BREEDING BETTER VEGETABLES for the SOUTH

at the U. S. Regional Vegetable Breeding Laboratory

Miscellaneous Publication No. 578

U. S. DEPARTMENT OF AGRICULTURE

Some of the principal problems of agriculture, though country-wide, are of special concern in certain regions. With this in mind, the Bankhead-Jones Act of 1935 provided for regional laboratories, to be administered by the Secretary of Agriculture, which would mobilize scientific resources for a fundamental attack on some of the most important of these problems. Nine such laboratories have been established. Each deals with a problem or group of problems selected in cooperation with the State agricultural experiment stations of the region as being among the most important faced by agriculture in that section of the country. The States cooperate with the Department in planning and carrying out the research program of each laboratory on a regional basis. At the same time the subjects under investigation are of importance to all major agricultural regions, and the results obtained by the laboratories contribute to agriculture on the national and local as well as the regional level.

This publication is one of a series, each of which describes the work of one of the Bankhead-Jones laboratories, covering the complete programs, the results obtained to date, and the continuing research. Papers on various phases of the work have been published by all the laboratories as Department publications and in technical journals.

The laboratories and their locations are as follows:

U. S. Regional Vegetable Breeding Laboratory, Charleston, S. C.
U. S. Regional Pasture Research Laboratory, State College, Pa.
U. S. Regional Soybean Laboratory, Urbana, Ill.
U. S. Regional Swine Breeding Laboratory, Ames, Iowa.
U. S. Western Sheep Breeding Laboratory, Dubois, Idaho.
U. S. Regional Animal Disease Research Laboratory, Auburn, Ala.
U. S. Regional Poultry Research Laboratory, East Lansing, Mich.
U. S. Regional Salinity Laboratory, Riverside, Calif.
U. S. Plant, Soil, and Nutrition Laboratory, Ithaca, N. Y.

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Cover Illustration.—United States Regional Vegetable Breeding Laboratory, Charleston, S. C.

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At the United States Regional Vegetable Breeding Laboratory [1]

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THE VEGETABLE BREEDING LABORATORY

The United States Southeastern Regional Vegetable Breeding Laboratory is one of a series of agricultural research agencies created by the Bankhead-Jones Act of 1935. Established in 1936 about 7 miles west of Charleston, S. C., it was the first of the nine so-called Bankhead-Jones laboratories to be set up. Its purpose is to conduct basic research in the heredity and behavior of vegetable crops and to develop vegetable varieties superior in quality and better adapted to the southeastern region of the United States than those being grown. The area served is shown on the map (fig. 1). Thirteen States are included in the region: Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, Oklahoma, Arkansas, Kentucky, and Tennessee. More than 37 million people have their homes in these States.

Wide variations in the character of the soils, in rainfall, and in seasonal temperatures exist in the region; plant diseases and insect pests attacking foliage, stems,

[1] This publication has been prepared by C. A. Magoon, Special Assistant to the Administrator, Agricultural Research Administration, through the cooperation of B. L. Wade, C. F. Poole, C. F. Andrus, J. E. Welch, P. H. Heinz, G. B. Reynard, and P. C. Grimball of the laboratory research staff. Grateful acknowledgment for helpful suggestions is made to J. R. Magness and V. R. Boswell of the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, and to the directors and research staffs of the agricultural experiment stations in the 13 Southeastern States.

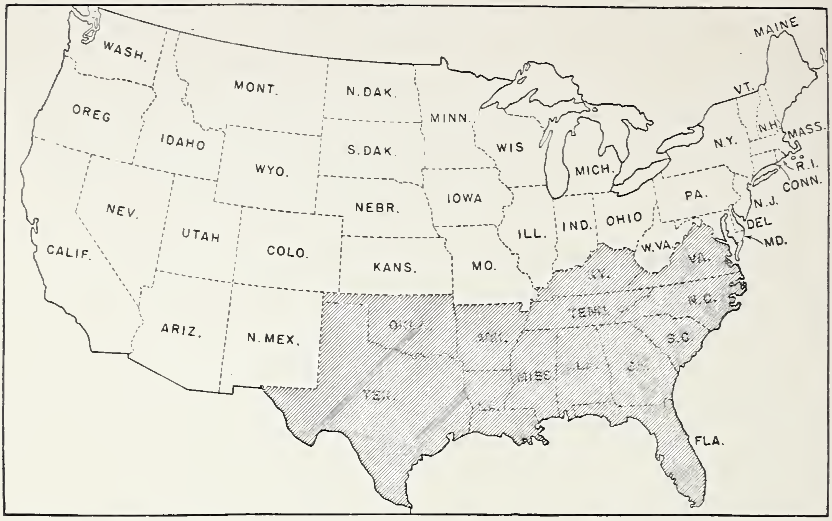

Figure 1.—The States included in the region served by the United States Southeastern Regional Vegetable Breeding Laboratory are shaded.

fruits, and roots of plants abound; nematodes, the microscopic parasitic worms that attack the roots of many plants and cause great damage, are widely dispersed; and frost hazards in spring and fall, excessive summer heat, and, at times, prolonged drought in some sections—all contribute to making the growing of vegetable food crops a difficult undertaking. Most important of all, the vegetables grown in the region, with the exception of certain newer varieties of sweetpotatoes, watermelons, collards, cowpeas, and kale, were developed chiefly in the Northern States and sometimes do not thrive under southern conditions.

VEGETABLES FOR THE NORTH AND THE SOUTH

In the States north of the region served by the laboratory are considerably more than 80 million people, approximately half (48 percent) of whom live in cities and are dependent on outside sources for their vegetable food supplies. Truck growers of these States are able to supply fresh vegetables in season, but the growing season is short and during many months of the year no vegetables can be produced there.

It seems logical that the region to the south, having large areas of land suited to truck farming and long growing seasons in both spring and fall—and in the far South, in winter as well—should be able to play a large role in meeting the fresh-market demands during those months when northern production is out of the question. Large quantities of market-garden produce are shipped north by southern growers, but the yield per acre is very much less than if high-quality, well-adapted varieties were available. The Regional Vegetable Breeding Laboratory is helping to meet this need.

Another aspect of the situation is that, lacking adapted varieties, a large share of the rural population in the southern area does not have sufficient garden vegetables to meet nutritional requirements. This was made clear by a careful survey conducted by the experiment station of one of the Southern States, which revealed that the diets of one-half of the white and three-fourths of the Negro farm families in the Piedmont section of that State were not adequate from a nutritional standpoint, and that a poor supply of vegetables was one of the reasons for the deficiencies.

Another significant fact is that, because of the lack of well-stocked vegetable gardens from which family needs could be supplied, large quantities of processed vegetable foods are purchased from other sections of the country. Though the diet of the population is improved thereby, obviously the procedure is economically unsound.

It is seen, then, that if vegetable varieties adapted to the region can be made available, not only may the truck-crop industry be benefited tremendously but an important contribution may be made to the nutritional and economic welfare of the people as a whole.

PROBLEMS BOTH REGIONAL AND LOCAL

These considerations give rise to many problems, some of which are regional in character and may be attacked most effectively on a regional basis, while others apply to more restricted areas in individual States, and if properly and adequately met must receive the attention of research workers within those States. For example, certain crop-plant diseases and pests are widespread in the region, and a central agency can best bring together and maintain resistant breeding stocks and take the preliminary steps to develop improved resistant varieties. On the other hand, it is beyond the proper range of activity and the ability of a central agency such as the Southeastern Regional Vegetable Breeding Laboratory to make practical tests of the adaptation of improved breeding strains and new varieties to all the individual areas where tests should be made. This must be done by the workers within the individual States concerned. It is clear, therefore, that in the conduct of this and related research the combined and coordinated efforts of both Federal and State agencies are necessary if the problems are to be solved.

With this in view, the objectives of the laboratory have been: (1) To bring together from all likely sources and to test plant materials believed to have value in the development of new strains or varieties of selected food crops adapted to southeastern conditions; (2) to study the inheritance of characters in these breeding stocks; (3) to make available to workers of the individual States the basic (heterozygous) breeding material developed at the laboratory for further selection and possible breeding for adaptability to specific areas; and (4) to introduce for general use any new, improved varieties of vegetables that might result from the breeding work.

The establishment of a vegetable breeding laboratory was decided upon in response to requests of the directors of all the State agricultural experiment stations in the region. When plans were being made, the directors were asked to name collaborators who would offer suggestions as to the problems that were most pressing for solution, cooperate in planning the research program, and look after the testing of newly developed stocks in their own States. This was done, and in order that there might be continuous cooperation, arrangements were made for regional conferences to be held from time to time. At such meetings an opportunity is offered for the State representatives to see the experimental crops growing at the laboratory and to make estimates of the value of certain strains under their own conditions.

The Regional Vegetable Breeding Laboratory is separated from the South Carolina Truck Experiment Station only by the width of the road between them. Opportunity is therefore provided for close cooperation and exchange of ideas and materials between the staffs of station and laboratory.

THE PHYSICAL PLANT AND THE SCIENTIFIC STAFF

Experience has shown that both land and physical equipment are excellently suited to the needs of the project. With respect to both soil and climate, the location of the laboratory is typical of a large number of the southeastern truck-growing areas. The tract contains over 200 acres of well-drained, sandy loam soil. Portable irrigation facilities have been provided so that in case of drought an ample supply of water is available to protect the plants in the experimental plots from damage or loss.

The physical plant of the laboratory consists of a brick laboratory and office building; a brick head house with two attached greenhouses, each 35 by 100 feet; a brick seed-drying, storage, and cold-storage building 30 by 80 feet, which also is provided with quick-freezing and dehydration facilities; large screen and lath plant shelters; and machinery sheds, barns, etc. Four residences provide housing for the director and some of the other members of the research staff.

The development of vegetable varieties meeting all requirements of the region is a complex undertaking and calls for a staff of workers trained in many lines of research. There has been assembled at the laboratory, therefore, a group of scientists trained in the genetics, cytology, pathology, physiology, and chemistry of crop plants, horticulture, dehydration and refrigeration of vegetables, and related fields. It is to be noted that though these men are specialists in their own fields emphasis is centered on the solution of the problem as a whole and not on the special technical interests of the individual workers.

THE CROPS BEING STUDIED

At the first meeting of the Federal workers and the collaborators from the various States, the entire range of problems needing solution was canvassed, and the following crops were selected to receive consideration: Snap beans, cabbage, watermelons, tomatoes, and sweet corn; and for later attention, garden peas. Work on these has been continuous and vigorously pursued, except that during the last 2 years, owing to wartime needs, less emphasis has been placed on watermelons and more attention given to those crops having higher nutritive value.

In the following pages the research and the results with each of these crops will be discussed.

SNAP BEANS

To be fully satisfactory for market gardening, shipping, processing, and growing in the home gardens of the Southern States, snap beans must be (1) hardy, or at least tolerant to considerable variations in seasonal temperatures; (2) drought-tolerant to a high degree; (3) productive, and able to yield profitable crops in unfavorable seasons; (4) resistant to mosaic, anthracnose, powdery mildew, and other diseases; (5) attractive in form and color of pods; (6) tender and free from stringiness at market maturity; (7) high in nutritive values; and (8) adapted by physical character and quality to processing.

At the outset of the work at the regional laboratory, there were brought together from various sources in different parts of the country seeds of many varieties and strains of beans, including those grown extensively in market gardens and home gardens, as well as others possessing special desirable properties. New varieties and strains have since been added to the collection.

Within this original group was included the U. S. No. 5 Refugee, a mosaic-resistant variety developed by the Department of Agriculture at Greeley, Colo., and introduced to the seed trade in 1935. Late in the spring of 1936 this variety, together with several others, was planted at Charleston for observation. The results with U. S. No. 5 Refugee were so favorable that it was decided to conduct more extensive trials of it, using for comparison the well-known standard variety, Stringless Black Valentine, most widely grown of all snap beans in the Southern States.

U. S. No. 5 Refugee and Stringless Black Valentine Compared

Since the success of vegetable crops in the southeastern region is greatly influenced by the time of planting, the first tests of the two bean varieties were made on the effect of this factor on their performance. Effects on each variety of the duration of picking, or length of the harvesting period, were later compared, and in 1940 comparative ability to recover from partial defoliation was studied. A complete report on these tests may be found in Department of Agriculture Circular 648, issued in April 1942.[2] Briefly, the story is as follows:

During the season of 1937 and again in 1938 the two varieties were planted side by side in paired rows 32 feet long, spaced 3 feet apart, and these paired rows were replicated, or repeated, 10 times. (An experimental plot of this size makes it possible to calculate yields in terms of pounds per acre directly from the weight in grams of produce harvested.) In 1937, plantings were made on April 30, May 17, and May 28. Four pickings were harvested from both varieties of the first planting and also from the two other plantings of the U. S. No. 5 Refugee. Two pickings only were obtained from the last two plantings of the Stringless Black Valentine. The average yields from the 10 plots, in pounds per acre, were as follows:

Planting date:	*U. S. No. 5 Refugee*	*Stringless Black Valentine*
April 30	4,557	1,277
May 17	3,070	126
May 28	2,364	133
Total	9,991	1,536

The difference—8,455 pounds—represents an increase of 550 percent for U. S. No. 5 Refugee.

Briefly, the yields from the 1938 plantings, made on May 19 and June 1, respectively, showed a difference of 4,652 pounds per acre in favor of U. S. No. 5 Refugee. In both plantings four pickings were obtained from this variety, as against two for the first and one for the second planting of Stringless Black Valentine.

It is to be noted that in the tests mentioned the planting dates were late. Ordinarily, beans are planted in the Charleston area from March 25 to April 15, and early plantings have usually resulted in longer harvesting periods and higher yields. Since, in these tests the U. S. No. 5 Refugee variety had longer harvesting periods than the Stringless Black Valentine, it was decided to determine the relative length of the harvesting periods for these two varieties when planted at the usual time. Accordingly, in the spring of 1939 and again in 1940, such plantings were made. To make the story brief, the U. S. No. 5 Refugee gave six pickings in both years, whereas only four were obtained from the Stringless Black Valentine, and the total yields of the former were much higher.

Experiments made during the season of 1940 also showed that the U. S. No. 5 Refugee was able to recover more completely from partial defoliation, such as might be caused by insect injury, than were the Stringless Black Valentine and Bountiful varieties grown for comparison.

[2] A list of all the publications of the laboratory since its establishment will be found on page 33.

U. S. No. 5 Refugee Shows Wide Adaptation

Cooperating agencies in Alabama, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia, where trials had been made of the U. S. No. 5 Refugee in comparison with other varieties, reported favorably on it, though in some cases heavier yields were obtained from other varieties or from crosses of this variety. Under Norfolk, Va., conditions it was found resistant to powdery mildew and to rust and somewhat resistant to moderate frosts. It yielded particularly well both in spring and in fall at Baton Rouge, La.; in Tennessee it was found to be valuable for midsummer planting, being able to set pods in hot and relatively dry weather; and in Mississippi it stood up well in dry weather, though both there and in central and western Oklahoma without irrigation the yields were exceeded by those of the Bountiful variety. At Weslaco, Tex., the yields were not so high as those of some of the stringless green pod types, but U. S. No. 5 Refugee was more resistant to leafhopper injury.

It is recognized that pods of No. 5 Refugee are shorter and lighter in color than most markets prefer at present. Its greatest value in the South would seem to be for home use and local markets during periods when the longer, darker green varieties cannot be satisfactorily produced. A technical description of this variety and details of its origination can be found in Department of Agriculture Circular 500, U. S. No. 5 Refugee, a New Mosaic Resistant Refugee Bean, by B. L. Wade and W. J. Zaumeyer, issued November 1938.

The foregoing statements show not only that the testing of this variety in comparison with others, by the laboratory and cooperating agencies, has already made a substantial contribution to the solution of the snap bean problems of the region, but that in the "blood" lines which this variety represents are to be found many characteristics desired in ideal bean varieties for the South.

New Varieties Developed

It should be said that, to meet fully the desires of the truck gardening and marketing industry, not only should beans possess all the desirable properties mentioned above but the pods should be long and straight, dark green in the green types or clear spotless yellow in the wax type, and tender and free from excessive fiber at harvest maturity.

The laboratory has gone even further in helping to meet this demand. September 1939 was unusually hot at Charleston, and many of the beans in the experimental plots were unable to withstand the heat. Some, however, including strains resulting from crosses of the U. S. No. 5 Refugee and other strains developed by the Department of Agriculture at Greeley, Colo., with varieties common in the South, came through reasonably well. An opportunity was thus offered to make selections for high yield and heat resistance. Within the group was the well-known variety Bountiful, which produced a fairly satisfactory crop. This variety was used as the standard, and the only plants or bean families saved were those yielding more than Bountiful and at the same time possessing fairly straight pods. Forty-seven of these strains were saved, and from them two varieties of wax beans of outstanding quality were selected and released to seedsmen. One, known as the Cooper Wax, is a market-type bean derived from a cross of Brittle Wax with a strain closely related to the U. S. No. 5 Refugee. In late spring plantings in which Brittle Wax, Stringless Black Valentine, and Bountiful gave very low yields, the new Cooper Wax came through with fair yields, and under adverse weather conditions showed much less tendency to curl than the Brittle Wax. The Cooper Wax is resistant to common bean mosaic and is little damaged by powdery mildew. The large pods are very tender and relatively free from fiber.

The other new bean is known as the Ashley Wax (fig. 2, *A*), a wax canning type that resembles the U. S. No. 5 Refugee in many of its characters. It was another segregate from the same cross as Cooper Wax (fig. 2, *B*) backcrossed to Brittle Wax. In productivity, Ashley Wax is one of the most prolific strains developed in the vegetable-breeding work at the laboratory. When planted at the usual time it has not been outstanding, but planted during the summer season it has performed exceptionally well. Ashley Wax is considerably earlier than the U. S. No. 5 Refugee. The pods are round, light yellow in color, and lose all trace of greenness before they reach harvest maturity. They are very tender, relatively free from fiber, and of very high quality. This bean is resistant to common mosaic and fairly tolerant to powdery mildew. It is not resistant to bacterial blights, but its leafiness seems to offset some of the losses due to them. It is believed that these two new beans should be widely useful in the South, the Cooper Wax as a market-garden shipper and the Ashley Wax as a canning bean.

Releases of new varieties are made cooperatively by State stations and the Department of Agriculture or independently, as may be appropriate. "Release" normally consists of putting an announcement and description of the variety in seed-trade and other agricultural publications and supplying an initial quantity of seed of the new variety to actual seed producers who request it. These producers increase the stock seed and make it available for sale through normal trade channels. In the case of varieties of local interest or importance, special arrangements for increase and release are sometimes developed. It takes 2 or more years from the time of release for a new variety to become generally available to growers through retail outlets. Advertising is sometimes slow in appearing. Seedsmen known to be specialists in the development and production of a given crop are generally the first to be able to supply a new item. Until a variety is generally available growers will need to get in touch with crop specialists at their respective experiment stations or with the Southeastern Regional Vegetable Breeding Laboratory for information on the first sources of supply.

Other Selections Made in Florida

An instance of the practical value of further study and selection of breeding material supplied by the laboratory is the work done at the Everglades Experiment Station in Florida in developing two new varieties of snap beans from seed sent from Charleston. These two varieties have been named the Florida Belle and the Florida White Wax. Because of their productivity and their resistance to heat and drought and to bean rust and mildew, they are particularly adapted to Florida conditions.

The Florida Belle was derived from a cross of Stringless Black Valentine with a close relative of the U. S. No. 5 Refugee backcrossed subsequently with Stringless Black Valentine. It is more productive than Stringless Black Valentine or Tendergreen. The pods are long, straight, slightly oval in cross section, attractive light green in color, fairly brittle, and without strings. The quality is good.

The Florida White Wax is a selection from a cross of Brittle Wax with a close relative of the U. S. No. 5 Refugee. It is resistant to common mosaic and to some forms of rust and mildew, tolerant of heat and drought, and fairly productive. The pods are medium in size, straight, slightly oval in cross section, almost white in color, brittle and stringless, and the quality is very good. The season is about a week later than that of Bountiful.

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Figure 2.—Two new varieties of wax beans developed at the Vegetable Breeding Laboratory: *A*, Ashley Wax; *B*, Cooper Wax.

The New Logan Variety

During recent years there has been an increasing demand on the part of the canning and frozen-pack industries, as well as market gardeners, for round-podded, dark-green snap beans of the Tendergreen type. To fill the demand the Tendergreen variety has been grown more and more extensively, at the expense of many of the older standard varieties. The Vegetable Breeding Laboratory has now developed a new dark-green, long-podded variety, the Logan, which is highly productive and also highly resistant to common mosaic and powdery mildew, and which seems to have considerable tolerance to bacterial blights.

This variety, one of the most promising developments of the station, comes from a cross between the Stringless Black Valentine and a sister line of the U. S. No. 5 Refugee. The pods are medium broad and plump, 6 to 6½ inches long, dark green in color, brittle, tender, stringless, fiberless, and of fine texture and excellent quality. The ability of Logan to set pods under adverse conditions makes it well adapted to spring, summer, and fall planting in the South. Tests have shown that it gives a very high quality canned product and compares favorably with Tendergreen and U. S. No. 5 Refugee when used for freezing.

To determine the relative productiveness of the Tendergreen, Logan, and Stringless Black Valentine varieties, plantings were made on the experimental grounds of the laboratory on August 16, 1942. There were four replications of the test plots. All the varieties bloomed on September 16, and the pods were marketably mature by October 5. All plots were irrigated twice after blooming. At harvest maturity the average yields of marketable pods per 10 plants were as follows: Tendergreen, 9.6 pods, Stringless Black Valentine, 129.4, and Logan, 259.4.

Vitamin C Content of Beans

While the development of snap bean varieties adapted to the southeastern region has been going on, extensive studies have been made at the laboratory on the ascorbic acid, or vitamin C, content of the various strains and varieties. The objective has been not only to find out what the range in vitamin content may be under various seasonal conditions, but to explore the possibilities of breeding varieties having more vitamin C. This work was begun in 1941.

The methods used in the making of these determinations are highly technical, and a detailed discussion of them is beyond the scope of this publication. It may be said, however, that the workers at the laboratory have made important improvements in the methods previously employed.

In the first series of tests, 46 hybrid strains and 3 named varieties were used both in spring and in fall plantings. Significant varietal differences in vitamin C content were found for each picking and for the average of all pickings. The strains tested showed a vitamin C content varying from 19.1 milligrams to 28.7 milligrams per 100 grams in the spring, 16.2 to 26.4 milligrams per 100 grams in the fall, and 17.7 to 27.5 milligrams for fall and spring combined—in other words, a difference of 50 to 60 percent. The variety having the most vitamin C was Bountiful, but hybrid bean VBL 46 contained almost as much. In experiments made in the fall of 1941 with several strains and varieties it was found that in general the higher quality varieties, such as Blue Lake, U. S. No. 5 Refugee, and Kentucky Wonder, had much less vitamin C than the more fibrous beans, such as the field bean Idaho No. 1 Mosaic Resistant Great Northern. In general, the stage of maturity seemed to have little influence on the vitamin C content. Examination of the different parts of the plant showed the leaves always much higher in vitamin C than the other parts, with the stem, pods, and roots following in that order.

Storage at 36° F. was much more effective in conserving the vitamin than storage at room temperature (70°). In a week at room temperature the pods lost approximately half their original vitamin C.

Later studies in 1942 with 39 bean varieties of both bush and pole types showed an average content of 25.7 milligrams per 100 grams for the 19 bush types as against 24.1 milligrams for the 20 pole types. More recently, these studies have been extended and determinations are now being made of vitamins B_1 (thiamine), B_2 (riboflavin), and carotene, as well as vitamin C in different strains and varieties of beans.

These studies have not only furnished valuable information on the vitamin C relation in snap beans, but have also indicated that by careful breeding the normal content may be considerably increased.

FIGURE 3.—In a South Carolina field, scientists of the Vegetable Breeding Laboratory examine snap bean plants that are affected with bacterial blight.

Breeding Disease-Resistant Beans

Another aspect of the snap bean problem that has been under investigation is bacterial blight (fig. 3). Two other bean diseases, mosaic and powdery mildew, need no longer be a menace to the bean grower, for all the new bean varieties developed by the laboratory are highly resistant to both. Bacterial bean blight is another matter. Unfortunately it is impossible to deal with all bean diseases in a single line of experiments. It has been necessary in studying bacterial blight to carry on research paralleling to some extent that done in other bean-breeding programs.

In order to develop new breeding lines possessing resistance to bean blight, it was found necessary to go back to the Idaho No. 1 Great Northern, a field bean, to find tolerance for the disease. While this variety has merit as a field bean, it has certain pod characters that would be highly undesirable in a snap bean. In using it in the development of a satisfactory blight-resistant snap bean, therefore, it has been necessary to eliminate these undesirable pod characters from the progeny while retaining the blight-resistant properties. This has taken time to accomplish. Blight-resistant beans equal in table quality to the best garden types, such as Tendergreen, have been developed, but it has been thought desirable to continue the work a little longer to make further improvement in the pod characters of the new lines before releasing them for general trial.

There are two types of bean blight—the common bacterial blight caused by *Bacterium phaseoli* and the so-called halo blight caused by *Bacterium medicagensis* var. *phaseolicola*. Both are being studied. In general, tolerance [3] of and resistance to the two types go hand in hand.

The causal organism is carried in the seed, and since southern home-grown seeds are likely to carry the germ, their use is discouraged. Seeds from certain western sources where blight does not occur are used at present as a means of control, but their use does not assure complete freedom from the disease, and losses are common.

For making the pathological tests in the greenhouse, special inoculation methods have been developed. The plants used are healthy and vigorous and are selected with great care. The secondary leaves are removed as soon as they appear, leaving the two primary leaves, which are always used in the test. To inoculate, a rubber sponge saturated with a suspension of the causal organism in water is held beneath the leaf, and a multiple-needle perforator is plunged through the center of each leaf into the sponge. As the perforator is withdrawn, the bacteria deposited on the surface of the needles are brought into the perforations where they have favorable opportunity to infect the leaf. The rate and extent of the breakdown in the perforated area, which is about 1 inch in diameter, gives a measure of the degree of blight susceptibility or tolerance. This is proving to be a very effective and useful method for testing the blight resistance of the breeding lines.

It should be said that complete immunity to any plant disease is rarely found; only a greater than usual degree of tolerance of or resistance to it can be hoped for. Blight resistance is being bred into types represented by such varieties as Logan, Stringless Black Valentine, Tendergreen, Bountiful, and Bush Kentucky Wonder.

Anthracnose is another important bean disease that has been given attention at the laboratory. It may be caused by any one of several pathogenic strains of *Colletotrichum lindemuthianum* (Sacc. and Magn.) Briosi and Cav. The sharp differentiation of these strains and the very different symptoms they produce suggested that bean anthracnose would offer a favorable medium for making a thorough study of the inheritance of resistance to a group of closely related strains of disease organisms. Accordingly, an investigation initiated in 1932 by a present member of the scientific staff of the laboratory was carried through to the spring of 1941. Fifteen parent bean varieties and selections in 30 combinations and three physiologic forms of the causal organisms were used.

A complete consideration of the genetic relationships revealed by this research is beyond the scope of this publication. Those interested will find a complete report of the work and its results in Department of Agriculture Technical Bulletin 810, The Factorial Interpretation of Anthracnose Resistance in Beans, by C. F. Andrus and B. L. Wade, issued in June 1942.

[3] By tolerance is meant the ability of the plant, through the development of an abundance of foliage, to mature a crop in spite of susceptibility to the disease.

A condition frequently encountered by bean breeders and growers is variegation. In light or mild cases, this manifests itself merely by slight variation in color or slight deformity of the leaves, but in severe cases the plants usually die before any pods are produced. The condition is the result of the inheritance of certain characters normally present in some varieties and appears not to be of parasitic origin. A number of the standard bean varieties show this characteristic to some degree.

It is apparent that in breeding beans, the elimination of variegation is important, and careful study has been given to certain forms of it at the Vegetable Breeding Laboratory. A complete discussion of the research and its results will be found in Genetic Studies of Variegation in Snap Beans, by B. L. Wade, in the Journal of Agricultural Research, 1941. (See p. 34 for complete citation.)

The growing of pole beans in the South is handicapped by the presence of the root knot nematode (*Heterodera marioni* [Carnu] Goodey), which thrives during the hot summer months and causes damage to many crops. Long-season summer crops are most affected by it. Relatively low temperatures retard the activities of the nematodes, but as the season advances they become more active, and during the hot summer months root galls develop rapidly. The pole bean is a late-maturing crop and consequently is often exposed to severe attack. Work has been undertaken at the laboratory to develop varieties resistant to the nematode.

CABBAGE

Cabbage is being given particular consideration in the research program because of its importance as a truck crop for shipment to northern markets from November to June, when freshly harvested, locally grown cabbage is not available. It is possible to harvest cabbage commercially in parts of the southeastern region virtually all the fall, winter, and spring each year, instead of in summer and early fall, as in the Northern States.

Cabbage is used to some extent in the South, but collards, kale, and turnip greens are more widely adapted and thrive better there. Many of the standard varieties of cabbage grown widely in the northern areas are not adapted to this region because growing conditions sometimes bring out variations in type that may not be evident under northern conditions. They lack cold hardiness and are susceptible to destructive diseases, characteristics which make them unreliable croppers. In addition, many of them show a tendency to bolt, or go to seed, before reaching market maturity in the spring.

The Copenhagen Market, Marion Market, and Charleston Wakefield are the varieties most widely grown in the southeastern area. None of them, however, possesses all the characters desired in a shipping cabbage. The Charleston Wakefield has a pointed head which does not fit well into a container and is injured more or less during shipment, and the Copenhagen Market and Marion Market are sensitive to seasonal conditions and cannot be relied on to produce satisfactory crops from year to year.

These considerations have determined the course of the work at the Vegetable Breeding Laboratory and have made clear what must be the objectives. Varieties satisfactory for the region must be (1) cold tolerant, and have the ability to produce crops under adverse seasonal conditions; (2) able to set a large percentage of heads; (3) resistant to the common cabbage diseases; (4) characterized by round, dense, small or medium-sized heads of good green color and small core; and (5) able to arrive at harvest maturity without showing a tendency to bolt (fig. 4).

The work on cabbage began in the fall of 1936, when over 700 strains of cabbage, cauliflower, collards, mustard, turnips, rutabagas, and related crucifers

FIGURE 4.—The cabbages in the row to the left are from an inbred line that is slow to bolt, or go to seed; those to the right, with the flower stalks, represent a quick-bolting line.

were planted in preliminary tests for the selection of breeding material showing disease resistance and climatic adaptation. Inbreeding and crossing of what seemed to be promising lines got under way in 1937.

It may be well at this point to explain why, in the improvement of vegetable crop plants, inbreeding is sometimes practiced. It is generally considered that inbreeding is to be avoided because of the likelihood of the appearance of abnormalities, weaknesses, and deformities in the offspring. This is true for many crop plants, but in the hands of skilled geneticists or breeders, inbreeding provides a valuable means of bringing undesirable characters to the surface and, therefore, making possible their elimination. By the same means, desirable characters may often be segregated. In the case of crop plants, the process consists of fertilizing flowers of the plant under consideration with pollen from other flowers of the same plant and providing suitable covering to prevent cross-pollination by means of insects or other agencies. Pure inbred lines developed in this way often prove extremely valuable for use in outbreeding or cross-breeding. In much of the breeding work of the laboratory this method is made use of, but always under carefully controlled conditions.

The late fall of 1938 was a significant period in the history of the cabbage research and marked the real beginning of the productive breeding program. At this time a severe freeze killed many of the plants in the experimental plots, but 3 of 31 varieties especially selected for their desirable characters and recommended by seedsmen proved to be more hardy than the others. These were the Charleston Wakefield, Volga, and All Head Early, which have since served as the foundation stock from which cold-hardy and otherwise valuable lines have been developed.

In November of 1939 the breeding stocks went through another severe cold-hardiness test, making possible the choice of valuable selections for hardiness and resistance to bolting.

Vitamins in Cabbage

Within some of the surviving inbred lines, tests showed a very high vitamin C content, even exceeding the values reported for grapefruit, limes, and orange juice and equaling that of lemon juice. This finding marked the beginning of another important phase of the cabbage-breeding program—breeding for high vitamin C content (fig. 5).

FIGURE 5.—In the laboratory, research workers study cabbage breeding lines and analyze the heads for vitamin content.

The war has made the peoples of the world vitamin C conscious, and scientists of many countries have gone far afield in the search for this very important food constituent. It has been known for some time that cabbage contains substantial amounts of this vitamin, but it has been the good fortune of the workers at the Regional Vegetable Breeding Laboratory to prove that cabbage may be a much more important source than has been suspected and, what is more, that the amount may be materially increased by selective breeding. Recently released tables showing the proximate mineral and vitamin components of foods give an average value of about 50 milligrams of the vitamin per 100 grams of the raw, edible portion of the cabbage. The work at the laboratory confirms the findings of other workers that not only is there wide variation in the vitamin C content of different varieties and strains, but values vary in the different parts of the cabbage head. The vitamin C may vary also depending on whether the plant was grown in the spring or fall.

Taking all these facts into consideration, comparative analyses have been made of a considerable number of the standard varieties and strains grown under known conditions and it has been found that in many cases the average amount present may be considerably less than 50 milligrams per 100 grams. Selected breeding lines developed in the experimental plots at the laboratory, however, have shown values ranging from 68.6 to 81.6 milligrams per 100 grams of material and in one case an average within one breeding line of 94 milligrams. There is reason to believe that the possibilities have by no means been exhausted. The variety Volga has been found particularly valuable as a parent stock for the development of strains high in vitamin C as well in cold resistance and heat tolerance.

A very interesting and valuable study carried on at the laboratory has recently been reported. This deals with the vitamin content of the different parts of the cabbage head when the same varieties are grown in the spring (November to May) and in the fall (August to November). Analyses were made not only for vitamin C (ascorbic acid) but for vitamins B_1 (thiamine) and B_2 (riboflavin). The parts of the head studied were (1) the six outer or wrapper leaves which are usually removed before the housewife sees the cabbage, (2) the outer six solid head leaves, and (3) the inner portion of the head next the core. Four varieties were included in the test: Copenhagen Market, Marion Market, Charleston Wakefield, and Round Head 18.

Little difference was noted in the relative proportions of the three vitamins for the two seasons—vitamin C was always about 1,000 times more abundant than B_1 and B_2—but for the total quantities produced in the two seasons there were interesting differences. The wrapper leaves, in both seasons, invariably contained the largest amounts of all the vitamins. For example, in the May cabbage there were 1.5 times more vitamin B_1, 2.0 times more vitamin C, and 3.7 times more vitamin B_2 in the wrapper leaves than in the outside leaves of the solid head. In the November cabbage, however, the concentrations of each vitamin were appreciably less. In the May cabbage the outer leaves of the head outyielded the inner leaves next the core, but in the November cabbage the reverse was true; in other words, as the season became progressively cooler more vitamins accumulated about the core, while as the season became progressively warmer the vitamins were most abundant in the outer portions of the head.

The average yield of all three vitamins was greater in the November than in the May cabbage, and there was less variability and more uniform distribution of the vitmins in the fall than in the spring.

The relative ranking of the different varieties from season to season was fairly constant. Copenhagen Market was generally best of these varieties in vitamin C but only fair in thiamine and riboflavin. Round Head 18 was best of all in the B_1 and B_2 vitamins but poorest in vitamin C.

It is of interest to note that the wrapper leaves of the cabbage were found to be as important sources of the vitamins as turnip greens and kale.

Observations on Dehydrated Cabbage

Differences in flavor between different varieties and strains after dehydration were difficult to detect; the appearance of the products, however, differed considerably. Color of dehydrated cabbage was retained better in cold storage than at ordinary room temperatures. These observations were made on the laboratory product only.

Two New Cabbage Varieties Released

Important advances have also been made at the laboratory in the development of cabbage meeting the demands of the market as to size, shape, height of head, cold hardiness, disease resistance, and freedom from bolting. Two new cabbage varieties, Huguenot and Madison (fig. 6), have recently been released by the laboratory. The Huguenot was obtained by selection of round-headed plants

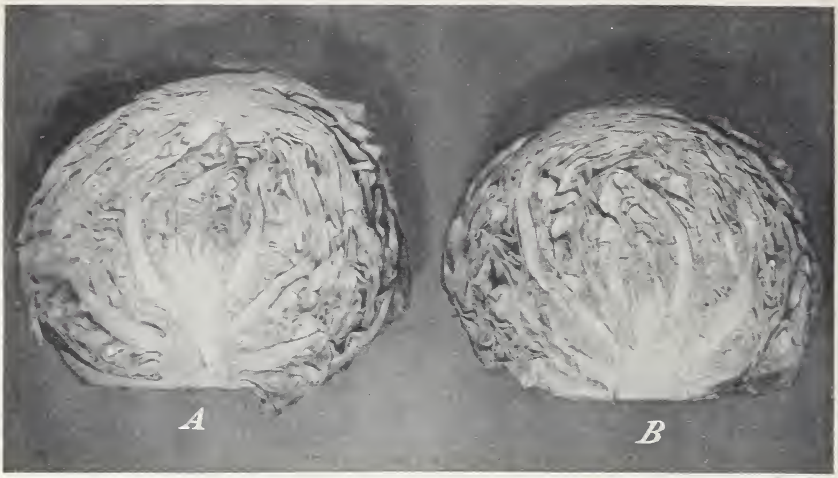

FIGURE 6.—The two new cabbage varieties developed at the Vegetable Breeding Laboratory for adaptation to the Southeastern States both have dense, round heads and relatively small cores: *A*, Huguenot; *B*, Madison.

from the progeny of a pointed Charleston Wakefield that survived the killing temperatures of the winter of 1938–39. The Madison was obtained at the same time from a plant of Wisconsin Ball Head.

Both strains were produced by self-pollination of plants selected for cold hardiness and nonbolting habit when grown in the test plots of the laboratory as spring cabbage overwintered in the field. Other characteristics are compactness of head, good quality, and high vitamin C content when grown at any season. When grown at the same time and in the same field, both outranked Golden Acre, Copenhagen Market, Charleston Wakefield, and Marion Market in vitamin C content. Huguenot outyielded all four commercial varieties on a weight basis and Madison outyielded all except Marion Market. Other selections nearly ready for release are considered to be improvements over these.

WATERMELON

Research on watermelon improvement, as already mentioned, has been held in abeyance during the last 2 years because of war conditions and other demands. The work will be resumed, however, as soon as possible, and it may be worth while to restate the objectives and to review the progress made thus far.

In growing watermelons, problems arise out of two sets of conditions: (1) The wide distribution of anthracnose, downy mildew, and fusarium wilt, diseases that may destroy a farmer's crop almost overnight; and (2) the considerable lack of uniformity and dependability in quality of watermelons, and, in some cases, inability to withstand the rough handling to which they are subjected between the shipping point and the consumer. This lack of dependability is frequently responsible for disappointment on the part of the consumer.

The flesh of a watermelon should be of fine texture, sweet, and of good flavor; the rind should be tough so that the melon will not break or "explode" in transit; and the plant must be able to maintain itself in spite of fusarium wilt, anthracnose, and other diseases. Attractive color of the flesh and prominent, dark-colored seeds are considered desirable characters by some, but they are of minor importance.

Disease resistance, high quality of flesh, and toughness of rind have been the main considerations in the watermelon breeding at the laboratory to date.

The initiation of this work coincided with the establishment of the laboratory, when varieties and strains from various domestic sources were brought together and planted in the field for observation and selection. Cross-breeding of what appeared to be promising lines was begun. In 1937, about 25 varieties or strains of watermelons said to be wilt resistant were under test along with about 300 other sorts. The following year seeds of approximately 400 new accessions were received, for the most part from foreign countries, and these were tested for disease resistance and adaptability to the southeastern region. Among them were found several lines that appeared to have some resistance to anthracnose, and two of them that came from Africa possessed an unusual degree of sweetness and indicated possible value in breeding for quality improvement. Some information was also obtained on the inheritance of size and color of the seed and of size and shape of the melon.

Tests in 1939 on breeding material in the greenhouse revealed no commercial variety with sufficient resistance to anthracnose to offer any promise in breeding for this factor, but natural infection of plants in the field indicated that some were slightly tolerant to the disease.

Up to this time, 186 selfed (self-pollinated) lines had been developed that apparently possessed some degree of tolerance to wilt, and greenhouse inoculation tests of plants from seeds of open-pollinated lines gave a few promising individuals. Tests of standard varieties also showed evidence of wilt resistance in some of them.

After inbred selected lines of watermelons carrying the factors of earliness, sweetness, desirable flavor, and resistance to fusarium wilt had been developed in the earlier work, cross-breeding within this group was carried on in 1940. Out of 114 populations from a cross made to obtain wilt resistance, 19 were found to possess it to a satisfactory degree and 8 of the best of these were outcrossed to correct recognized deficiencies. No correlation was found between resistance to fusarium wilt and melon weight, shape, sugar content, or seed color.

Continued progress was made during the following year in producing inbred lines of important commercial varieties of watermelons to stabilize their desirable characteristics, and further attempts were made to increase the level of wilt resistance by intercrossing and selection.

Promising Breeding Stocks

It was at about this point that war conditions made it necessary to halt the work, but not before some very promising breeding material had been brought to light. Among named varieties showing particular merit were the following:

1. The Hawksbury. Obtained from Australia, though probably of American origin, this variety has shown a high degree of resistance to fusarium wilt and proved to be dependable as a producer of melons of fairly good quality. The flesh is not as sweet as desired but high wilt resistance makes the variety a very promising breeding stock.

2. The Dove (also known in the South by a large number of synonyms) (fig. 7, *A*). An outstanding variety of the long-type melon, reaching a weight of 45 to 75 pounds and having flesh of fine texture and excellent table quality, this melon is acclimated to the southeastern region and strains of it have shown considerable wilt resistance. The fault of this variety is a brittle rind which makes it liable to cracking and injury in shipment so that it requires very careful handling. It brings top prices in the northern markets, however, and seems to offer much

promise for breeding purposes. A melon with the table quality of the Dove but with a tougher rind would go a long way toward filling the present need, and it is believed possible to produce such a melon by further breeding.

3. The Northern Sweet (fig. 7, *C*). A Minnesota-bred, Russian-type melon of the round type, weighing 10 to 13 pounds, its particular merits are a tough rind and sweet flesh. It is coarse in texture, and because it is susceptible to fusarium wilt it is not adapted to the region. By careful breeding and selection, however, it is believed the desirable characters of the Dove and the tough rind character of Northern Sweet may be combined in a new melon of outstanding merit (fig. 7, *B*).

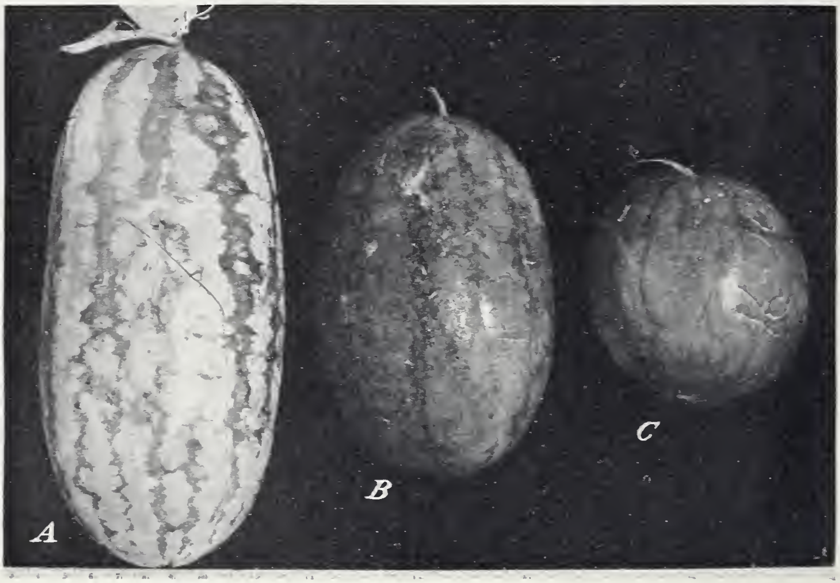

FIGURE 7.—The Dove variety of watermelon (*A*) was crossed with the Northern Sweet variety (*C*) to produce the hybrid (*B*), which combines some of the desirable characteristics of both parents.

Other watermelon varieties possessing high wilt resistance and showing much promise have been developed at State experiment stations in the South. Among these are the Leesburg and Blacklee, produced by the Florida workers. These have been used in the breeding program of the Regional Vegetable Breeding Laboratory, and their further use is anticipated when the work of the watermelon project is resumed.

This gives a general idea of what has been done with this crop and the present status of the project. Seeds of several lines, constituting a group selected for high sugar content, good flavor, wilt resistance, and tough rind, and representing several types and sizes of melons, have been sent to four collaborating State stations, but no releases of named varieties have been made from the laboratory. Insistent demands are being received from watermelon growers in the South for improved varieties, and it is hoped that the work may be resumed in the near future.

TOMATOES

The grower of tomatoes in the southeastern region of the United States is confronted with many problems. One or more fungus diseases may quickly strip the plants of their foliage and ruin his crop; fusarium wilt is widely distributed and very destructive; nematodes may attack the roots of the plants and cause heavy losses; collar rot of the young plants may be particularly serious in the seed beds; and early blight does great harm. Locally bacterial wilt, stem blight, and other diseases abound. Of particular significance is the fact that tomatoes are essentially a spring crop in most sections of the South and the picking season lasts for only about a month. The yields are likewise very low compared with those in more favorable sections of the country. The tomato fails to thrive during the hot summer months in the South and sets fruit only sparingly, if at all. True, excellent tomatoes are grown in the South, but only under greatly restricted conditions. The southern family, therefore, contrary to common belief, generally cannot enjoy tomatoes from the garden all summer but must obtain them from northern sources during this season.

Ever since its establishment one of the principal objectives of the vegetable breeding program of the laboratory has been the development of tomato varieties that will not only be able to withstand the ravages of the various tomato diseases but will also produce fruit over a much longer period.

The general plan has been essentially the same as that followed in the improvement of the other vegetable crops at the laboratory; that is, standard commercial varieties grown in various parts of the world and the breeding stocks of other workers have been brought together from as many sources as possible; seeds of wild types and species have been imported from other countries; and through cross-breeding, inbreeding, selection, and the various other standard procedures, the geneticists are gradually eliminating unwanted characters, developing new combinations of desirable characters, and subjecting the resulting lines to the most rigorous tests that can be devised. The story of this research, as told by the workers themselves, is extremely interesting. The main features of it will be considered here.

Tomato Diseases

Particular attention has been given to the diseases causing defoliation. Early blight and septoria leaf spot are the two most common and serious diseases of this type affecting the tomato in the southeastern region.

Early blight is caused by the fungus *Alternaria solani* (Ell. and Mart.) Jones and Grout. The first symptoms usually appear on the older leaves as irregular, brown, concentrically ringed spots with a yellow halo. The greatest injury usually occurs after the fruit is well set. If high temperatures and high humidity prevail at this time, much of the foliage may be killed. The fungus also attacks the stems and often causes blossom drop and loss of young fruit. Mature fruits also are often affected and frequently drop, but even if they do not drop they are unfit for marketing.

Collar rot, another phase of the same disease, affects the stems of young plants at or near the ground level in seedbeds and cold frames. It kills many of the plants, weakens others, and has become a really serious problem to growers who ship young plants to the northern markets.

As yet no type or strain of tomato showing marked resistance to early blight has been found, though a high degree of resistance to collar rot has been demonstrated in certain types. Just why there should be resistance to collar rot and not to early blight, when both are caused by the same organism, is not clear. Statistical analysis of some of the experimental data has shown that plants resistant to collar rot are somewhat less susceptible to early blight, but so little that it is of slight practical significance. It is hoped that studies may be undertaken later to obtain a clear understanding of the factors involved in these relationships.

Even lacking this knowledge, it is thought by workers at the laboratory that the use of collar-rot-resistant plants in the field will lessen the losses from early blight through a decrease in the amount of inoculum (infective material) present.

The information already obtained in the collar rot studies will prove of great importance to the growers of seedling tomatoes in the South and in turn will profit northern growers who use their plants.

Practically all commercial tomato varieties in the United States have proved susceptible to collar rot. A high degree of resistance, however, has been found in the medium-sized Danish and English forcing tomatoes, such as Devon Surprise, and in strains of the South American currant (*Lycopersicon pimpinellifolium* Jusl. Mill.) and cherry (*Lycopersicon esculentum* var. *cerasiforme* [Dun.] A. Gray) types (fig. 8).

FIGURE 8.—Some of the types of tomatoes included in the collection of the Vegetable Breeding Laboratory: *A*, Red cherry tomato; *B*, South American red currant tomato, which has been found resistant to several diseases; *C*, small, extremely fasciated (having stems enlarged and flattened) fruit; *D*, medium-sized, moderately fasciated fruit; *E*, long pepper-type tomato; *F*, short pepper-type fruit; *G*, yellow plum tomato; *H*, small, red, flat type common in South America; *I*, oxheart tomato; *J*, red plum tomato; *K*, small, red, round type; *L*, box pepper type; *M*, hairy type (*Lycopersicon hirsutum*), with undeveloped fruit.

Steps have been taken to incorporate this resistance into the newly bred lines. Unfortunately, the breeding stocks possessing it produce small fruits, and this has slowed the production of resistant lines bearing commercial-sized fruit. Substantial progress has been made nevertheless, and fruit of nearly commercial size and of high quality has been developed. This work is being pushed as rapidly as possible.

Collar rot resistance is being bred into counterparts of such commercial varieties as Pan America, Rutgers, Marglobe (fig. 9), Gulf State Market, "Montgomery" (an officially unnamed strain selected from a field in the vicinity of Montgomery, Ala.), and Victor. Gulf State Market and Montgomery are varieties of southern development; Victor is a northern early-market type.

FIGURE 9.—A hybrid tomato, produced by crossing the South American red currant tomato with the commercial variety, Marglobe, grows in the greenhouse at the Vegetable Breeding Laboratory.

Septoria leaf spot, caused by the fungus *Septoria lycopersici* Speg., is another foliage disease that occurs in this region. It is not at present as serious as early blight, but at times it occurs in epidemic form and causes severe defoliation. Search for parent breeding stocks entirely resistant to it has revealed none among commercial varieties. Considerable tolerance was found in a single small-fruited segregate from the Targinnie Red variety received from Australia, and breeding work employing this source of *Septoria* tolerance is already well advanced. *Lycopersicon hirsutum,* a wild, green-fruited hairy type of tomato from South America, apparently possesses some resistance to Septoria, but because of its tendency to produce near-sterility in the hybrid offspring, it is not being used at present in the breeding program.

Gray leaf spot, caused by the fungus *Stemphylium solani* Weber, is another destructive foliage disease of the region. As the name suggests, it is characterized by gray spots on the leaves. The disease is relatively new but is assuming considerable importance in the tomato-growing sections of the South, causing very rapid defoliation after the first picking of fruit. In some instances, it may have been confused with Septoria and bacterial leaf spots of tomatoes, and possibly also with early blight.

None of the present commercial varieties has been found to possess any resistance to gray leaf spot, but resistance has been discovered in some strains of the currant tomato of South America, mentioned before. Breeding to develop commercial varieties resistant to this disease is going ahead as rapidly as possible. Full commercial size has not yet been attained in the fruit but has been approached. Reports of trials on stocks sent to Hawaii and other places have been favorable.

Another disease that has received some attention from the workers of the Vegetable Breeding Laboratory is the so-called **cladosporium leaf mold,** caused by the fungus *Cladosporium fulvum* Cke. This is primarily a greenhouse disease and much less important than the others named, but it might become a local problem in the South. Resistance has been found in several tomato breeding lines, including the variety Vetomold, developed in Canada through the use of a strain of *Lycopersicon pimpinellifolium.* Crosses between this variety and the Pan America at the laboratory have resulted in a tomato that promises much as a resistant breeding line. Tests in Florida have proved favorable.

Fusarium wilt, familiar to all tomato growers throughout the south, is a destructive disease caused by the fungus *Fusarium oxysporium* var. *lycopersici* Schlecht. Development of resistant varieties has been the objective of intensive research. The Pan America, Targinnie Red, and several strains of the currant, cherry, and other small-fruited types possess very high resistance and some of these have been used in the breeding work at the laboratory.

Testing for Resistance or Susceptibility to Diseases

A very effective greenhouse method for inoculating test plants with disease-producing fungi has been developed, and since it has been of tremendous value in determining the degree of resistance or of susceptibility of plants and has resulted in great saving of labor, space, and time in the breeding work, it will be discussed briefly.

The disease-producing fungus is grown on a liquid nutrient medium in culture flasks for 2 weeks, and then the entire culture is reduced to a uniform consistency by means of an electric homogenizer. The suspension is then diluted 3 to 12 times its volume with water, the degree of dilution differing with the different disease fungi. It is then ready for use. The plants to be tested are started in greenhouse flats and when large enough are pricked off into 4-inch greenhouse pots, three plants to the pot. In some cases the plants are used directly from the flats. At the end of 4 weeks from date of seeding, the plants are inoculated by immersing the tops in the fungus suspension (fig. 10). Plants inoculated directly from the flats are transplanted to the observation beds; those treated in the pots are placed on the benches and given the usual greenhouse care.

Observations on the development of disease symptoms are made at the end of 7 and 14 days and the results recorded. Survivors may be planted in the field and later used in breeding or made the subjects of other tests as desired.

In the case of collar rot, susceptible varieties usually show 100 percent infection by the end of 7 days. In the case of plants showing a greater degree of resistance, observations and records are made at the end of 14 days, the survivors are lifted, the soil is washed from the stems and roots, and the degree of resistance, tolerance, or susceptibility is determined by the nature and extent of the lesions found on the stems. In the case of foliage diseases only, readings are of course made without lifting the plants.

In applying the method to the study of resistance to foliage diseases, the plants, after inoculation, are placed in a moist chamber, where infection of susceptible plants takes place promptly. In the case of collar rot and root inoculations, the plants are transplanted to soil beds warmed to favor infection. Modifications in this general method are made to meet specific needs. This is known as the "dunking" method, and it is a godsend to workers who have many thousands of plants to handle.

FIGURE 10.—Tomato plants being tested for resistance to disease. *A*, "Dunking" a tomato plant in a fungus solution to test its resistance. *B*, Many of the exposed plants have succumbed. Those that resist infection will be used in the breeding work.

In carrying out the selection of progenies developed for resistance to the various tomato diseases, it has been found of much practical value to test the same lot of plants for resistance to fusarium wilt as well as for collar rot or gray leaf spot. For example, by the use of the dunking method, a test is made first for resistance to collar rot, and then the survivors are tested for fusarium wilt resistance. This procedure eliminates vast numbers of susceptible plants that otherwise would occupy valuable space and require a great deal of labor.

Adaptation to Climatic Conditions

While these lines of work have been going on, intensive study has also been given to the adaptation of the tomato to climatic hazards, particularly to summer heat in the South. The small-fruited South American currant and cherry types are able to set fruit well in hot weather, and there are a few commercial varieties, such as the Summerset, Bounty, and Victor, that set fruit fairly well; but the latter do not appear very promising as parent stocks because of their tendency to crack badly and their inferior quality when grown under southern conditions. Breeding lines including characters derived from the South American small-fruited types are being developed and it is expected that the fruiting period of tomatoes in this region may eventually be considerably extended.

Vitamin Studies

Studies of the vitamin content of tomatoes are another phase of the tomato research being carried on at the laboratory. It has been found that small-fruited varieties contain more vitamin C than large-fruited. This is of particular interest since the former are being used in the development of varieties resistant to disease, and it may well be that along with disease resistance may go a higher content of vitamin C in the new varieties.

A valuable part of the work of the laboratory is the help it has been able to render to other workers in this field by supplying them with breeding stocks from its very extensive collection of varieties, strains, and types assembled from all over the world.[4] Hundreds of these are maintained in vigorous condition for prompt use, and many workers have availed themselves of this service.

Owing to the complexity of the tomato problem and the many factors that have had to be taken into consideration in the work, it has not yet been possible to release new varieties for trial. The work has progressed, however, to the stage where there is good basis for belief that valuable new varieties adapted to culture in the southeastern region will be available in the near future.

SWEET CORN

The sweet corn project of the Vegetable Breeding Laboratory is aimed primarily at developing garden sweet corn for the southeastern region, but with the additional ultimate objective of making available to truck growers of the South a product that can be placed on the northern markets at a favorable season. At the time the laboratory was established, there was no variety of sweet corn that was well adapted to southeastern conditions, because of failure to develop a satisfactory stalk on southern soils as well as because of earworm injury and the depredations of raccoons, opossums, and other "varmints." Leafhoppers and fungus diseases are also troublesome. The well-known "roasting ear" is from the starchy

[4] The laboratory is greatly indebted to the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils, and Agricultural Engineering, for aid in obtaining plant material from foreign sources.

type of corn, which is often lacking in tenderness and general table quality. There is a considerable demand for a well-adapted sweet corn of good quality, and if it could be developed it would add materially to the food supply and the economic well-being of the region.

The work on sweet corn was begun in 1936. Particular attention has been given to breeding for earworm resistance and for ability to withstand the ravages of animals.

The corn earworm (*Heliothis armigera* Hbn.) is widely distributed and very troublesome in some of the sweet corn producing sections of the North as well as in the South, and much study has been given to the matter of control. Because of the ability of the earworm to thrive on many plants other than corn, no satisfactory method has yet been found, and particular consideration has been given by various workers to the possibility of breeding resistant corn varieties. Many observations had led various workers to the conclusion that the degree to which the husk extended beyond the ear and the thickness of the husk wrapping were measures of natural resistance. Had the situation been as simple as that, the problem of the breeder would have been easier. Careful studies made by one of the laboratory scientists, however, indicated that earworm resistance in corn is not correlated with this characteristic and made it clear that it is due to some inherent chemical constituent of the corn plant, probably volatile in character. Later workers have been able to demonstrate the soundness of these conclusions by showing that eggs of the moth carefully placed on the ears of resistant strains and held under favorable conditions fail to hatch and eventually perish.

With this background of information, a substantial part of the investigation of the laboratory scientists has been the search for highly resistant strains for breeding stocks and the incorporation of this character of resistance into the progeny of selected parents.

To prevent damage by animals, electrically charged barbed wire around the breeding plots has been found effective, but this means of protection is, of course, not available for southern field conditions. The practical approach to this phase of the problem has proved to be to breed for stout, tall stalks with ears borne high above the ground and in large part out of reach of the troublesome animals.

Breeding Earworm-Resistant Sweet Corn

The course of experimentation was, briefly, as follows: The first experimental plantings were made in 1936. In the following year, first-generation hybrids, second-generation hybrids, and back-cross populations from earlier crosses were tested comparatively and about 300 inbred lines and 100 controlled cross-pollinated stocks were obtained for further breeding. In 1938, both inbreeding and cross-breeding were continued. Several inbred lines from crosses of starchy or field corns with sweet corns, possessing earworm resistance and tenderness, were given further tests for adaptation. Variety tests continued to indicate consistent differences in earworm resistance and in quality.

In 1939 inbred lines of sweet corn carried to the third generation of selfing (self-pollination) showed higher resistance to the earworm than had plantings of the two previous years. About 400 lines were selected for planting, representing 22 of the original 29 stocks used in 1936. A new series of inbred lines was initiated with 13 varieties of high table quality, and in addition about 100 new crosses between twice-inbred lines having high earworm resistance were made for inbreeding and selection. This work was continued in 1940 and new crosses were made in the greenhouse during the winter between the best starchy lines possessing high resistance to earworm and high-quality sweet lines. Although the best lines that had been developed at the station were much better than anything available from commercial sources, further improvement seemed feasible and the work was continued.

The records of 1941 showed the breeding stocks to be comprised of 49 lines inbred 5 times, 26 lines inbred 3 times, 72 F_3, or third generation, lines from crosses made in 1938 and 1939, and three F_2 populations from crosses made in 1940. The Iowa 45 proved to be the best Golden Bantam inbred line for earworm resistance and was used extensively in crosses made to improve table quality.

The work up to this time had shown seven inbred lines that were consistently highly resistant to the earworm, and in 1942 these were crossed with other breeding lines. The best of them were sent to several cooperating stations for trial and breeding. The starchy lines most resistant to the earworm were crossed with high-quality sweet lines and the hybrids backcrossed to the inbred resistant parents. These last were self-pollinated in the green house. Efforts were made to develop corn types that the local farmers could maintain and possibily top cross with certain specially adapted, high-quality lines from outside sources. Particular attention was given to this matter in 1943. Meanwhile, the other lines of work were continued and seed of sweet corn strains were distributed to collaborators in several States for test.

New Sweet Corn Varieties Released

In response to the insistent demands from various parts of the South for high-grade sweet corn, it was decided in 1944 to release the laboratory's first four varieties. These were named Kiawah, Edisto, Wappoo, and Carowa from local place names of Indian origin. The Kiawah resulted from the crossing of an inbred line of Cuban Yellow Flint with Oregon Evergreen (sweet), the progeny of which were inbred and selected for earworm resistance for 5 successive years and then open-pollinated. This corn grows to a height of more than 9½ feet, and produces an ear nearly 7 inches long. Resistance to the earworm is indicated by the fact that it has shown scarcely more than injury to the silk. It averages 12 to 14 rows of kernels to the ear. To reach full milk stage, this white corn requires about 99 days in the Charleston area.

The Edisto is another tall, late variety which resulted from a cross of Mexican June with Golden Bantam. This is a yellow corn with stalks reaching an average height of nearly 9 feet, and it is nearly as resistant to the earworm as the Kiawah. The ears average nearly 7 inches in length and the rows per ear average 12 to 14. In the Charleston area, it arrives at full milk stage in about 94 days.

The Wappoo is an early yellow variety derived by making combinations between an inbred line of Iowa 45 and Oregon Evergreen. This grows to a height of 6 feet and produces an ear of about the same length as the two mentioned above, but averages fewer rows to the ear (10 to 12). The earworm resistance is equal to that of Edisto, and the corn reaches full milk stage in the vicinity of Charleston in about 76 days.

The fourth variety, Carowa, is also an early yellow sweet corn and resulted from open pollinations from the start within the single cross hybrid, Iogold. This grows to an average height of 6½ feet and has an ear averaging over 7 inches in length. There are 10 to 12 rows of kernels to the ear. This variety suffers little damage from the earworm but is not quite so resistant as the other three. It requires about 76 or 77 days to reach table maturity in the Charleston area.

These varieties were purposely made open-pollinated in the belief that this would be most acceptable at this time to the farmers of the South, but further work is in progress looking toward the development of superior hybrid types for which these varieties will form the basis. Good reports on the performance of these types in the sweet corn section of the North Central States have been received.

Although the sweet corn research to date has been highly productive of results, the workers at the laboratory are by no means content with their accomplishments. Corns having longer ears, finger quality, and greater resistance to earworm injury and to diseases will be sought.

PEAS

The grower of garden peas in the southeastern region of the United States is faced with the basic fact that the time during which planting may be done with reasonable assurance of a successful crop is very short. If spring planting is done early, he encounters the risk of loss from late frosts; and if planting is much delayed, the plants are lost because of high temperatures. This fact, combined with the prevalence of destructive pea diseases, has made the growing of peas a more or less hazardous undertaking. Because of the high food value of peas and their importance as a market-garden crop, efforts to overcome all these handicaps by breeding appear fully justified.

The pea-breeding research program was initiated when several hundred strains of peas resulting from earlier breeding work in various parts of the United States by a member of the scientific staff were grown in the experimental plots of the laboratory. These were planted at the usual time for this locality, but it proved to be too late, for most of the plants succumbed to the high temperatures before reaching maturity and only a few survivors were saved.

Seeds of commercial varieties grown in various parts of the country and of breeding lines from other workers were assembled, and these, together with the survivors of the first season's test, formed the experimental material for further trials. From these tests it was possible to select lines that showed considerable cold hardiness, and most of them were resistant to fusarium wilt. These were tested further for cold hardiness and disease resistance, and in 1940 promising strains resembling Progress, Hundredfold, or World Record varieties and possessing fusarium wilt resistance or cold tolerance or both were released to several of the cooperating State experiment stations for trial.

In the course of the work at Charleston, it was found that strains tolerant to cold could be planted earlier so that the crop would come to market maturity with more certainty, and, further, that cold, heat, and drought tolerance appeared associated in the same strain. Such strains, therefore, could not only be planted earlier but might even be planted a little later than usual and still stand a fair chance of yielding a reasonable crop.

Reports of trials on the peas released to cooperating stations showed that they possessed a good degree of cold hardiness and also desirable horticultural characters. They were reported as performing distinctly better than the commercial varieties generally used in the region. Seeds of these frost-tolerant strains of market-garden peas were sent to the U. S. Department of Agriculture, Huntley Field Station, Huntley, Mont., for increase, and the resulting stocks were distributed in considerable quantities to the cooperating State experiment stations.

New Pea Variety, Wando, Released

One of these selections, the Wando, proved of such outstanding value that it was released to the seed trade for general distribution in 1943. This variety was developed from a cross of Laxton Progress and a hardy Perfection strain which had shown some tolerance to hot weather. The cross was made to obtain a large-seeded, dark-green, Perfection type pea suitable for canning or freezing.

The stems of the plant are thick with zigzag internodes and show a decided tendency to branch during cool weather. The variety blooms in the spring about 6 days later than Little Marvel or Laxton Progress. The stems remain upright even when heavy winds cause many varieties of the same type to fall over. The Wando is hardier than the Creole, which is grown somewhat in the South, and is suitable either as a home or market-garden pea. In pod size and character of peas it compares with Little Marvel.

One needs to see the Wando growing in the field plots alongside other varieties to appreciate its worth as a horticultural crop for the South. It has made good yields when the standard varieties were completely killed.

In tests conducted to determine its suitability for freezing preservation, it has shown up well.

To develop other varieties with still greater tolerance to cold and thus extend the pea season, further breeding is being carried on. Some exceptionally cold-hardy and productive small-podded peas have resulted from a cross of Willit's Wonder (otherwise known as Belle of Georgia and Current) with Wando, and other promising lines have resulted from crosses of Willit's Wonder with several large-podded early strains.

It has been found feasible by sending seed to northern Maine and planting seed from there at the laboratory, to get two and sometimes three generations a year. Also it has been possible to plant in late summer and obtain readings on cold resistance in the fall. Some extra early dwarf types have been obtained from some of the crosses.

The principal diseases of peas in the South are powdery mildew and ascochyta blight. Powdery mildew is not at present serious but is likely to become so if peas are developed for off-season growing. The ascochyta blight is most serious where cold injury has taken place. Breeding work has been under way during the last 2 years at the laboratory looking toward the elimination of these diseases as a menace to pea growing.

Along with the breeding work, determinations have been made on some 40 strains of peas for their content of thiamine, riboflavin, ascorbic acid, crude chlorophyll, and carotene. Highly significant strain differences have been noted.

Several strains of peas produced during the last season have yielded excellent frozen products.

CARROTS

The value of carrots as a truck crop in the South and their importance as a source of carotene (the precursor of vitamin A) have led to the initiation of a carrot-breeding project at the Vegetable Breeding Laboratory.

Three crops of carrots may be grown yearly: (1) A spring crop planted about December 1 and harvested in April and May, (2) a fall crop planted about August 1 and harvested in November, and (3) a winter crop planted about the middle of September and harvested in March. Each of these crops has its own particular handicap. The roots coming to market in April and May are most attractive in appearance and quality; but as the harvesting season advances and the weather becomes hot, the foliage, which adds so much to the attractiveness and salability of the crop, is attacked by a leaf blight caused by the fungus *Macrosporium carotae,* which often causes nearly complete defoliation. The roots are not immediately affected seriously in appearance or food value, but marketability as bunching carrots is ruined. The crop reaching market maturity in November is grown in the shortest time, but owing to heat, late-summer drought, and other seasonal hazards, there is a considerable amount of deformation of the roots and a consequent reduction in their value for shipping purposes. The seeds planted at this time also usually give a poor stand of plants. The winter crop harvested in March has the disadvantage of poor color and less desirable table quality. The best seasonal temperatures for carrots appear to be about 60° to 70° F.

The breeding program, therefore, is directed toward the development of varieties resistant to blight, having high color and high carotene content, relatively free from malformation, and of improved table quality. In preparing for this work, approximately 45 varieties and strains of carrots representing the commercial varieties grown throughout the country have been brought together at the laboratory. Analyses of the carotene content of the commercial varieties are being made. Inbred lines are being developed from crops grown at the three different seasons in order to stabilize inherent characters and facilitate the work of recombination in cross-breeding.

In the case of carrots of the spring crop, the plants selected in May are held in cold storage until October. The best of them are then put into greenhouse pots and left outside until they begin to flower, or until outdoor temperatures approach the freezing point, when they are moved into the greenhouse for flowering and pollination. The others are held in cold storage until they are planted in the field in December.

Selections are made from the fall crop in November and transplanted in the field 3 by 3 feet apart.

Selections from the winter crop are made in March and held in cold storage until October, when they are handled in the same way as selections from the spring crop.

It is important to note that every carrot entering into the breeding program is examined individually. The lower third is cut off and the interior examined for texture and color. Just prior to planting the upper two-thirds is treated with a fungicide to prevent rot and is used for the development of flowers for pollination and for seed. Cold storage consists in holding at temperatures just above the freezing point, with high humidity provided by wrapping in toweling that is kept moist but not wet. For flowering every plant is caged, and pollination is performed by blow flies especially reared for the purpose. In the determination of carotene content of the commercial varieties, 10 typical roots are selected from each field replication. These are quartered lengthwise and a section 1 to 2 millimeters thick is taken from the cut surface of one of the quarters of each root to make a composite sample for chemical analysis.

The breeding lines derived from different sources show great variations in carotene content. Some strains contain twice as much carotene as the standard varieties, the amount varying somewhat with the season. Those having high carotene content are used in the breeding program. So far the selected lines have been inbred once and will probably be inbred three times more before crossing is attempted.

A large collection of foreign wild varieties, foreign commercial varieties, and commercial strains from United States carrot breeders is being propagated to serve as a reservoir of genetic material. Carrots from sources in Iran and India have so far been found more susceptible to blight than the commercial stocks of this country.

No processing studies have been made as yet on carrots. These will be made, as with other crops, on selections nearing release for general trial. In other words, this is a phase of the final testing of selected lines.

LIMA BEANS

There is a season in the southeastern part of the country, varying in date and length in different sections, when there are few fresh vegetables to be had except those shipped in from other parts of the country. In the vicinity of Charleston, S. C., this is from about July 15 to September 15. One of the objectives of the Vegetable Breeding Laboratory is to find or develop vegetable varieties to fill this gap. Among these, lima beans seem to offer some promise, and since they are of high food value as well as highly acceptable as a table product, investigations are now under way to see what may be done to fit them into the crop picture of the region. The purpose is to develop by breeding and selection new varieties of lima beans of high quality that may be grown in the South, especially at the time when the need for them is greatest.

This work was started in the spring of 1943 when 110 strains of selected bush lima breeding lines sent to the laboratory from the Division of Fruit and Vegetable Crops and Diseases, Plant Industry Station, Beltsville, Md., were planted in the experimental plots and the study of performance began. In 1944 the breeding stocks were increased by additional lines derived from the same source and from plant breeders in the South. Miscellaneous named and unnamed varieties and all the commercial strains of both bush and pole types were also included.

Two plantings may be made of lima beans, the first in early April and the second about May 1.

Tremendous differences in yields have been obtained between varieties and strains, and marked differences have been noted in table quality.

Lima beans, like other legumes, are largely self-pollinating; therefore, once a line has been established it is likely to remain relatively pure. Artificial inbreeding by the geneticist is not generally required and the breeding schedule may be got under way rather promptly.

From the collection in hand, therefore, selections have been made, and the process of developing plants for cross-breeding is beginning.

ASPARAGUS

In view of the fact that the market demand for asparagus in many parts of the South is usually greater than the supply and that this crop is already being grown to some extent in this area, it has seemed desirable to determine whether its culture may not be extended. Strains of the best commercial varieties are being assembled at the laboratory and initial steps are being taken to bring them to the point where selections may be made and a breeding program developed at some later date.

OTHER ACTIVITIES OF THE LABORATORY

Several other activities of the Vegetable Breeding Laboratory call for brief mention.

1. *Physiological studies.*—It would be helpful to know what fundamental inherent factors are involved in the adaptability of a crop or variety to the heat of the summer months. Further, it is desirable to determine the value of various hormone treatments in dust or spray form for various crops, as well as the relative value of different types and concentrations of fertilizers applied as side dressings. It would be helpful to know also the nature and relative proportions of the different sugars present in the various vegetable products. It has been possible so far to make only preliminary excursions in these lines of inquiry, but it is hoped that they may be more fully explored as time goes on.

2. *Tests on the suitability of newly developed breeding stocks and varieties for freezing preservation.*—In the fall of 1943 a multiplate freezing cabinet and a separate storage or "zero" box having a capacity of 1 to 2 thousand pounds

were installed as a permanent part of the Vegetable Breeding Laboratory equipment. They are used to determine how the various vegetable products developed there are adapted to freezing preservation. As already noted, snap beans and peas have been tested so far, with satisfactory results.[5]

3. *Tests on the suitability of newly developed breeding lines and varieties for dehydration.*—Early in 1943, a laboratory tray drier, heated by steam radiators and having a capacity of about 300 pounds of raw material, was installed. Here again, the objective was to determine by means of standard procedures the suitability of the breeding lines and prospective releases of different vegetables for dehydration. Snap beans, cabbage, sweet corn, and tomatoes have been subjected to this test. In the case of snap beans, the pods harvested at a slightly immature stage in most cases yielded a product superior in flavor to those harvested at market maturity, but in some unnamed strains no differences were apparent. In general, snap beans have responded satisfactorily to this method of preservation and many strains when dehydrated and prepared for the table compared favorably in quality with canned snap beans. As other investigators have found, the losses in vitamins C and B_1 have been high—as much as 97 percent for the former and 41 percent for the latter.

Cabbage was found well adapted to dehydration, and no marked differences in flavor were noted among the products of different varieties and strains.

Sweet corn yielded an excellent product, the better strains, when prepared for the table, comparing favorably with superior canned corn. Differences in quality were noted among the different strains.

Tomatoes have not proved well adapted to dehydration. In most cases, while the flavor of the products has been good, they have been unattractive in appearance and texture when prepared for the table. A loss of 84 percent of the vitamin C was noted during dehydration.

These observations on cabbage, sweet corn, and tomatoes apply to the products of this laboratory only.

4. *The development of new chemical and pathological techniques.*—Last but by no means least, workers of the chemical and pathological laboratories have given much time and thought to the development of special techniques which speed up the research work and make it more effective. For example, more efficient methods have been devised for the determination of vitamin C in large numbers of samples, and methods are now being developed for testing breeding lines for vitamins B_1 and B_2. Mention has already been made of some of the methods adapted to the testing of large numbers of plants for disease resistance, and new and improved techniques are constantly being sought.

MUCH FURTHER IMPROVEMENT POSSIBLE

So far the Regional Vegetable Breeding Laboratory has developed and released to the public three new varieties of snap beans, two new varieties of cabbage, four new varieties of sweet corn, and one new variety of garden peas, all of which have proved, under the conditions found in the Charleston, S. C., area, far superior to any varieties grown generally in the South. It has also assisted in the development of two other new varieties of snap beans adapted to Florida conditions; made marked progress in the development of disease-resistant tomatoes adapted to growing in the South; and done much toward the development of watermelons of higher table and shipping qualities. Fur-

[5] Those interested in the subject of marketing, canning, or freezing of snap beans will find it fully discussed in Farmers' Bulletin 1915, Snap Beans for Marketing, Canning, and Freezing, by B. L. Wade.

ther active research in all these fields is now under way, and studies have also been undertaken with carrots, lima beans, and asparagus.

Many other problems remain to be attacked. Though the products released are distinct improvements over what were available before, they are not necessarily by any means the best that may ultimately be developed. Moreover, a variety that meets with high favor today or in one place may fail to meet the demand of tomorrow or of another place. The region served is extensive, and differences in climate, soils, and other factors give rise to many problems. Below are listed some of the objectives of further work now in the minds of the investigators:

1. Snap beans: More color in the pods, white seeds, and higher vitamin content, combined with hardiness and superior table quality; general-purpose beans, resistant to all the more common diseases and pests.

2. Cabbage: Earliness, combined with high vitamin content and greater penetration of green color into the head.

3. Peas: Darker green color of the peas within the pod, more attractive appearance, and higher thiamine content.

4. Corn: Larger ears of high table quality and greater resistance to earworm and to diseases.

5. Tomatoes: Larger fruits, high color in flesh and juice, better setting of fruit, resistance to cracking and to diseases.

6. Watermelons: Combined resistance to anthracnose and wilt, tough skin, high dessert quality, and very attractive appearance.

One point needs particular emphasis. If the most value is to be realized for the labor and funds expended, the productions of the laboratory must be subjected to thorough practical tests throughout the entire southeastern region. Only by such testing can the degree of adaptation be determined and the full merits of the new products evaluated. Excellent cooperation has been received from workers of individual States, but far wider testing by State and other agencies is needed. It is earnestly hoped that the people of the 13 Southeastern States will take full advantage of this opportunity not only to serve their own individual interests but to contribute to the well-being and prosperity of the region as a whole.

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