rainfall to sink into the ground, thereby reducing erosion. This machine, which has attracted much attention, can be used both as a cultivator for row crops and as a surface-tillage implement for fallow. The important feature about it is a set of alternating shovels which work up and down so that with the forward motion of the machine the shovels scoop out dirt and leave holes in the ground. The excavations thus made alternate with piles of dirt, dropped between each pair of adjacent holes. The surface condition produced when the machine is run up and down the hill should be as effective in conserving water as that produced when operating along the contours. As now constructed, the machine leaves approximately 10,000 holes to the acre, each hole having a capacity ranging from 2 to 3 gallons of water. Although the holes collectively impound a large amount of water, their greatest value comes from the fact that the water is held still and given a chance to soak into the ground. Furrows, such as accelerate run-off, are not produced. When the holes are filled with water the overflow must escape by zigzagging around the piles of dirt. This results in slowing down the rate of flow and in increasing the amount of soil-absorbed rain water.

A set of regular cultivator shovels precede the digging shovels and can be used in case the latter do not destroy all the weeds. The digging shovels destroy the furrows of the cultivator shovels. This implement is still in the experimental stage. A machine of this

kind is needed and should find a very worth-while place in the exceedingly important problem of erosion control and moisture conservation.

EDUCATIONAL PROGRAM

More and more interest is being aroused in this great national problem. The educational side of the soil and water conservation program is being carried on as effectively as possible. The extension agencies of the Nation are taking hold of the problem in a determined way. They are carrying erosion-control information direct to the farmers as rapidly as it becomes available. Soil-saving campaigns are being put on in regions where until recently there was little or no interest in the matter.

The various erosion experiment stations are attracting much attention on the part of the farmers, agricultural colleges, high schools, vocational schools, county agents, bankers, insurance companies, implement manufacturers, and railroad officials of the regions affected. Frequent visitors are coming to the stations and are being shown the various experiments in detail. A recent field meeting held at the Bethany (Mo.) station was attended by hundreds of farmers, bankers, teachers, county agents, and others. Twenty-six Missouri counties and 20 Iowa counties were represented.

SOIL-FERTILITY INVESTIGATIONS

COTTON SOIL-FERTILITY STUDIES

The experiments with cotton on ratio of inorganic and synthetic nitrogen to organic nitrogen of vegetable and animal waste origin have shown that best results are obtained with fertilizers containing the nitrogen in ratio of about 80 per cent inorganic or synthetic to 20 per cent organic. This result is strikingly shown in experiments on Cecil clay loam at Youngsville, N. C., and is in general harmony with the results of experiments conducted by several State experiment stations on many soil types in the South. These investigations have been extended cooperatively with the North Carolina Agricultural Experiment Station in experiments on Ruston sandy loam at Fayetteville, N. C.

Three years' results have been secured in cooperative experiments with the Georgia Agricultural Experiment Station on the fertilizer requirements of Norfolk sandy loam at Waynesboro, on Orangeburg sandy loam at Fort Valley, on Carnegie sandy loam at Cuthbert, on Cecil clay loam at Yatesville, and one year's results on Clarksville silt loam at Adairsville. The experiment on each soil type includes plots in five replications and will be continued five years on the same plots. The results thus far secured, which have a practical and scientific value, show varying fertilizer requirements for the different soil types.

POTATO SOIL-FERTILITY AND FERTILIZER INVESTIGATIONS

Cooperative soil-fertility and fertilizer studies of the past year on potatoes in Maine, New York, New Jersey, Pennsylvania, Michigan, Ohio, and Virginia cover factors influencing the growth, composition, quality, and yield of potatoes when grown on prominent

soil types. The yield studies in 1931 were conducted in cooperation with agricultural experiment stations and leading potato growers. The soil-fertility and fertilizer investigations on potatoes continue to furnish results of practical benefit to the $400,000,000 potato industry.

The results obtained during the fiscal year have continued to furnish information with respect to the proper ratio of nitrogen, phosphoric acid, and potash for use in potato production on prominent soil types; the kind and amount of nitrogen materials to employ; the kind and amount of potash materials to use in fertilizer mixtures; the amount of phosphoric acid necessary for optimum production; and the most economical rate of application of fertilizer for potatoes on prominent soil types. In the commercial potato-growing regions close contact was maintained with potato growers and their organizations, meetings were held in various sections, and the work was explained to the growers.

Soil-fertility and fertilizer investigations covering the influence of fertilizer composition and ratio on the shape, quality, and yield of potatoes were completed. This work was conducted cooperatively by the Bureau of Chemistry and Soils and the New Jersey Agricultural Experiment Station. A further coordinated field and laboratory investigation conducted by the Maine and New Jersey stations and the Bureau of Chemistry and Soils along similar lines has been completed, and the results are being assembled for publication.

The effect of different potash salts on starch, protein, and total solids content of potato tubers has been continued and results of interest obtained.

A study to determine the influence of ordinary strength and concentrated fertilizers on fresh-cut and suberized potato seed stock, conducted cooperatively by the Bureaus of Chemistry and Soils and Plant Industry was terminated during 1931. The data obtained indicate clearly the advantage of suberization. Better germination was secured with suberized stock, and the yields were proportionately better. The significance of the results is evident when it is considered that more and more highly soluble chemical salts are being used in fertilizer mixtures, thereby necessitating greater care in the application of modern fertilizer mixtures, particularly on our light soils. Cooperative investigations were established in 1931 with the Michigan, New Jersey, and Ohio stations to study the comparative effectiveness of a number of methods of placement of fertilizer on potato germination, stand, and yield. Through such an investigation it is expected that results of practical importance to potato growers will be obtained.

SUGAR BEET SOIL-FERTILITY INVESTIGATIONS

During the past year, permanent field headquarters for soil-fertility and fertilizer studies with sugar beets have been established at Scottsbluff, Nebr., and at St. Paul, Minn.

Under a cooperative agreement with the Nebraska Agricultural Experiment Station, a tract of land was acquired by the latter for a cooperative fertilizer-rotation experiment with sugar beets, barley, corn, and potatoes. The purpose of the experiment is to study the residual effect on other crops of fertilizers applied to sugar beets.

In addition to the above experiments, other fertilizer experiments with sugar beets are in progress at Sterling, Colo., and at Mitchell, Nebr., on the Scottsbluff substation.

A series of fertilizer experiments on sugar beets to test the response from different types of soil, using the same mixture on each, were located as follows: Kanawha, Iowa; Hector, Georgetown, Winthrop, Gaylor, and Bird Island, Minn.; and Grand Forks, N. Dak.

Crops from two cooperative fertilizer experiments with the Division of Western Irrigation Agriculture of the Bureau of Plant Industry, located at Huntley, Mont., and Newell, S. Dak., were harvested and reports submitted to the two cooperating offices. It is expected that, with the three years' results available this fall, the data will be submitted for publication during the fiscal year 1932. Other experiments with sugar beets harvested in 1931 included two fields at Kanawha, Iowa, and one at Chaska, Minn.

Five complete triangle fertilizer experiments in cooperation with the Bureau of Plant Industry were conducted at Oxnard, Calif.; Twin Falls, Idaho; Fort Collins and Rocky Ford, Colo.; and Saginaw, Mich.

Increases in tonnage from 2 to 7 tons an acre were obtained with phosphate alone, which is apparently the controlling element in sugar-beet fertilization, but there is an apparent wide difference in the results from different soil types. Experiments are now in progress to study this phase of the problem.

STRAWBERRY SOIL-FERTILITY INVESTIGATIONS

Seven field experiments with strawberries are being conducted in cooperation with growers. These are located in the Chadbourn, N. C., district on the Norfolk, Coxville, and Dunbar soil types. A cooperative experiment with the Bureau of Plant Industry is in progress on the North Carolina Coastal Plain Experiment Station at Wallace.

It has been the general practice in the Chadbourn district to use about 1,500 pounds an acre of a well-balanced commercial fertilizer annually, in two applications—one in late summer and the second in late winter. The experimental work has shown that yields are greatly increased when all the fertilizers are applied in late summer or early fall. Fifteen hundred pounds an acre of fertilizer applied in late summer increased the acre yield from 400 to 500 quarts of berries more than split applications of fertilizers, that is, one-half in summer and one-half in winter. The berries also matured earlier. This change in time of applying fertilizers resulted in an increased profit of $75 an acre this season, as berries sold from $5.50 to $7.30 per 32-quart crate.

Experiments planned to determine the best ratio of nitrogen, phosphoric acid, and potash to use in growing berries have shown that mixtures containing from 4 to 6 per cent nitrogen have given best results and most profit. One important effect of potash this season was to increase the firmness and keeping quality of the berries to such an extent that they kept much better when stored or hauled than did berries grown without potash. Muriate of potash and sulphate of potash have had about the same comparative effects.

SOIL-FERTILITY INVESTIGATIONS WITH SUGARCANE

The soil-fertility and fertilizer investigations with sugarcane included both field and laboratory studies. Separate reports covering the accomplishments for the year were submitted for the two subprojects, one of which will appear in the near future as a joint bulletin of the Louisiana Agricultural Experiment Station and the Bureau of Chemistry and Soils. The report of field investigations includes a complete description of the main soil series as determined by a reconnaissance survey of the entire sugarcane belt of Louisiana. The individual soil types on which the various fertilizer experiments were placed are also described in detail. The results of experiments showed very definitely that although nitrogen is the controlling factor, on certain soil types the best results are to be expected from a better-balanced ration of all three fertilizer elements.

The soils of the sugarcane belt have been grouped as follows: (1) Mississippi alluvium, terrace soils; (2) Mississippi alluvium, first bottom soils; (3) Red River sediments; (4) Mississippi-Red River sediments; and (5) coastal-prairie sediment of the Gulf coastal plain.

First-year results were also obtained from a series of experiments to determine the various rates of application and sources of nitrogen, including ammonium sulphate, cyanamid, cal-nitro, calurea, and sodium nitrate. From the one year's results only slight differences were obtained from the different sources of nitrogen, and an application of about 40 pounds of nitrogen to the acre appeared to give the most profitable results. Soil studies to determine the soil reaction most favorable to sugarcane production were continued at intervals throughout the year.

Samples of juice milled from the cane grown on the various fertilizer plots were collected and analyzed to determine if possible the effect on the juice of the application of different fertilizer mixtures such as are included in the five triangle experiments of 21 different mixtures each. A report on this work is being prepared.

A complete set of representative samples of the main soil types of the sugarcane belt is being collected at the Houma laboratories, and it is expected that the analytical work on these samples will be completed during the coming year.

Within the past year studies have been undertaken of different chemical and biological methods designed to hasten the decomposition of bagasse and other cane waste.

CONCENTRATED-FERTILIZER EXPERIMENTS ON PROMINENT SOIL TYPES (NORTHERN STATES)

During the past year further results of importance were obtained showing the crop-producing and economic value of concentrated fertilizers. The close experimental contact made possible between farmers and their organizations has served to bring to their attention the economies to be effected through the use of concentrated fertilizers, such as savings on mixing, bags, freight, hauling, and handling. In Aroostook County, Me., for example, the short growing season makes the use of high-analysis fertilizers particularly appropriate. The results obtained there by the Bureau of Chemistry and

Soils during 1931 and preceding seasons have done much to guide potato growers in the selection of fertilizers and to assure them that the use of fertilizers was warranted. A report of the cooperative results was issued by the Maine Agricultural Experiment Station. The results obtained with concentrated fertilizers during the year emphasize the necessity of exercising the utmost precaution in the use of concentrated fertilizer mixtures on the lighter, sandier soil types. Continued research is essential on such soils, especially that pertaining to the distribution and placement of concentrated fertilizers. Evidence is abundant that the promiscuous use of high-analysis fertilizers on light soils has been followed by retarded germination, broken stand, and reduced yields. It is on such soils that the importance of proper distribution and placement of concentrated fertilizers is becoming more evident.

Other crops used as indicator plants in the 1931 field work have been corn, wheat, Lima beans, string beans, peas, sugar corn, sweet-potatoes, and tomatoes.

The greater purity of synthetic fertilizer salts makes it imperative that a greater volume of investigational work be established, particularly on leachy soils. Results obtained during the year have indicated that, on such soils where systematic rotations are not practiced, the continued use of the relatively pure fertilizer salt mixtures may create serious deficiencies of minor elements like manganese, boron, copper, iodine, and similar elements.

Studies of this kind are in progress in New Jersey, but up to this time no appreciable curtailment of yield, regardless of the composition of the fertilizer, has been noticed.

CONCENTRATED-FERTILIZER EXPERIMENTS ON PROMINENT SOIL TYPES (SOUTHERN STATES)

Experiments with concentrated fertilizers are in progress in the Southern States in North Carolina, South Carolina, Georgia, and Florida. The field work is conducted partly in direct cooperation with farmers, and partly on State farms, cooperatively with State experiment stations. The investigations with concentrated fertilizers are concerned with a study of methods and time of application in order that this class of fertilizers may be used to best advantage, and with a view to supplying deficient essential elements which may not be contained in the pure salt concentrated fertilizers and which may be essential for successful crop growth on certain deficient soils.

Experiments with cotton have been in progress and are being continued on Cecil clay loam at Raleigh, N. C.; on Norfolk sandy loam at Holland, Va.; and on Norfolk deep sand at Pontiac, S. C., cooperatively with the experiment stations of these States. A study of time and method of application is being made in these experiments. Concentrated fertilizers, as compared with ordinary so-called low-analysis fertilizer, have caused a slight delay in germination of seed and frequently in poor stands, especially when the fertilizers are placed in contact with the seed or under the seed. There is less interference with seed germination when the fertilizers are placed to the side of the seed or applied about 10 days before planting and well mixed in the soil. The accumulation of soluble salts in the topmost 2 inches of soil, the region of seed placement, was greater with the use of concentrated fertilizers than with ordinary fertilizers. The

effect on yield has been to decrease it below that of ordinary fertilizers, especially when used on the same plots year after year on the coastal-plain soils.

The possible result of concentrated fertilizers failing to supply all the essential nutrients is being investigated in experiments with cotton on Norfolk sandy loam at Goldsboro, N. C.; on Cecil clay loam at Newton, N. C.; and Cecil sandy loam at Experiment, Ga.; with sweetpotatoes on Norfolk fine loamy sand in Currituck County, N. C.; and on tomatoes, truck crops, and citrus fruits in Florida.

The addition of calcium, magnesium, and a number of the heavy metals, such as nickel, copper, zinc, and manganese, to concentrated fertilizers has been to increase crop yields on most soils worked with. The yields of cotton in the North Carolina and Georgia experiments and of tomatoes in Florida have not been so large from concentrated fertilizers as from ordinary fertilizers. With the addition of some or all of these chemicals to concentrated fertilizers, the yields increased and were as large or larger than when ordinary fertilizers were used.

COTTON ROOT-ROT INVESTIGATIONS

The program of field fertilizer experiments on the relation of fertilizers and soil-fertility factors to cotton root rot, inaugurated in Texas in 1929 and 1930, is being conducted along the same general lines. There has, however, been some expansion in number and size of fields, in order to provide for comparative trials of new fertilizers, more comprehensive tests of phosphate sources and particle size of new fertilizers, experiments leading to a more practical and economical system of fertilizer usage, and extension of tests on the effects of subsoiling and deep tillage. New experiments were made of combined planting and fertilizer distribution, using a standard 2-row planter, which is important in respect to the development of a practical fertilizer usage for the black-land cotton root-rot region.

Seventeen field fertilizer experiments are being conducted in cooperation with farmers. These are located in nine counties in the black-land belt of Texas. In addition to these, cooperative experiments are in progress at substation No. 5, a branch station of the Texas Agricultural Experiment Station. Cooperative field experiments with the Bureau of Plant Industry are in progress at the United States cotton-breeding station at Greenville, Tex., and at the United States field station at San Antonio.

In general, consistent and significant increases in yield have been obtained from applications of fertilizer mixtures containing combinations of phosphate and nitrogen. In some instances the response was predominantly to phosphate, in some others nitrogen was predominant in effect. In most cases the increases were profitable from an economic standpoint, and in most cases they were of such magnitude as to offset losses due to root rot. The more highly phosphatic fertilizers led to a marked acceleration of maturity. This effect is of such a degree as to constitute a very promising means of evading losses from root rot. Certain of the newer concentrated fertilizers containing combinations of phosphate and nitrogen are particularly effective. The increase in yield of cotton and the acceleration of maturity resulting from the use of appropriate

fertilizers may constitute an effective means of offsetting and evading losses due to root rot.

Late-summer subsoiling in conjunction with a rotation crop is highly successful in reducing root-rot infestation. In an experiment on root-rot infested Houston clay, a section subsoiled in late summer and returned to cotton the following year, only 1.5 per cent of the plants succumbed to root rot, whereas 27 per cent of the plants on a nonsubsoiled section died. The cotton on the subsoiled area showed superior plant growth and produced a very appreciably heavier yield than on the control area. As a means of direct control of cotton root rot, midsummer subsoiling in conjunction with a noncotton rotation crop appears very promising. Growers in general, and cooperators in particular, have been greatly impressed by the favorable effects of subsoiling and chiseling as a means of controlling cotton root rot. The use of phosphate fertilizer on subsoiled land has resulted in profitable increase in cotton yield.

Complete chemical analyses have been made of a large number of samples representing the common variations of the principal soil types of the black-land region of central Texas. The data yield important information on the fundamental character of the several soils. In most instances heavily infested areas are calcareous and alkaline, whereas noncalcareous soils of neutral and slightly acid reaction are much less subject to infestation or are entirely free of the disease. Soils low in soluble phosphoric acid are conducive to cotton root rot. Cotton root rot is minimized on soils containing an appreciable quantity of water-soluble phosphoric acid. Readily available phosphoric acid applied to cotton root-rot infested soils hastens maturity and increases the yield of the crop.

FERTILIZER INVESTIGATIONS WITH PECANS

Field experiments are in progress in some of the principal pecan sections of the South to study soil and fertilizer factors which influence tree growth, nut yield, and quality of the pecan. The field offices are maintained in conjunction with divisions of the Bureau of Plant Industry and the Bureau of Entomology, which are working cooperatively on pecan problems.

Four field experiments in progress in the Albany, Ga., section are located on some of the principal soil types used for pecans, including Norfolk deep sand, Bladen fine sandy loam, Greenville sandy loam, Orangeburg sandy loam, Norfolk sandy loam, Elkton silt loam, Miller loam, Lintonia loam, and Ruston fine sandy loam. These experiments have shown that nitrogen is the most important fertilizer element for tree growth and yield of nuts, but that phosphate and potash are also required for best results. When leguminous cover crops are grown for green manure, some nitrogen is supplied. Fertilizers containing from 4 to 6 per cent nitrogen, 8 to 10 per cent phosphoric acid, and 3 to 4 per cent potash have given good results on most soils of the southeastern pecan belt. The fertilizer problems of many of these soils are complex and are being studied to determine the most suitable time to apply fertilizers, the relation of fertilizers to cover crops, and other features of the pecan industry.

Chemical work in progress in well-equipped laboratories at Albany and Shreveport is expected to throw much light on the problems

under study, including (1) chemical changes in soils as a result of the use of fertilizers of varying composition and the use of different green-manure crops, (2) the relation of soil type, soil composition, and soil moisture to pecan production and nut quality, and (3) the influence of fertilizer on the filling and eating qualities of the pecan.

FERTILIZER INVESTIGATIONS WITH SWEETPOTATOES AND POTATOES

The fertilizer investigations with sweetpotatoes and potatoes in North Carolina are being continued. Experiments which have been conducted for four years are in progress with potatoes on Bladen fine sandy loam at Aurora, N. C. The year's results are in harmony with those obtained in the three preceding years, showing that a fertilizer containing 5 per cent nitrogen, 7 per cent phosphoric acid, and 4 per cent potash gives larger yields than other fertilizers that have been analyzed, and that 2,000 pounds an acre is the most profitable quantity to use. The results also show that the source of nitrogen in the fertilizer mixture is important. Fertilizer having its nitrogen derived 80 per cent from mineral or synthetic sources and 20 per cent from organic sources of vegetable or animal waste origin has given best results.

Fertilizer studies with sweetpotatoes, which have been in progress for several years on Norfolk loamy fine sand in Currituck County, N. C., are being continued on concentrated fertilizers, sources of nitrogen, sources of potash, and placement and time of applying fertilizers.

Low-grade potash materials, such as manure salts and kainit, when used in fertilizers with superphosphate and nitrogen caused damage to young potato sprouts, resulting in a great loss. In the bureau's experiments with fertilizers containing mineral or synthetic nitrogen as source of nitrogen, or kainit as source of potash, the accumulation of water-soluble salts around the roots of the young plants during the first three weeks was high, and the salt concentration correlated with the percentage of plants dying in the plots. The investigations further show that fertilizers can be used with less injury to potato sprouts if applied to the side of the potato row, or if applied either broadcast over the top of the row or as a side dressing about two weeks after the plants have been transplanted and after they have developed a root system.

A report is in course of preparation for publication, giving the results of fertilizer experiments with sweetpotatoes on Norfolk loamy fine sand in Currituck County, on Portsmouth fine sandy loam in Craven County, on Norfolk sandy loam in Carteret County, and on Cecil sandy loam in Catawba County.

This project is cooperative with the agronomy division of the North Carolina Agricultural Experiment Station.

INVESTIGATIONS WITH PEACHES

An experiment to study the winter injury to peaches, as influenced by fertilizers, green-manure cover crops, and tillage operations, at Experiment, Ga., cooperative with the Georgia Agricultural Experiment Station, is in progress. Analysis of peach-tree twigs for stored

plant nutrients in fall, midwinter, and early spring is being made, with the thought of correlating fertilizer practice, green-manure usage, and tillage operations with growth factors and winter killing of trees. The analytical work was begun in 1931 on trees fertilized differently since 1929. The experiment is planned to study factors causing loss of peach trees by winter injury.

INVESTIGATIONS WITH CITRUS AND TRUCK CROPS

Nineteen field fertilizer experiments with truck crops inaugurated in Florida in 1930 were continued in 1931. Experiments are in progress in the principal trucking sections of the State, including Alachua, Brevard, Dade, Hillsborough, Indian River, Orange, Manatee, St. Lucie, St. Johns, and Seminole Counties, with cabbage, celery, beans, lettuce, peas, peppers, potatoes, strawberries, and tomatoes. Some of the experiments are located on State branch experiment stations and some on farms in cooperation with growers.

Fertilizers containing quickly available nitrogen salts of inorganic or synthetic origin have given best results on such truck crops as cabbage, lettuce, beans, and garden peas. Where the nitrogen contained in the fertilizer was principally from organic materials the crops developed slowly and were late in maturing. An application of low-grade organic-nitrogen material before planting followed by the use of quickly available nitrogen during the growth period brought best results. On many crops, especially celery, the use of physiologically acid fertilizer, such as urea and ammonium sulphate, was unfavorable, unless the soil was well limed prior to planting. Other soils, more acid in reaction, have given better results with fertilizers containing sodium nitrate. On certain truck soils, where strawberries and peas were grown, concentrated fertilizers, composed of pure salt chemicals, when fortified by the addition of traces of manganese, zinc, copper, nickel, and borax, have given more vigorous plants and larger yields than did the concentrated fertilizers or old-line fertilizers.

On the calcareous glade soils of Dade County, Fla., concentrated fertilizers gave reduced yields of tomatoes, as compared to yields from fertilizers made from superphosphate, potash salts, sodium nitrate, ammonium sulphate, tankage, and fish scrap. The addition of manganese to concentrated mixtures increased yields appreciably. The addition of copper, zinc, nickel, and manganese gave relatively larger increases which greatly exceeded the yield from pure salt-concentrated fertilizer or from old-line fertilizers.

Experiments are in progress with citrus fruits to study the effects of manganese sulphate on tree growth, leaf chlorosis, fruit production, and fruit quality. On some soils, especially those having a slightly acid or alkaline reaction, the addition of manganese sulphate improved the vigor of the tree, the character of the foliage, and the size and quality of the fruit. The results are sufficiently promising to justify an extension of this line of investigation with citrus-fruit soils, and well-planned experiments are being inaugurated with rare essential chemicals and concentrated fertilizers in groves located on four distinct soil types. In these experiments concentrated fertilizers

have given good results as to tree growth and fruit yields. There are some indications, however, that the quality of the fruit and the percentage of juice it contains are not so desirable as when fruit is grown with old-line fertilizers.

GREENHOUSE SOIL-FERTILITY INVESTIGATIONS

The greenhouse investigational work during 1931 included a study of the influence of different phosphorus carriers on the growth and yield of lettuce, sugar beets, millet, wheat, rye, and grain sorghum. In general, it was found that the response to the phosphorus carriers was directly proportional to the availability of the phosphorus. In some instances, however, interesting departures occurred. For example, sugar beets responded markedly under greenhouse conditions to the less soluble phosphates. If the same response occurs in some of the sugar-beet growing sections of the West, the results will be an economic advantage to phosphate producers and consumers.

Studies with two natural potash carriers, alunite and polyhalite, in comparison with sulphate of potash have given indications that they possess a fair degree of availability in their natural state. These tests were conducted on oats and wheat and will be continued on other crops.

New work was started in 1931 in an attempt to determine the relative value of synthetic and natural sodium nitrate on the growth of certain vegetable crops. This greenhouse research involves primarily the question of appraising the value of uncommon elements.

A considerable volume of service and routine work was accomplished for other divisions and bureaus of the department, such as lime requirement, nitrate, moisture, and other determinations, as well as carrying on pot studies in the greenhouse.

COOPERATIVE SOIL-FERTILITY INVESTIGATIONS

The work of the Bureau of Chemistry and Soils on the cooperative project with the Bureau of Dairy Industry, Bureau of Plant Industry, and the South Carolina Agricultural Experiment Station has continued at the Sandhill experiment station. Chemical studies are made of changes in soil and the character of soil organic matter as a result of various green-manure crops in experiments conducted by the division of forage crops and diseases of the Bureau of Plant Industry. During the year several thousand chemical determinations were made.

Green-manure fertilizer experiments indicate that the addition of commercial fertilizers in the growing of cotton and corn in the sands of the station is essential. The use of a commercial fertilizer containing a high percentage of nitrogen (6 per cent), in conjunction with the turning under of stubble from a previous green-manure crop, has given larger yields than the use of a fertilizer containing a low percentage of nitrogen (2 per cent) in conjunction with the turning under of stubble and all vegetative matter of a previous green-manure crop. This result has an important economic bearing on the cropping system of the sand-hill region.

A system of 24 lysimeter tanks is being installed to supplement field plots in a study of fertilizer and green-manure problems pertaining to the building up of the soils of the sand-hill region. It is believed that more exact and reliable data can be obtained, which will contribute to solving these problems in a shorter period.

PLACEMENT OF FERTILIZERS

A comparison of methods of applying fertilizers to cotton has been under investigation in South Carolina in cooperative experiments conducted by the Bureau of Chemistry and Soils, the Bureau of Public Roads, the South Carolina Agricultural Experiment Station, and the National Fertilizer Association.

Greatest yields were obtained with the fertilizer placed closest to the seed, when injury to germination was not serious. The distance between seed and fertilizer for best results was shown to depend on factors such as character and moisture content of the soil and climatic conditions. The placement of fertilizers in relation to the seed has become important since fertilizers have undergone a change in composition in regard to their content of quickly soluble salts. Results from these studies have been helpful in obtaining good stands of cotton in regions where large quantities of fertilizers are required for cotton production.

Owing to the demand of fertilizer manufacturers, potato growers, and their organizations, field studies were started in 1931, in cooperation with the New Jersey, Ohio, and Michigan Agricultural Experiment Stations to compare different methods of fertilizer placement for potatoes.

SOIL CHEMISTRY AND PHYSICS INVESTIGATIONS

In connection with the laboratory investigations of the physical properties of the soils from the erosion experiment stations, laboratory studies are in progress to determine the maximum field moisture-carrying capacity of the horizons of each soil profile, with a view to a correlation of this property with field data.

Much fundamental data is being accumulated regarding the physical and chemical character of soils which erode badly. Results obtained and published in 1930 describe determinations that are particularly valuable in evaluating the erosional characteristics of soils. These, as well as complete mechanical and chemical analyses, are being carried out on samples from soil profiles of each of the erosion stations. As soon as field data are accumulated at the erosion stations, correlation will be made with the laboratory results. In connection with erosion investigations a study was made of field percolation rates. The results of this investigation, which have been recently published, show that percolation in the field is governed to a much greater extent by holes, cracks, and crevices, irrespective of origin, than by the mechanical composition of the soil. The capacity of the soil to disperse in water and to fill such cracks is the most important factor in regulating the rate of water percolation through soils. A soil auger was devised suitable for taking cores of undisturbed soil from the field for use in this investigation.

Work has been carried almost to completion on soil colloids as semipermeable membranes. This work has an important bearing

on moisture conditions in the soil. The results to date show a general relationship between the osmotic pressure developed with soil colloids as membranes and the major chemical constitutents of the colloids.

Studies of the mineralogical composition of soils from various series indicate that the mineralogical composition of soils may vary to a considerable extent without materially affecting the classification of the soil by the soil-survey method. Work on soil colloids is being continued. One phase of the work, which is nearing completion, deals with the fractionation of colloidal material from different soil groups and shows that from many soils successive fractions of colloid may be approximately constant in character, whereas others may be effectually fractionated into groups of widely differing chemical characters.

The research on the causes of infertility of certain soils has had to do particularly with soils of high magnesium content. This work is nearing completion and will be published soon.

An investigation of the physical and chemical characteristics of certain American peat profiles has been completed and the results published. This work shows that the chemical composition of peats is greatly influenced both by the character of vegetation from which the peats have been derived and by the climatic conditions which prevailed during their formation.

Experiments are in progress with a view to ascertaining the value of certain peats as ingredients of fertilizer from the standpoint of their decomposition and the availability of the nitrogen. Experiments just completed and submitted for publication show that the base-holding power of peats and particularly of peat colloids is relatively high, suggesting the probability of a beneficial effect from this standpoint when they are added to soils, especially those which have been greatly weathered and leached. Investigations in progress show that peat colloids and colloidal materials from other organic sources possess high and varying absorbing power for water and for plant-food materials. Knowledge of the specific properties of such materials should aid in the selection of those best suited for top-dressings of sod and for special cultural purposes.

It has long been known that phosphatic fertilizers are much more efficacious on certain soils than on others. An investigation under way shows that the colloidal materials of soils differing in character are quite unlike in their effect on the assimilation of phosphorus by plants. Progress is being made in correlating this effect with the chemical character of the soil colloids and thereby giving a basis for predicting something of the degree of beneficial action which might be expected from applications of phosphatic materials. A study is also being made of soil treatments that will increase the efficiencies of phosphatic fertilizers.

Tests of the new method of dispersing soil material by means of supersonic waves have been completed and the results submitted for publication. It was found that dispersion could be obtained more readily than by conventional physical methods, but that even with the aid of the powerful supersonic waves complete dispersion in some cases could be obtained only after very prolonged treatment.

In several instances this division has assisted in carrying out research projects which are being pursued primarily by other divi-

sions of the bureau. One of these, dealing with the physical and chemical composition of finely divided natural phosphates, has been completed. The pipette method developed for the mechanical analysis of soils has been successfully applied to natural phosphate materials. Some relation has been found between phosphoric-acid content and specific gravity in the case of natural phosphates. Samples with high phosphoric-acid content have higher specific gravities than the lower-grade materials. Another project nearing completion involves a crystallographic examination of various mixtures of concentrated fertilizers. The results to date show that in most cases of mixed fertilizer ingredients a much shortened microscopic examination is entirely adequate to identify the chemical compounds present.

The routine physical and chemical analyses of the division included approximately 600 mechanical analyses and 500 chemical examinations and analyses. About 80 of these involved chemical determinations of all constituents present. Many of these examinations were made for the soil survey, soil erosion, and smelter fumes investigations, as well as for other divisions of this bureau. Others were made for the Forest Service, Bureau of Public Roads, Bureau of Plant Industry, and for other Government departments.

SOIL MICROBIOLOGY INVESTIGATIONS

The division of soil microbiology has continued to follow two general lines of work: (1) The investigation of the legume nodule organisms as an adjunct to crop growing, together with the inspection of cultures offered for sale for this purpose, and (2) the study of the character and activities of the general micropopulation of the soil.

Commercial preparations of nodule and other soil bacteria presumably beneficial to plant growth have been collected under more than 50 trade designations to the extent of more than 600 samples. In addition to these, 25 samples of seed inoculated with material of several kinds have been obtained.

Field comparisons of materials applied wet and dry have given results favorable to the former.

The samples collected, whether seed or cultures of organisms in packages, have been examined or are in the process of examination for their flora of microorganisms, principally their content of legume-nodule organisms, and for their ability to produce satisfactory nodulation and plant vigor on the legumes for which they are intended.

The quality of the samples of inoculating material for legumes of the major producers continues to be fairly good, but it was found that there are several small producing firms which manufacture practically worthless cultures.

Information concerning the quality of inoculants has been disseminated by letter, published lists, through the Extension Service, and by personal contacts. Companies which cooperate with the bureau have been notified of defects found in their material.

ROOT-NODULE BACTERIA

Several strains of nodule organisms for each of the common legume crops are maintained continuously by the bureau, and many of them are tested each year. For the less common crops, cultures are ob-

tained by exchange or by isolation, wherever possible. The collection contains cultures favorable for nearly all the legumes grown in the United States. These cultures are available for experimental work with other bureaus, colleges, experiment stations, or individuals doing research work in this field. Cultures belonging to various series are furnished from time to time to institutions or firms supplying the farmer with inoculating material.

The need for definite experimental results in the use of nodule bacteria under local conditions in widely separate regions is being met by cooperation with States and corporations or associations.

There has been much doubt expressed as to whether inoculation of a field planted continuously to the same crop should be repeated every year. Although the results of many experiments have been inconclusive, the most recent experiments of the bureau clearly support the advice to apply a fresh active culture each year.

In cooperative work with the Bureau of Animal Industry in Louisiana, in 1929, a part of a field of Austrian winter peas showed good nodulation and abundant evidence of nitrogen fixation. Part of the field showed nodulation but no visible advantage to the crop, the nodule organisms present apparently being parasitic. The organism isolated from these nodules was tested in the greenhouse with the same result. In the winter of 1930–31 Austrian winter peas were again grown in the same field, part with favorable inoculation, part with the unfavorable strain, and part without inoculation. The unfavorable results were repeated except that where a favorable culture was applied to the seed in addition, the crop was fully benefited by the nodulation obtained. Manifestly the use of a good culture produced favorable results in spite of the presence of an unfavorable nodule organism in the field soil.

COOPERATION IN THE INTRODUCTION OF LEGUME BACTERIA

There continued to be a demand on the part of extension agents, instructors in vocational schools, chambers of commerce, and Members of Congress for assistance in the introduction of legume growing by furnishing free inoculation. These demands have been complied with so far as they have seemed reasonable. Some individual requests from farmers have continued to come in. The cultures sent out in response to various demands have totaled about 4,000 during the past year. Every effort is made to acquaint all inquirers with a list of institutions and commercial firms supplying inoculating material of satisfactory quality.

PAPER-MULCH STUDIES

The influence of paper mulch on the activity of the soil microorganisms has been studied, especially as regards the production of nitrates. The influence of the higher moisture of the mulched soil seems to increase the soil microflora but does not increase the nitrate content. It seems, however, to affect the distribution of the nitrates, and this may prove a very important factor. In the unmulched soil nitrates accumulate at the surface, whereas in the mulched soil they are evenly distributed to considerable depth.

STUDIES ON THE OCCURRENCE OF RADIOBACTER

Bacillus radiobacter has been found to dissociate in culture into the so-called " rough " and " smooth " types of growth. The crown-gall organism, *Phytomonas tumefaciens*, also dissociates, therefore these two can not be distinguished from each other by this phenomenon. Conditions favoring dissociation have been studied and attempts made to evolve a " radiobacter strain " from the pathogenic crown-gall organisms.

MICROBIOLOGICAL STUDY OF SELECTED SOILS

The experimental work for the purpose of following the changes in nitrogen in a number of selected soils has been continued. Soils were selected which are or have been used in connection with studies on other subprojects.

Of two sections of each soil in the greenhouse, one was kept fallow and the other was divided into two equal parts. One subsection was planted to corn and the other to wheat. Favorable conditions as to temperature, moisture, and aeration were maintained. Potash and phosphate fertilizers were applied in quantities sufficiently large to eliminate potash and phosphorus as limiting factors.

Continuous removal of crops of wheat and corn has decreased the yield, especially of corn, materially on all of the eight different soil types examined, except the " white alkali " soil from Colorado. The toxicity of this soil seems to have decreased, and yields obtained have shown gradual increase.

Studies of the microorganisms on the roots of the plants have shown that the roots of corn carry considerably greater numbers of fungi and bacteria than the surrounding soil. In certain slightly acid soils *Trichoderma* seemed to predominate, and in the alkaline soils no one species of microorganism seemed to outnumber the other.

GREEN-MANURING EXPERIMENTS

In green-manuring studies previously reported it was noted that the different green-manuring treatments had noticeably different effects on the succeeding corn crop. The treatments were therefore continued and records kept of the crop yields.

Where corn was planted immediately after the green manure was turned under, the rye had an inhibiting effect on the growth of corn. This was true on both limed and unlimed plots. However, when vetch was used in the same way the results were beneficial, and high crop yields were obtained.

GREENHOUSE AND FIELD STUDIES OF SOIL

Twelve plots of Keyport clay loam were established in the greenhouse. The following crops are grown for green manures: Timothy, peas, wheat, vetch, rye, and corn. On one plot of each kind the crops are turned under and in the duplicate plot the crop is left on the surface. Each plot is divided into two subplots, and corn is grown on one and the other is left fallow. The results to date show that the successive corn crops give the best returns when the green

manure is turned under. Evidences of nitrogen starvation are especially noticeable on the nonlegume plots. Records of yields and nitrogen removed are being kept, and the nitrogen-fixation question on these plots will be studied.

FUNGI OF THE SOIL

Cultures from vetch and rye left to decay on the surface show that the number of fungi in the decomposing material increased enormously, whereas the numbers in the soil, except in the surface one-fourth inch, did not change materially.

The distribution and character of the fungous element in all bacterial-culture work has been followed and reported with the bacteriological results, project by project. As a result of these observations a revised system of sampling has been developed in which the plant remains on the surface of the soil are taken first, then the soil is taken layer by layer to the usual depth of about 6 inches. Studies by this procedure have clearly shown that the fungi play a much larger part in the decomposition of organic remains on the surface than in material buried deeply in the soil. The numbers of microorganisms involved in such surface decomposition are prodigious in contrast to those in the homogenized sample of soil alone, sieved free from obvious organic remains.

Scrutiny of the organisms taking active part in this surface decomposition, shows that black and brown fungi predominate. Selected species of Alternaria and Cladosporium characteristic of this group, when grown in pure cultures and analyzed for lignin, show roughly 20 per cent ligninlike bodies in dry matter. Since the lignin complexes form a large part of the so-called humus of the soil, these black and brown forms are shown to be direct contributors to soil organic matter. This led to studies in cooperation with the division of soil chemistry and physics, which are showing that these same fungi make a notable contribution to the colloid fraction of the soil.

Experiments to determine just what part each of these groups of organisms plays in the breakdown of crop residues and other plant remains are in progress.

Another group of colorless and bright-colored soil fungi have been found, in the cooperative work with the division of soil fertility, to produce other organic constituents of the soil, the source of which had been previously unknown.

The study of the Myxomycetes, whose presence in the decomposing matter on the surface of the soil and in the soil itself was reported last year, has been continued. Surveys have shown amoeboids and plasmodia of this group to be present in decaying grasses and crop residues in many areas in the vicinity of Washington. Samples of soil at various depths, even mud from the bottom of lily ponds, have shown these organisms. Experiments to determine their physiological requirements and significance show that the organisms are most active vegetatively at 55° to 65° F., temperatures common in the soil during much of the growing season, whereas at higher temperatures they tend to fruit. In laboratory cultures they attack and disintegrate mold colonies and infest

other organic materials. Quantitative determinations of their biochemical activities are difficult because of the fact that it is practically impossible to grow them free from bacteria.

COOPERATIVE WORK

The National Institute of Health has continued to refer to this bureau calls for information about molds and for their identification, even in connection with human diseases.

The significance of certain common molds as causes of the allergic diseases has been worked out in cooperation with specialists on asthma and hay fever. Several groups of investigators in this field are making demands on this division for identification of their cultures and for the use of cultures already found active in connection with our experiments.

The importance of this field to the relief of individual suffering is considerable. Species of Aspergillus, Penicillium, Alternaria, Cladosporium, Polyporus, Monilia (Neurospora), and Cephalothecium have already been found accountable for these diseases in a series of cases, and the work has only begun.

There is continued interest in the application of species of Penicillium, Aspergillus, and related genera, long studied in this division, to industrial fermentations and to decompositions of various kinds involving loss or deterioration of different substances. A steady demand for conference, for the identification of organisms, and for supplying named cultures, is the natural corollary to the work already done.

During the past year collections of type cultures of Aspergillus and Penicillium have been furnished to Harvard University, the New York Botanical Garden, the Missouri Botanical Garden, and the University of California. A series of pill-box type specimens is being prepared for Kew Gardens, London, England.

FERTILIZER AND FIXED NITROGEN INVESTIGATIONS

This unit of the Bureau of Chemistry and Soils has for its objective the development of better and more economical methods of fertilizer production and use, to the end that our farmers and manufacturers, as well as the consuming public, may realize the maximum benefit to be derived from manufactured plant food. Inasmuch as it is the aim to improve a going industry, a little explanation of the situation as it is now will be helpful in reporting the activities and accomplishments of the year.

The American farmers' fertilizer bill amounts to approximately $250,000,000 a year. This is what they pay for some 8,000,000 tons of material prepared for application to the soil and containing about 350,000 tons of nitrogen, 800,000 tons of phosphoric acid, and 350,000 tons of potash in such form as to be available to growing plants within a reasonable length of time.

The fertilizer business of to-day is the result of 80 years of progressive change. With each improvement its scope of usefulness has been increased until now the industry contributes to the well-being of a large part of humanity. The United States ranks second only to Germany in the total quantity of commercial fertilizer used

and may be reasonably expected to take first place at any time and hold that position indefinitely, since there is no other competitor for first place. This country is independent in its phosphate supply and is rapidly becoming independent in its nitrogen supply, because of the recent growth of nitrogen fixation in the United States. However, a large part of the potash required is still imported.

Unquestionably the increase in fertilizer consumption is due mainly to the fact that its judicious use reduces the cost of crop production. Low prices and narrow margins of profit, such as the farmer must now contend with, leave little incentive to larger production except as larger yields mean lower unit costs. The farmer's faith in the ability of commercial fertilizer to help even in times of depression is evidenced by the fact that fertilizer sales have held up remarkably well and compare favorably with other lines of business in spite of reduced buying power on the farms. Fortunately nature restores a part of the soil fertility removed by cropping or by leaching and erosion or other damaging processes, but the maintenance of a high state of productivity requires, in addition, an artificial supply of certain of the elements lost.

The very best methods must be discovered and employed in the production and application of plant food if the maximum economic advantage is to be secured. It is an extremely intricate problem. The research activities include the development of new manufacturing processes and the improvement of those already in use, the production of new compounds, the investigation of new raw materials or by-products from other industries, and the determination of the characteristics of new products suggested for fertilizer use. The solution of the main problems often calls for the use of much fundamental chemical data which can be developed only by a comprehensive research program.

NITROGEN

Fixed nitrogen has a multitude of uses in agriculture and refrigeration, and in the manufacture of chemicals and explosives. Agriculture leads with a consumption of 75 per cent of all nitrogen used in the United States and 87 per cent of the world's supply. By the year 1900 it became apparent that nitrogen would be required in addition to the current supply of organic materials, Chilean nitrate, and ammonium sulphate from the by-product coke ovens and gas works; therefore, the problem of fixing atmospheric nitrogen was studied diligently by scientists in Europe and the United States, with the result that three commercial processes—the arc, the cyanamid, and the direct synthetic-ammonia processes—were developed on a commercial basis. For many years this bureau has been active in promoting the establishment of nitrogen fixation in the United States, especially the direct synthetic-ammonia process which is now an important factor in American industry. The trend has been definitely toward the use of the direct synthetic-ammonia process, and therefore the bureau has confined its research very largely to this process which seems to have the greatest possibilities for cheapening the cost of producing fixed nitrogen. Working in close cooperation with the industry, this bureau has contributed in a major way to the understanding of this chemical process by American manufacturers

whose fixation plants have been constructed and are being operated by organizations containing many chemists and engineers formerly engaged in the work of the bureau. The fixation industry in the United States has increased its capacity rapidly during 1930 and 1931, with the result that this country is practically self-sustaining and would suffer only slight and temporary inconvenience should all imports of nitrogenous materials be stopped at any time.

CATALYSTS FOR AMMONIA SYNTHESIS AND OXIDATION

In the fixation of atmospheric nitrogen by the direct synthetic-ammonia process a highly purified mixture of nitrogen and hydrogen, in the proper proportions to form ammonia, is highly compressed and passed over a catalyst at an elevated temperature. The catalyst, consisting ordinarily of iron containing small percentages of such substances as aluminum oxide and potassium oxide, greatly increases the rate at which the two gases combine. In fact, nitrogen gas is so inert that the process depends directly on the presence of a material that can speed up the reaction. A considerable part of the early research activities of the laboratory was devoted to the production of a suitable catalyst for use under manufacturing conditions, and this work resulted in decided success. The research activities along this line are being continued, but at the present time are more concerned with the factors that influence and determine the activity of catalytic substances. By studying the fundamentals of catalytic reactions and discovering how and why these substances act as they do, a sound basis is established for the improvement of catalysts and thus also of the efficiency and usefulness of the nitrogen-fixation industry. Much of the information being obtained is also directly applicable to numerous other chemical industries in which catalytic processes are coming into more common use.

Investigations during the year have gone far toward determining the mechanism by which ammonia catalysts function. The indications are that the iron catalysts are particularly effective in ammonia synthesis because, as experiments during this last year have shown, nitrogen can react with active iron atoms on the surface of the catalysts to form a surface iron nitride. This nitride in turn is capable of reacting with hydrogen to produce ammonia and form again the catalytic iron. Recently completed experiments on the composition, conditions of formation, rates of thermal decomposition, and rates of reduction by hydrogen of the various nitrides of iron are in agreement with this postulated mechanism of ammonia synthesis. The results of these experiments will also be of use to those interested in case-hardening steels by nitriding with ammonia.

One of the leading processes for the production and purification of hydrogen used in ammonia syntheses is also dependent on a catalyst. The hydrogen produced by the passage of steam over hot coke contains some 35 per cent carbon monoxide, a substance which is very poisonous to ammonia catalysts. The removal of this impurity is ordinarily effected commercially by causing it to react with steam over proper catalysts to form hydrogen. Work during this last year on the iron oxide catalyst usually used for this purification has resulted in much new data of use not only in the prepara-

tion and purification of hydrogen but also in the metallurgy of the reduction of iron ores by hydrogen at high temperatures.

Nitric acid and nitrate fertilizers are produced from synthetic ammonia by a process known as ammonia oxidation. In fact a major part of the synthetic-ammonia production of the country is used in this way. In the first step of this process the oxygen of an air-ammonia mixture is caused to react with ammonia by means of a catalyst, such as platinum, to form nitrogen oxides. The oxides can then be converted easily into nitric acid and various nitrates for direct use as fertilizers. The platinum catalyst performs a function in this reaction analogous to that performed by iron in ammonia synthesis and is likewise easily poisoned by certain impurities that are sometimes present in the gases involved. Studies have been completed recently on the effects of various poisons on these platinum catalysts for the oxidation of ammonia to oxides of nitrogen; the results should prove of interest both to the industrial chemist and to those interested in the mechanism of catalytic reactions in general.

HIGH-PRESSURE STUDIES

Commercial ammonia synthesis is carried out at pressures ranging from 1,500 to 15,000 pounds per square inch. Under these conditions the physical properties of the gases can not be estimated even approximately by the laws governing the behavior of gases at ordinary pressures. Accordingly, in order to design high-pressure machinery and completely to understand the chemical equilibria involved, the behavior of the gases alone and in mixtures must be measured in detail over a wide range of temperatures and pressures. Such data, when they have once been worked out for the benefit of the nitrogen industry, are equally valuable to other industries using high-pressure gas reactions.

The first investigations were detailed studies of the two gases essential to ammonia synthesis, namely, hydrogen and nitrogen; more recently the work was extended to include carbon monoxide and methane, both of which are of interest in connection with the production of hydrogen. During the year helium was added to the list, as it is considered desirable to know the compressibility of this chemically inactive gas which is only slightly adsorbed by most catalysts. Such knowledge is needed in the determination of the adsorption of various gases under high pressure. The solubility of hydrogen in water at 25° C. and at pressures up to 15,000 pounds per square inch has been determined. The work will be extended to include the solubility of the other gases in water under similar conditions and at various temperatures and also their solubility in liquid ammonia.

UREA PRODUCTION

The product of the synthetic-ammonia process is ammonia which is a gas under ordinary conditions and therefore not directly applicable as a fertilizer. It is a very cheap nitrogenous material and is readily converted into products suitable for use on the soil. For example, great quantities of ammonium sulphate, ammonium phosphate, sodium nitrate, calcium nitrate, and ammonium nitrate are

made in this way at various plants throughout the world. The ammonia output is now the controlling factor in the nitrogenous-fertilizer market. Another material, urea, seems to have good possibilities, since it is a highly concentrated fertilizer and requires only ammonia and carbon dioxide for its production. Since carbon dioxide is produced in great quantity and wasted as a by-product at the synthetic-ammonia plants, its use with ammonia by means of an efficient process should yield a cheap and desirable product. Although already produced and marketed for fertilizer use, the cost of production is still too high to encourage general use.

On being mixed, ammonia and carbon dioxide unite almost instantaneously to form a solid compound, ammonium carbamate, from which urea may be obtained by heating to a temperature of 150° C. in a closed vessel. A small-scale plant, constructed by the bureau several years ago for the production of urea in this way, was operated to obtain information on the conditions favorable to urea formation and gave much useful data and also brought out the need for more exact knowledge concerning the reactions and equilibria involved. A series of laboratory investigations was initiated and is still in progress to give the required information. The conditions for the synthesis of urea from carbon dioxide and ammonia have been fairly well worked out, and attention is now directed especially to the recovery of unconverted carbon dioxide and ammonia from the urea formed, either by separation of liquid from solid or of gas from liquid. The present study of vapor pressures over synthetic mixtures will indicate the conditions necessary in the operation of a still for the separation of the gases from a solution of urea.

Results from a study of the melting temperatures of conversion mixtures of ammonium carbamate to urea have furnished information valuable for the removal of the mixtures from the autoclave and in the recovery of gaseous carbon dioxide and ammonia. A minimum temperature of 65° C. in the still has been shown necessary for the recovery of these gases. Also the possibility has been indicated of a partial separation of urea from the other products by withdrawal at a temperature of 70° to 80° C. of liquid from a solid formed.

PHOTOCHEMISTRY OF NITROGEN

There are various ways of rendering the inert nitrogen molecule chemically active. Heat and electricity are effective when properly applied, and results obtained in this bureau have indicated that ultraviolet light having very short wave lengths is an agency to this end. This suggested numerous possibilities and explained some of the facts already known. Spectroscopy has recently furnished detailed knowledge of the structure of the nitrogen molecule, and it is now possible by means of ultra-violet light to alter the structure so as to render this exceedingly inert substance chemically active.

During the past year the study of the elementary processes leading to the oxidation of nitrogen has yielded results decidedly encouraging to the effort which is being made to elucidate the fundamental changes that bring chemical reactivity into the ordinarily inert nitrogen molecule. The methods of band spectra and molecular physics seem to allow a direct way of getting to the answer of this

problem. The progress of a study of the formation of nitric oxide from activated nitrogen molecules has been reported during the year. In connection with the molecular structure investigations, a complete report has been submitted and accepted for publication covering the work on the structure of the ozone molecule, an important substance in the chemistry of the nitrogen oxides, and also a molecule possessing remarkable similarity to the molecule of nitrous oxide. The investigation of the structure of nitrous oxide, planned beforehand logically to follow this, has progressed rapidly, and a first report is nearly completed. It has been shown that this molecule is probably broken to pieces as a primary process by the absorption of ultra-violet light, and it seems very probable that it will be possible to specify what the resulting fragments of this dissociation are. This last result, at first not foreseen, came somewhat unexpectedly and illustrates the peculiar adaptability of spectroscopic methods to these studies. Investigation of certain of the properties of some nitrogen-containing molecules has recently been started through a study of their infra-red spectra, a method suited to this investigation because of the relative simplicity of the spectra of these molecules in this region.

The work on the photochemistry of nitrogen originated as an outgrowth of work on the arc process of nitrogen fixation but is not now being conducted with any idea of developing an improved arc process; the purpose is more fundamental, namely, to get at the scientific explanation of how and under what conditions light can so radically modify gaseous nitrogen.

NITROGEN FIXATION BY LIVING ORGANISMS

Although we have no way of estimating the quantity of nitrogen fixed annually by biological agencies, it is generally conceded that the total supply produced by industrial processes is but a small part of that constantly being fixed by natural agencies. This means that the main supply of nitrogen used by crops has been previously fixed by living organisms. The three types of nitrogen-fixing organisms, responsible for most of the fixation, are being studied. These consist of the free-living soil organisms, such as Azotobacter; the nodule bacteria that live on the roots of leguminous plants; and certain blue-green algae. The purpose of this work is to discover the mechanism by which these lower forms of plant life are able to use inert nitrogen gas. Such living organisms fix nitrogen at ordinary temperatures and pressures and require no appreciable energy other than for growth. If nature's apparently simple system were known, it might be possible to devise very simple industrial fixation processes. An intensive study is being made of this promising field of investigation.

Previous experiments with Azotobacter conducted by this unit had shown that no appreciable quantity of energy is required for fixation; furthermore, that either calcium or strontium is essential, and that small concentrations of a readily available nitrogen compound are sufficient to prevent all fixation. Further studies with Azotobacter, conducted during the past year, have thrown additional light on the chemical mechanism by which these bacteria fix nitrogen. It has been shown that the first step in the process of fixation is brought

about by means of an enzyme. This enzyme has been named azotose and a number of its physico-chemical properties determined, such as dissociation constant, heat of reaction, free energy of reaction, and temperature coefficient with respect to nitrogen gas. As one method of attempting to isolate this intracellular nitrogen-fixing enzyme, a study has been made of the behavior of Azotobacter under abnormal conditions. It was desired to prevent growth and respiration without causing a general deterioration of the whole organism, especially the nitrogen-fixing mechanism. A number of methods of doing this were studied, including variations in acidity, temperature, hydrogen peroxide, nitrite, carbon dioxide, and oxygen deficiency. Conditions have been found in which growth and respiration are prevented, but the nitrogen-fixing enzyme is unaffected. Until the enzyme has been obtained free of the bacterial cell, however, we can not be certain of its exact chemical composition. Possibly either calcium or strontium, known to be essential for fixation, is definitely connected with the enzyme.

Another phase of the work with Azotobacter has dealt with the energy requirements of the organisms for growth on the one hand and for fixation on the other. A method of determining the energies of certain reactions, occurring within living organisms, has been developed and applied to nitrogen fixation. The energy requirement for the first step in nitrogen fixation was found to be negligibly small. Considerable energy is, of course, required for the growth of the organisms apart from fixation. The Azotobacter studies are, in their present stage, of a strictly fundamental nature.

It had been previously demonstrated that legume-nodule bacteria did not fix nitrogen when growing apart from the host and that bacteria had been grown under a variety of pressures of nitrogen, hydrogen, and oxygen. During the year studies with leguminous plants grown with artificial light sources have been made. Variations in light sources, intensities, and length of day have been studied in an attempt to obtain growths more nearly comparable to those obtained in sunlight. The effect of numerous factors on nodule production and in turn on nitrogen fixation have been considered. Methods for growing plants under aseptic conditions in the presence of known gas mixtures are being developed.

Blue-green algae, the only chlorophyll-containing plants definitely known to fix nitrogen without the aid of bacteria, have been isolated from the soil and the fact established that these organisms grow practically as well in the absence as in the presence of fixed nitrogen, using sunlight as their only source of energy. The mineral requirements of certain nitrogen-fixing blue-green algae are being studied. These studies are planned to determine the elements essential for growth but more especially the elements required to catalyze the fixation process. It is also desired to determine if chlorophyll plays a direct part in the fixation mechanism or merely enables the plant to utilize light as a source of energy. The economic importance of these organisms can not be estimated from our present limited knowledge, but they are widely distributed in soils, fresh-water lakes, and streams and are doubtless responsible for considerable nitrogen fixation.

RELATION OF NITROGEN TO ORGANIC COMPOUNDS

It has been noted that most of the fixed nitrogen available in nature is that fixed by living organisms. These nitrogen-fixing organisms store the fixed nitrogen almost wholly in organic form, principally as proteins and amino acids. We do not as yet know the first step in the fixation process, but this, too, is probably organic in character. It seems reasonable that eventually a nitrogen-fixation method can be found to use organic materials without the aid of the living organism. An attempt to do this is being made by cooperation with those working with living nitrogen-fixing organisms and by a study of certain organic compounds which appear to possess promising properties with respect to nitrogen.

The cracking at high temperatures of certain organic compounds known as ketazines has been studied. They were found to give off nitrogen freely at a temperature of 300° C. The end products were identified and quantitatively determined. The second phase of this work, which involves a study of the behavior of this process at high pressures of nitrogen, is now being carried out. This will show whether or not an equilibrium exists and consequently whether or not the reaction can be reversed so as to fix nitrogen.

Results have been obtained which indicate that many common organic compounds are actually highly active chemically. Certain classes of these compounds, the ketones and aldehydes, are known to be present in bacteria, and it seems possible that the fixation of nitrogen by bacteria may involve the attachment of nitrogen to these free radicals. This lead is being pursued not only synthetically but also from the standpoint of studying the chemistry of the Azotobacter. Considerable progress has already been made in this latter direction and fairly large quantities of bacteria are now being produced.

Another phase of the work deals with chlorophyll, the plant substance responsible for the fixation of carbon in nature. The energy-containing materials, synthesized by means of the chlorophyll, using sunlight as a source of energy, are essential for biological nitrogen fixation. In the case of the nitrogen-fixing algæ the question arises as to how closely the chlorophyll present plays a part in the fixation process. In the case of bacteria the rôle is necessarily an indirect one. The relationships between nitrogen fixation by organisms, their process of photosynthesis, and utilization of energy are so interwoven that it becomes highly expedient to treat the subject as a whole in the research program. The results obtained should be of direct interest to those working on various plant problems and in other branches of agriculture. During the past year most attention has been given to the preparation of pure chlorophyll. Its production and that of the yellow pigments, carotene and xanthophyll, have now been placed on a semicommercial basis. Quantities considerably larger than those ordinarily made in a research laboratory are being turned out.

POTASH

American agriculture is still largely dependent on foreign sources for the potash which it requires. Although the domestic production for the year was essentially the same as for the preceding year and amounted to less than 20 per cent of the requirements of the country,

developments were initiated that will, when completed, have a marked effect on the situation. The plant of the largest present producer was in process of expansion at the end of the year and an entirely new factor has been introduced with the opening of a potash mine in New Mexico. This mine is already producing crude potash salt suitable for direct use as fertilizer, but too low in potash to justify shipping to the more distant fertilizer-consuming areas of the United States. However, the crude salt is water soluble and adapted to refining by the simple methods used in the European potash industry, and it is reported that a plant will be constructed for this purpose. It seems that the output of this mine, when well into production, together with the output of the enlarged California plant, using natural potash-borax brine, will go a long way toward the realization of an American potash industry commensurate with the needs of the country.

However, potash imports amounting to some 900,000 tons must be replaced by domestic production before the country is independent in respect to this fertilizer material. One purpose of the research work of this bureau is to find methods for the production of potash at low cost from our abundant potash-bearing minerals that have as yet proved too refractory for economical utilization.

The several methods now in use or being developed for potash manufacture may conveniently be grouped under two general types namely, wet extraction and furnace methods. In the wet-extraction processes the potash is produced by crystallization from natural brine or brine made from solid salt or by treatment of the mineral with such reagents as mineral acids, certain alkalies, and nitrogen oxides in the presence of water. The furnace methods differ radically from all others in that the potash salts are volatilized and recovered directly from the furnace gases.

WET-EXTRACTION METHODS

The potash-bearing mineral, alunite, which occurs in large deposits in southern Utah, represents an entirely logical raw material for potash and alumina manufacture because of its high content of these constituents and the relative ease with which they may be separated, yet the processes heretofore applied commercially have failed to meet the economic requirements of competitive conditions. Contributory to this situation is the fact that the alumina, a by-product of importance if not essential to the success of the proposed manufacture, has not been obtained sufficiently pure to enable it to enter the preferred market. This has been due to the fact that certain impurities, particularly silica, naturally present in the potash-bearing mineral, accumulate in increased concentrations in the alumina. A process has been devised and tested with affirmative results whereby the silica is eliminated as fluosilicic acid. Further work in progress has as its objective the elimination of iron. Improvements in heat treatment are expected to yield more uniform products, reduce fuel costs, simplify plant equipment, and reduce losses. A further objective is the utilization of the lower-grade alunite, as well as the high-grade mineral to which past operations have been restricted, with a view to increasing the potash potentialities of that raw material.

Enormous deposits of another potash-bearing mineral, leucite (Wyomingite), occur in Wyoming. Fortunately, large deposits of high-grade phosphate rock and various other raw materials useful in fertilizer manufacture, together with abundant and cheap fuels, are near by. Various researches are in progress to develop chemical processes best suited to this unique industrial situation. The production of available potash from leucite by treatment with the oxides of nitrogen and the various industrial acids is being studied, particularly from the viewpoint of by-product recovery.

Other potash-bearing materials, such as the greensands of New Jersey and the shales of Georgia, are being subjected to lines of attack similar to those used for leucite. In the case of the acid extraction of greensand, iron and aluminum salts and adsorptive silica (glaucosil) are obtained as useful by-products.

FURNACE METHODS

Fundamental research on the furnace treatment of various minerals for the volatilization of potash from its ores by blast furnace procedures is yielding promising results. Electrical precipitation is used in this method for the recovery of the potash salts evolved as finely divided particles in the furnace gases. Preliminary results indicate the entire practicability of the method, particularly so when the furnacing of the leucite is combined with that of phosphate rock to yield both phosphoric acid and potash. The combination of these two fertilizer essentials to form the highly concentrated fertilizer salt, potassium phosphate, is contemplated as a logical means of reducing distribution costs. These costs must be given serious consideration where the fertilizer resources are far removed from the fertilizer-using areas. The blast furnace offers itself as a useful nucleus around which to assemble other chemical activities, due to the large volume of surplus gas it generates. The technology of potash recovery by blast-furnace methods, once developed as a part of the problem of smelting potash silicates, should also be applicable to the recovery of potash now currently liberated and lost in the iron and cement industries.

A number of small blast furnaces have been built and operated during the last three years. The furnace in use during the latter part of the year is built to handle some 30 tons of raw materials per week of operation (24 hours per day). The furnace plant is a complete unit provided with an electrical precipitator for recovering the product, and it burns its own gas for preheating the blast. New Jersey greensand has been smelted in short preliminary runs, and it is hoped that further work will result in a commercially profitable industry based on this abundant material.

PHOSPHATES

It has been noted that the American farmers spend about $250,000,000 annually for fertilizer. About one-third of this represents the cost of phosphoric acid.

Fortunately, this country is well provided with large reserves of phosphate rock, in Florida and Tennessee, to supply the phosphate requirements of the South and East, where fabricated fertilizers are now more generally employed. Wyoming, Montana, and Idaho

have enormous deposits in juxtaposition to large potash deposits, to supply the future fertilizer requirements of the Middle West. Here the logical expansion of fertilizer use is to be promoted by a reduction in distribution costs to follow the development of close-by industries and more highly concentrated products. In this connection it should again be pointed out that although fertilizers are sold on the basis of plant-food content, freight is paid on weight. Distribution costs are accordingly reduced in proportion to concentration increase, a factor favoring producers wherever located.

Present methods of manufacturing superphosphate require high-grade rock. Accordingly, in mining, the better grades of rock are recovered, and the rest are discarded as waste except where flotation methods are used. The main purpose of the phosphate-research program of this bureau is to work out methods for the more economical conversion of these phosphate minerals into suitable available fertilizers with the conservation of the by-products. It is desired particularly to develop methods for the utilization of the low grades, or run-of-mine phosphate rock, thus not only materially reducing mining costs but also greatly prolonging the life of the deposits.

The furnace methods discussed in connection with potash manufacture are being applied with minor variations to the production of phosphoric acid. The work indicates that these methods will allow the utilization of low-grade phosphate rock, now discarded, and produce highly concentrated products. Tennessee "blue rock," a phosphate mineral not commercially useful for fertilizer production, has been smelted with every indication of success. Run-of-mine Florida phosphate rock also has been used in the furnace without preliminary treatment, such as washing, sintering, and briquetting. The principal cost in the furnace production of fertilizer phosphates is the cost of the coke fuel. The aim of the work is to reduce this cost by improved furnace design and operation.

A study of the complete chemical composition of the various grades and types of phosphate rock has been completed. Several papers bearing on this investigation have been published in the technical and trade journals, and the results of the completed study are being prepared for publication as a department bulletin. This information is necessary as a basis for work on methods for the production of phosphate fertilizers and for the recovery of any impurities in phosphate rock that appear to have commercial value. Particular attention has been given to the occurrence in phosphate rock of magnesium, nickel, copper, manganese, chromium, vanadium, arsenic, and iodine, which may be either beneficial or detrimental to plant growth. X-ray studies have shown that phosphate rock consists principally of a complex calcium phosphate having the general structure of the crystalline apatites. The relation of the various impurities in phosphate rock, such as carbonates, sulphates, and fluorine, to the chemical constitution of the natural rock is being investigated. This question has an important practical bearing on the concentration of crude phosphates by flotation processes which are coming into use in the Florida and Tennessee phosphate fields. Results have shown that fluorine is definitely combined as a part of the phosphate-bearing mineral. Critical studies of methods for determining the various elements in phosphate rock have been made, and several improved

methods, particularly for the determination of fluorine, have been developed.

Extensive investigations are being carried out on the chemical constitution, preparation, and properties of the complex calcium phosphates present in phosphate rock, in bone, and in superphosphates that have been treated with relatively large quantities of ammonia. These studies are of a fundamental character and it is expected that the results will be of great value, not only to the phosphate-rock and phosphate-fertilizer industries but also to the agronomists, soil scientists, and biochemists. The X ray is playing a very valuable and essential part in these studies.

Most of the phosphoric acid manufactured in this country is now produced by the sulphuric-acid process. Possible improvements in this process have been given consideration. Investigations on the use of dilute phosphoric acid and of mixtures of phosphoric acid and sulphuric acid in the manufacture of concentrated superphosphates were continued.

Particular attention is being given to laboratory methods for determining the availability of phosphatic fertilizer materials. In this connection studies on the solubility of a wide variety of phosphates in neutral ammonium citrate and 2 per cent citric-acid solutions were made, and the factors affecting the solubility of dicalcium and tricalcium phosphates in ammonium-citrate solutions were investigated. This work is closely related to the investigations on ammoniated superphosphate discussed elsewhere.

Among the important by-products of phosphate production are fluorine compounds, particularly the fluosilicates. These offer interesting possibilities as substitutes for arsenic compounds in the manufacture of insecticides. The factors involved in the production of fluorine compounds as by-products of the phosphate-fertilizer industry are being investigated. The comparatively low availability to plants of raw phosphate rock seems to be due principally to the fact that the phosphate is combined with fluorine, and the conversion of phosphate rock into readily available fertilizers requires the breaking up of this complex. Particular attention is being given to methods for the removal of fluorine from the rock. This work is of practical importance not only from the standpoint of the fertilizer industry but also from the standpoint of the use of phosphate rock as a mineral supplement in the feeding of livestock, since it is known that fluorine is detrimental to the health of animals.

NEW FERTILIZER MATERIALS AND IMPROVED DISTRIBUTION

The most interesting of the recent developments in fertilizer manufacture is the direct use of synthetic ammonia in fertilizer mixtures containing superphosphates. The present price of ammonia is considerably less than that of any other form of nitrogen, and its use as a fertilizer material has thus resulted in a marked reduction in the cost of fertilizer nitrogen. The use of free ammonia in the manufacture of fertilizer mixtures has the further advantages that it greatly improves the mechanical condition of the mixture, prevents rotting of the bags, and affords a means for reducing freight and handling charges by increasing the concentration of the fertilizer.

It has been found, however, that the direct use of free ammonia in the manufacture of fertilizer mixtures brings about an apparent reduction in the availability of the phosphoric acid in the fertilizer, as indicated by the present official method for determining availability, when the ammonia added is in excess of about 1 per cent of the mixture. The present use of free ammonia is therefore limited to about one-fourth of the maximum that it is possible to include in a fertilizer mixture.

A study made in this bureau of the composition and properties of the products formed in the reversion of phosphoric acid indicated, however, that the availability of these materials to plants should be greater than the present official method for measuring phosphoric-acid availability would indicate. This was later confirmed on submitting samples of various forms of reverted products prepared from ammoniated superphosphate to different agricultural experiment stations throughout the country. The importance of this problem and the interest that was taken in the work is evidenced by the fact that the tests were undertaken in 25 different State experiment stations and other institutions in the United States.

The results obtained in this collaborative study show that it should be possible at least to double the quantity of free ammonia now used in preparing fertilizer mixtures without decreasing appreciably the fertilizing value of the phosphoric acid in the mixture. Steps are accordingly being taken by the official organization of the State control chemists which will allow an increase of about 100 per cent in the use of free ammonia in the preparation of fertilizer mixtures. This will provide for an increase in the use of synthetic ammonia in the ammoniation of superphosphate in this country of at least 80,000 tons per annum, having a wholesale value of about $8,000,000.

The direct use of anhydrous ammonia in fertilizer mixtures is of further interest in that it neutralizes any excess of acid present, and the heat developed when the ammonia is incorporated in the mixture provides a means for eliminating any excess moisture. A study is accordingly being made of the possibility of applying a continuous process in the preparation of complete concentrated fertilizers by treating phosphate rock with an excess of phosphoric acid with or without the addition of sulphuric acid, neutralizing the resulting slurry with free ammonia after the addition of such other components as are required in the mixture, and utilizing the heat of the neutralization to aid in the granulation of the mixture. A fertilizer prepared in this way offers advantages over simple mixtures of alkali salts as are now found on the market in that (1) it does not segregate, (2) it has better drillability, (3) it contains a lower proportion of readily soluble salts, and (4) it provides necessary plant-food elements, such as calcium and sulphur, in addition to the ordinary fertilizing elements.

A study has been made of methods of imparting different colors to synthetic fertilizer materials with a view to providing a means for readily differentiating between materials that are without marked distinguishing characteristics. The extent to which segregation takes place in fertilizer mixtures can be easily followed by this means, thus facilitating the study of methods for preventing this undesirable feature of mixed fertilizers.

A method of measuring the drillability of fertilizers has been devised that will enable implement manufacturers to calibrate fertilizer distributors more accurately than in the past. This method should also be of value to fertilizer manufacturers desiring to produce goods of uniform drillability and to agronomists in making field tests, since it gives control of a variable which in the past has been neglected but which nevertheless affects crop yields.

Some mixed fertilizers remain constant in composition during drilling, whereas others do not. The causes of this tendency of some mixtures to segregate are being studied with a view to devising preventive means.

Ways and means of promoting efficiency in the use of fertilizers for cotton are being studied in cooperation with the Bureau of Public Roads and the South Carolina Agricultural Experiment Station. This work has shown that greater uniformity of distribution than is commonly obtained with commercial distributors would increase the profits from the use of fertilizers. The placement of the fertilizer in the soil with reference to the seed has been found to be very important. When it is applied in contact with the seed at the rates recommended in the Southeastern States, germination is frequently injured and the stand is severely damaged. Results secured thus far indicate that when placed in bands about 2 inches to each side and at a depth about 2 inches greater than that of the cottonseed, ordinary fertilizers at a rate of 800 pounds per acre and double-strength fertilizers at a rate of 400 pounds per acre are both safe as regards germination and efficient in increasing yields. The most efficient placement, however, is yet to be determined. Some evidence has been obtained which indicates that the amount of increase in yield produced by fertilizer depends partly on the size of its grains. This project is being continued.

The work on the preparation of potassium nitrate by treating solid potassium chloride with oxides of nitrogen has been continued. Theoretical considerations and preliminary experiments indicate that the nitrosyl chloride formed during the preparation of potassium nitrate by the above procedure is perhaps best utilized by oxidizing it to nitrogen peroxide and chlorine, the former to be returned to the process to make more potassium nitrate. The chlorine may be sold as a by-product or otherwise disposed of.

ECONOMICS

The economic aspects of the work have been given due attention, probably closer attention than during any previous year. The general business and agricultural depression has served as a reminder of the necessity of directing effort in a way to assist most effectively the fertilizer industry and agriculture.

In estimating the probable value of any research project it is necessary to know the magnitude of that branch of the industry that may be affected by the results. Fertilizers of all sorts are world commodities, and their commerce is extremely complex. It is, therefore, not sufficient to know what is going on in the United States; a world view is required as a working basis in this field. Information of this character is gathered and published by the bureau for its own use as well as for the public service.

One of the outstanding events of the year was the reduced or part-time operation of the nitrogen industry throughout the world, due to the inability of the market to take the output of the manufacturing facilities which had been expanded so rapidly during recent years. This condition calls for the development and promotion of more economical methods for the conversion of ammonia into fertilizer materials.

COOPERATIVE ENTERPRISES

The investigations of the fertilizer and fixed nitrogen investigations unit have required the installation of special equipment and the development of advanced methods for such work as that being done in catalysis and on the properties of gases under high pressure. Modern physics technic, through the X ray, spectroscope, and other radiation methods is also being applied in a very effective manner. It is the policy of the bureau to make its highly specialized methods and apparatus available to all those interested and to cooperate with other branches of the department and with outside agencies. For example, during the past year cooperative tests were carried out for the Bureau of Aeronautics of the Navy Department on the catalytic purification of gases. A cooperative project with the Bureau of Standards is now being actively prosecuted for determining specific heats at low temperatures, heats of combustion, and free energies of organic substances suitable for use in nitrogen-fixation and fertilizer investigations. This bureau is working in close cooperation with the Smithsonian Institution on problems involving radiation methods as applied to nitrogen fixation and agriculture in general. As examples of cooperation on problems of mutual interest with agencies other than governmental might be mentioned the Carnegie Institute, Rockefeller Institute, Franklin Institute, universities, and colleges of this country. Through these contacts some of the more theoretical phases of the work originating in this unit, but remotely connected with the projects, have been carried out by these institutions and the results made available to the bureau.

PUBLICATIONS OF THE BUREAU OF CHEMISTRY AND SOILS ISSUED DURING THE YEAR JULY 1, 1930, TO JUNE 30, 1931

TECHNICAL BULLETINS

No. 211. Some Methods for Detecting Differences in Soil Organic Matter.

No. 212. Mechanical Analysis of Finely Divided Natural Phosphates.

No. 214. The Physical and Chemical Characteristics of Certain American Peat Profiles.

No. 225. Results of Fertilizer Experiments on Norfolk Fine Sandy Loam and on Norfolk Sandy Loam.

No. 228. Character of the Colloidal Materials in the Profiles of Certain Major Soil Groups.

No. 229. Variations of the Colloidal Material Extracted from the Soils of the Miami, Chester, and Cecil Series.

No. 232. A Laboratory Study of the Field Percolation Rates of Soils.

FARMERS' BULLETIN

No. 1643. Fire Safeguards for the Farm.

CIRCULARS

No. 129. Survey of the Fertilizer Industry.

No. 138. Development and Use of Baking Powder and Baking Chemicals.

No. 139. Method and Procedure of Soil Analysis Used in the Division of Soil Chemistry and Physics.

LEAFLETS

No. 69. Preservation of Leather Bookbindings.

No. 70. Home Mixing of Fertilizers.

No. 71. Fertilizers for Pecan Soils.

JOURNAL OF AGRICULTURAL RESEARCH ARTICLES

The Effect of Ethylene on the Chemical Composition and the Respiration of the Ripening Japanese Persimmon.

Progressive Changes in the Waxlike Coating on the Surface of the Apple During Growth and Storage.

The Adsorption of the Anions of Acid Dyes by Soil Colloids.

Vitamins in Sugarcane Juice and in Some Cane-Juice Products.

Notes on the Histology of the Almond.

Effect of Rye and Vetch Green Manures on the Microflora, Nitrates, and Hydrogen-ion Concentration of Two Acid and Neutralized Soils.

The Effect of Salt on the Microbial Heating of Alfalfa Hay.

Dispersion of Soils by a Supersonic Method.

SOIL SURVEYS

Muskingum County, Ohio
Milam County, Tex.
Hancock County, Ind.
Kent County, Mich.
Bartow County, Ga.
Prince Georges County, Md.
Eugene Area, Oreg.
Montgomery County, Ala.
Sauk County, Wis.
Bear Lake Valley Area, Idaho.
Wheatland Area, Wyo.
Menominee County, Mich.
Putnam County, Ind.
St. Lawrence County, N. Y.
Bergen Area, N. J.
Keith County, Nebr.
Clay County, Kans.
Navarro County, Tex.
Burke County, N. C.
Claiborne County, Miss.
Buckeye-Beardsley Area, Ariz.
Davie County, N. C.
Orange County, Va.
Polk County, Mo.
Grande Ronde Valley Area, Oreg.
Arkansas Valley Area, Colo.
Jackson County, Mich.
Washington County, Ohio.
Lee County, Ga.
Lenoir County, N. C.
Hardin County, Tenn.
Tuscola County, Mich.
Rankin County, Miss.
Wadena County, Minn.
Dukes and Nantucket Counties, Mass.
Lincoln County, Nebr.
Clarke County, Ga.
Watauga County, N. C.
Franklin County, Nebr.
Clay County, Nebr.
Camden Area, N. J.
Labette County, Kans.
Manitowoc County, Wis.
Crawford County, Kans.
Hamilton County, Nebr.
Hampshire County, W. Va.
Buchanan County, Iowa
Salt River Valley Area, Ariz.
Deming Area, N. Mex.
Lyon County, Iowa
Butler County, Ohio.
Custer County, Nebr.

MISCELLANEOUS

Fertilizer Experiments with Truck Crops. (Joint publication of the Florida Agricultural Experiment Station and the U. S. Department of Agriculture.)

Preliminary Report on Three Years' Fertilizer Experiments with Early Irish Potatoes on the Farm of A. W. Baker, Aurora, Beaufort County, N. C., 1928–1930. (Joint publication of the North Carolina Agricultural Experiment Station and the U. S. Department of Agriculture.)

Sources of Nitrogen for Potato Fertilizers in Aroostook County. (Joint publication of the Maine Agricultural Experiment Station and the U. S. Department of Agriculture.)

Use of Commercial Fertilizers in the Growing of Cotton. (Joint publication of the North Carolina Agricultural Experiment Station and the U. S. Department of Agriculture.)

YEARBOOK ARTICLES

Vat Dyes Play Big Part in Broadening Cotton Goods Market.

Legume Inoculation by Cultures Depends Finally on Field Test.

Hides and Skins Require Prompt, Thorough Curing to Bring Best Prices.

Paper Industry Concerns Farmer as Raw-Material Producer and Consumer.

Fruit Juices Preserved by Various Methods Find Steadily Growing Market.

Ethylene-Ripened Tomatoes Not Equal in Vitamins to Naturally Ripened Fruit.

Oranges Impaired in Vitamin-C Content by Arsenical Spray.

Fertilizer's Value Much Affected by Method of Applying It to Soil.

Nitrate Bacteria, Main Source of Soil Nitrates, Depend on Farm Practice.

Manure Substitutes Are Made from City Wastes by Various Processes.

Potash Extraction from Domestic Sources Has Great Possibilities.

Nitrogen Fixation by Legumes Essentially a Cooperative Process.

Fertilizer Studies Show Manner of Distribution Is Extremely Important.

Leather Injured by Mud, Water, and Heat; Preserved by Grease.

Insecticidal Plants Investigated as Possible Farm Crops.

Fruit Products Preserved Successfully by Freezing with Solid Carbon Dioxide.

Manganese and Other Less Common Elements Have Fertilizer Value.

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