THE IMPROVEMENT OF TOBACCO BY BREEDING AND SELECTION.

By ARCHIBALD D. SHAMEL,
Scientific Assistant, Plant-Breeding Laboratory, Vegetable Pathological and Physiological Investigations, Bureau of Plant Industry.

INTRODUCTION.

The production of different types of tobacco adapted to the many demands of the manufacturers is one of the most important problems confronting the growers of this crop. The market grades are clearly defined and classified according to the character and quality of the manufactured product. The value of the crop depends upon the ability of the grower to produce a type conforming most nearly to the market standard for each particular grade. Of particular importance is the production of a superior grade of cigar-leaf tobacco. We are dependent to-day upon tobacco from foreign countries for most of the wrappers and fillers used in the manufacture of the better class of cigars. It has been demonstrated that there are certain well-defined areas in this country where the soil and climatic conditions are favorable to the production of types of tobacco suitable for the manufacture of the best grade of cigars. These areas will produce more profitable crops than are at present grown of this sort of tobacco, when uniform types have been developed and established by careful breeding and selection. The value of this addition to the tobacco industry lies in the fact that the money now expended for the imported article will be distributed among the American growers.

The inferiority of a large proportion of the tobacco produced in the long-established tobacco regions from native varieties may be attributed in part to deterioration of yield and quality due to lack of systematic and careful seed selection. It is a well-known fact that the proportion of the poor-grade tobacco in some of these districts is increasing, resulting in a corresponding loss to the growers.

Pennsylvania and Ohio fillers sell for 10 cents to 25 cents per pound, while imported Cuban fillers bring from 50 cents to $1.25 per pound. We can certainly produce a filler that will take the place of the ordinary to medium Cuban. An increase in yield in the native varieties due to improved methods of cultivation and fertilization involves greatly increased cost of production. Some other means of increasing the value of the crop is necessary and new types more nearly approaching the Cuban standard should be developed in order to supply the
demand of the trade for a better grade of filler tobacco. The development of such types depends upon seed selection as well as upon improved methods of cultivation and fermentation. Wrapper tobacco grown in Massachusetts and Connecticut brings from 40 cents to 80 cents per pound, while the imported Cuban and Sumatra varieties bring from $1.50 to $3 per pound, to which must be added a duty of $1.85 per pound for Sumatra, and $1.48 per pound for Cuban tobacco. To produce a wrapper leaf in the Connecticut Valley which will compare with the Cuban and Sumatra standards, new types must be developed which will more nearly approach the standard of the imported varieties and possess their desirable qualities. This can doubtless be done by careful breeding and selection. In the varieties grown for plug wrappers and fillers, the export trade and the manufacture of pipe tobacco, the development of new types is less important. In these types, however, there is need of a general improvement of the crop, more especially in yield and quality.

The many varieties of tobacco now in existence are supposed to have had a common origin, and the different types are the result of seed selection or hybridization, either accidental or intentional. The value of selection in tobacco is shown by the origin of some of the most important varieties now under cultivation. These varieties for the most part have been developed by the selection of seed from sports or striking variations, which have accidentally appeared in the established varieties. The differences which now exist among these varieties, and their marked and continuous variability, is sufficient evidence of the possibility of the production of new and improved types superior to those now under cultivation. The purpose of the selection of a variety depends on the use of the crop by the manufacturer; as, for instance, the qualities of aroma and flavor are important in filler varieties, but not so important in wrapper types. The general methods of seed selection, however, apply to all types and varieties.

Tobacco is more highly specialized and grown under a more intensive system of cultivation than any other general farm crop. It is a well-known fact that the tobacco plant is exceedingly sensitive and responds readily to soil and climatic conditions. Varieties grown in the Connecticut Valley are recognized as cigar-wrapper types, while varieties produced in Pennsylvania and Ohio are used for the most part as cigar fillers. Owing to the great influence of soil and climatic conditions and methods of culture on the yield and quality of the crop in areas adapted to tobacco growing, highly improved machinery and methods of cultivation have been developed by the growers in order to increase the profits from the crop. Instances of this tendency to adopt the most advanced methods of culture are shown by such practices as the application of $100 worth of commercial fertilizer per acre, covering the fields with slat or cheese-cloth shade, and the installation of
VARIATION IN TYPE OF CONNECTICUT SUMATRA TOBACCO PLANTS.
extensive systems of irrigation, in some cigar-wrapper districts. This attention to certain phases of tobacco production has resulted in the partial neglect of the equally important factor of seed selection. Methods of selection have not kept pace with the improvements along other lines, and to-day are essentially the same as those used by the pioneer tobacco growers.

The suggestions which are made here for the improvement of tobacco by breeding and selection are based on the result of a careful study of cigar-wrapper varieties conducted by the writer. The experiments of the Bureau of Soils and the experience of planters in Connecticut in the growing of Sumatra wrapper tobacco demonstrated conclusively that the industry would not prove successful in that section unless new and improved types of the Connecticut Sumatra could be developed which would give a much larger proportion of leaves of uniform size, shape, and quality than the original imported seed. Experiments were accordingly undertaken by the writer in the production of such uniform types, and the results already obtained show conclusively that new types of the kind desired can be produced, and the application of the methods of seed selection and breeding developed in the course of these experiments is recommended to the growers of all classes of tobacco as a means of increasing the yield and value of their crops.

THE ADAPTATION OF TOBACCO TO SOIL AND CLIMATIC CONDITIONS.

The general principle of the necessity for the adaptation of seed to soil and climatic conditions, which is recommended by the best authorities in plant breeding, is forcibly emphasized by the experience of the writer with tobacco. In the case of cotton and corn Dr. H. J. Webber has made the observation that evidence is accumulating which shows that these crops must be bred and adapted to soil and climatic conditions, and that in order to obtain the best results growers must select their seed in the locality where the crop is regularly grown. From the fact that the tobacco plant is influenced in such a marked degree by soil and climatic conditions, this crop is a particularly striking example of the benefits to be derived from the selection of seed in districts where it is to be grown.

During the seasons of 1901 and 1902 Florida-grown Sumatra seed was introduced into the Connecticut Valley by the Bureau of Soils and grown extensively on the tobacco plantations of that region. This tobacco seed was imported into Florida from the island of Sumatra several years previous to its introduction into the Connecticut Valley and had become adapted to Florida conditions. The crops grown in the Connecticut Valley from this seed showed a lack of uniformity, which resulted in the breaking up of the variety into a number of distinct types. Illustrations of these types are shown in Plate LVIII. A small proportion of the plants in these fields held
true to the Sumatra type and produced a satisfactory yield of desirable wrapper leaves, but not more than 5 per cent of the first generation were typical Sumatra plants, and the remainder were divided into a large number of distinct, clearly defined types, most of which were radically different from the parent variety. Some of these types were apparent reversions to varieties not adapted for wrapper purposes, the leaves lacking the proper shape, body, elasticity, gloss, and other characteristics of the Sumatra tobacco. The individual plants in these types also showed great variability, and the cultivation of such a mixed and variable crop entailed a great loss to the growers on account of the small proportion of high-priced tobacco obtained and the increased cost of sorting this irregular product. The crop of 1903, grown from seed saved from that of 1902, according to the ordinary custom of tobacco planters, showed continued variability and a reproduction of the undesirable types. In 1903 typical plants of all of the different types were selected for seed purposes and the seed protected from cross-fertilization by covering the flowers with paper bags. In 1904 the plants grown from seed saved in this manner were strikingly uniform in type and closely resembled the parent plants in all characters.

One of the best illustrations of the effect of the change of soil and climatic conditions upon tobacco is the experience of the growers who used imported Cuban seed for the production of wrappers in the northern districts of the United States. The crops grown from such seed produced a large proportion of the so-called freak type of plants, which are very undesirable and bear a large sucker or branch at the axil of every leaf. The leaves of such freak plants are very small, sharply pointed, thick and heavy, and practically worthless for wrapper purposes. According to a very careful estimate this type of plant constituted at least one-third of the crop grown from freshly imported seed from Cuba. Among the types constituting the remainder of the crop were typical Cuban plants producing a desirable tobacco which was used as a substitute for Cuban-grown wrappers. This variation in type was commonly attributed by the growers to the Cuban practice of saving the seed from sucker plants. However, seed selected in the season of 1904 from the most desirable plants that could be found in Cuba, and taken from the main stalks, produced crops in the Connecticut Valley which showed only a slight improvement in uniformity of type over previous crops grown from the ordinary Cuban seed taken from suckers in the usual way. The crop in Cuba from which this especially selected seed was harvested was particularly uniform in shape and size of leaf and general type; therefore, the variation in type observed in the northern-grown Cuban plants must be attributed to the effect of the change of soil and climatic conditions. In 1903 plants grown in the Connecticut Valley from
Florida-grown Sumatra seed were grown in South Carolina with a view to producing cigar wrappers. The leaves harvested from these plants were very thick and heavy, resembling the South Carolina plug-filler type of tobacco. They possessed none of the characteristics of cigar wrappers except the shape of leaves. This change of type was doubtless due to the influence of the soil and climatic conditions in this section of the South.

It has been frequently observed that when a variety of tobacco has been grown in a particular region for a number of years it undergoes a gradual change, and produces a type peculiar to that region or locality. This condition explains the adaptability of certain sections for the production of types of tobacco supplying special market demands. In most of these crops a small proportion of plants are found which produce leaves most nearly conforming to the market standard for this class of tobacco. By saving the seed from these plants according to the methods of selection to be described later, a uniform crop of the desirable type may be secured which will be adapted to the local soil and climatic conditions.

**IMPORTANCE OF GROWER SELECTING HIS OWN SEED.**

The character of the soil in any region varies to such an extent that every farm presents a different set of conditions peculiar to its location. In view of the effect of a change of conditions upon the character of the plants, it is important that the grower select his tobacco seed on his own farm. After a variety has become adapted to the grower's conditions of soil and climate the yield and quality of the crop can be improved by the selection of the most desirable plants in the field for seed production. In buying seed the grower has no evidence from the seed itself as to the nature or quality of the plants which it will produce, and he is likely to lose a crop owing to the use of undesirable seed. The type of tobacco grown on the individual farm establishes a reputation in the market and determines to a considerable degree the value of the crop produced. The careful selection and improvement of the type by the grower not only increases the yield and quality of his crop, but the reputation thereby acquired insures a high price and a ready market for such tobacco.

Many tobacco growers follow the plan of saving a large amount of seed from a desirable crop, and using this seed for several years, instead of depending on the selection of seed from every crop. They entertain the idea that vitality of tobacco seed does not deteriorate with age, and that the continued growing of the same tobacco on one farm causes a deterioration in the yield and quality of the crop. Such a practice may be advisable where the farmers give no attention to seed selection or follow the ordinary method of saving seed without a careful study of the seed plants and the quality and yield of leaves
they produce. Tobacco seed is known to retain its vitality for several years if kept under the proper conditions, but it has been demonstrated that the vigor of germination is reduced and the value of the seed impaired by age, even though the circumstances of storage are very favorable. Owing to the possibility of the failure of a crop, due to unfavorable seasons or the destruction of the plants by storm or other accident, enough seed should be selected from every successful crop to produce plants for two or three seasons. The surplus seed need not be used for planting, unless the resulting crops are injured or destroyed by unfavorable circumstances, in which case this plan will prevent the loss of the type grown and selected by the farmer. The yield and quality of the crop will certainly deteriorate where the best plants are topped, where proper attention is not given to the principles of seed selection, and where the injurious effects that may follow from cross-pollination in the tobacco plant are not recognized.

VALUE OF LARGE AND HEAVY SEED.

In all samples of tobacco seed there is great variation in the size and weight of the individual seeds. Owing to their small size, making it extremely difficult to distinguish the large and heavy from the light seed except by close examination, there has been little attempt by growers to separate the different grades before sowing the seed beds, and many of the weak and undesirable plants always found in the beds may be attributed to this cause. Careful comparative tests of light and heavy seed have proved that the best developed and most vigorous plants are always produced from the large, heavy seed, while the light seed produce small, irregular, and undesirable plants. In an experiment with Cuban seed the writer separated the sample with a current of air into light, medium, and heavy grades. The germination of the heavy seed was almost perfect, while less than 5 per cent of the light seed sprouted. The plants from the heavy seed grew more rapidly than those from the light seed, and reached the proper size for transplanting from seven to nine days earlier than the plants from the light seed. Representative plants produced by each grade of seed are shown in Plate LIX, figure 1. This advantage of earliness is of special importance to tobacco growers in northern districts, where the short growing season makes it necessary for the grower to secure very early plants in order to transplant as soon as the weather will permit. The heavy seed also produced more uniform plants than the light seed, thus reducing the amount of seed-bed space needed for growing sufficient plants for the field. The growers commonly sow three or four times the area of seed bed needed in order to secure enough plants of sufficient size to set out their fields at the proper time for transplanting. If heavy seeds are used, this extra expense for seed beds can be considerably reduced, and more hardy and desirable plants secured.
The most satisfactory means of separating the light from the heavy seeds is by using a current of air. A simple and effective device for the purpose is shown in figure 57. The material necessary for constructing this machine can be obtained by tobacco growers from almost any chemical supply house. The foot bellows (a) is connected by means of a rubber tube (b) to the valve tube (c). The glass tube (d) is fitted with a rubber cork (e), in which the valve tube is inserted. The top of the cork is covered with a piece of finely woven gauze, in order to prevent the seeds from entering the valve tube. About an ounce of seed for separation is placed in the glass tube and a current of air is injected by means of the foot bellows. The strength of this current must be regulated by the valve (c), so that only the dirt, chaff, and light seed will be blown out of the top of the tube. It is advisable to screen out all of the large particles of hulls and trash before putting the seed in the tube.

An imperfect separation of the heavy from the light seed can be made by throwing the seed into a vessel of water, and allowing the heavy seed to settle to the bottom and skimming off and rejecting the light seed. This method does not make a thorough or complete separation for several reasons, one of them being the fact that the heavy seeds do not always sink, owing to the bubbles of air which adhere to them. If this plan is followed the heavy seed should be dried promptly or used for planting immediately after separation. This method of separation is recommended by Dr. L. Trabut. The conclusions on the results of his valuable experiments are as follows:

I observed that tobacco seed were often badly formed and had only a light density. By throwing tobacco seed into ordinary water it was observed that only half of the seed reached the bottom of the vessel. The seed which floated germinated, but gave less vigorous plants during their whole development. Seed beds were made in earthen bowls divided into two parts. In one part was sown the seed that floated, and in the other part the seed that went to the bottom. The young plants from the heavy seed were greener, more vigorous, and of larger size. All of the plants were transplanted in the same field, alternating one plant from the heavy and one plant from the light seed. All of the plants conserved their characters, but the plants from the heavy seed produced greener and wider leaves and were more vigorous. The plants from the light seed developed slowly and had a tendency to flower before sufficient development. The yield from the plants from the heavy seed was 12.5 kilograms, and the yield from the light seed was 6.4 kilograms.

*a Bulletin No. 17. Dr. L. Trabut, Directeur du Service Botanique, Gouvernement General de l’Algerie.
If neither of the above plans is used, a less effective method of selecting the heavy seed is to use sieves with a size of mesh which will remove as large a proportion of the small and light seeds as possible.

**SELECTION OF PLANTS IN THE SEED BED.**

The tobacco grower has opportunity for the selection of a desirable type of plants in the seed bed at the time the young plants are transplanted to the field. From the time the young plants first appear in the seed bed until they are ready for transplanting they show great variability in type and vigor of growth. When the plants have reached the proper size for setting out in the field, the characteristic shape and comparative size of leaf may be determined by a careful study of the plants in the seed bed. At this time a definite selection of the most vigorous plants possessing the desired shape and type of leaves will improve the uniformity and increase the yield and value of the crop. The time for transplanting is a busy season for the grower, and, in order to secure enough plants to set out as great an area as possible, all the plants of the necessary size are usually pulled without much attention to the variation among the young plants. The work of pulling the plants is frequently delegated to someone without experience and incapable of making a selection of desirable plants at this early stage. The differences which distinguish the poor from the good plants are very small, and a familiarity with the variety and type of tobacco grown, combined with a close observation of the plants during their period of growth in the seed bed, is necessary in order to make a successful selection of the desirable type. In the cigar-wrapper varieties the characteristic shape of leaves of these types is clearly shown by the young plants while still in the seed bed, and as this character is of primary importance for these varieties, the value of such selection is obvious. Two types of plants selected from the same seed bed are shown in Plate LX. This selection of plants in the seed bed is supplementary to the final selection of seed plants in the field, and gives an opportunity to eliminate most of the undesirable types of plants. It may be compared in part to the roguing process in other crops, where the undesirable plants in the field are destroyed in order not to interfere with the development of the remainder of the crop. The transplanting process in tobacco makes it possible to rogue the plants before they are set out, thus saving the expense of cultivating undesirable plants.

**SOME POSSIBLE IMPROVEMENTS.**

The possibility of improvement in the yield and quality of the tobacco crop has been demonstrated by the results of a series of experiments in the breeding of cigar-wrapper varieties conducted by the Department of Agriculture in the Connecticut Valley. The Sumatra variety grown in this valley showed a greater amount of
FIG. 1.—TOBACCO SEEDLINGS FROM LIGHT (31-3), MEDIUM (31-2), AND HEAVY (31-1) GRADES OF SEED.

FIG. 2.—TYPICAL LEAVES OF HYBRID AND PARENT TYPES OF TOBACCO.
[1, Havana seed, female parent; 2, hybrid; 3, Sumatra, male parent.]
FIG. 1.—Rounded Type of Leaves.

FIG. 2.—Pointed Type of Leaves.

Variation in Shape and Type of Leaves of Tobacco Seedlings.
variation in type and individual plants than any of the other varieties grown for the purpose. The improvement made in the yield and value of this type is given as an illustration of the possibilities for the improvement of other varieties of tobacco. In the Sumatra variety selections were made from a representative field in which the plants showed a variation in type similar to the variation observed in all other fields of this tobacco. In this field ten separate and distinct types were observed and described, and selections of seed were made from typical plants of each. The seed was saved under bags and sowed the following season in separate sections in the seed bed, each section containing the seed from a single parent plant, and later the young plants from each section were set out in separate rows in the field. During the early stages of growth in the seed bed the distinctive characteristics of each type, particularly the shape of leaf, could be readily observed and the different types distinguished without difficulty. As the plants in the field reached maturity the particular characteristics of each parent became more clearly and strikingly apparent. In every selection in each of the ten types, the type characteristics were uniformly reproduced. In the different selections in each type slight differences were observed, representing the differences in the individual parent plants. Of the progeny from each parent every plant was uniformly of the type of the parent plant. So clearly and strikingly was this uniformity of type impressed upon the progeny of all plants selected that the most casual observer could easily note and distinguish the difference between the various types and, in most cases, pick out the progeny of the individual parents in the group of selections constituting each type. The uniformity of type in the progeny of selected seed plants is shown in Plate LXI. The grower can therefore select in the field a plant of the type he desires to grow, and by saving the seed under bag, in most cases at least, reproduce this type uniformly in the succeeding crop.

The number of leaves borne by the parent plants selected from the Connecticut Sumatra variety was found to vary from 4 to 40. This variation is illustrated in Plate LXII, figure 1. When plants with a small number of leaves were selected it was found that their progeny produced on the average about the same number of leaves as the parent; and the progeny of parents having a large number of leaves was found to produce on the average about the same large number of leaves. The increase in number of leaves was not accompanied by a corresponding increase in the height of the plants. In the case of the plants bearing few leaves the internodes were from 6 to 8 inches in length, but where a large number of leaves were produced the length of the internodes was from 2 to 3 inches. The variation in length of internodes among plants in the same type is shown in Plate LXII, figure 2. The difference in the time of ripening of the lower and upper
leaves on the plants producing a large number of leaves was no greater than where few leaves were produced. Therefore the time of ripening of the top leaves is not delayed by the increase in the number of leaves on the plant. The leaves were found to be the most uniform in size, shape, and other characteristics where a large number were borne on a single plant. It is possible, therefore, for a grower to select plants with a large number of desirable leaves and, by saving the seed from these plants under bag, to secure that increase in number of leaves in his crop. The average number of leaves in the tobacco crops of the country can doubtless be greatly increased, so that the yield will be correspondingly increased if this method of selection is carefully pursued.

In the case of selected plants having leaves with rounded tips the crop grown from the different parents invariably showed the characteristic rounded tip of leaf in all of the plants. Where the selections were made of parent plants having pointed leaves the progeny uniformly showed pointed tips. The pointed tips were almost invariably found to be associated with narrow leaves. The variation in shape of the different types of Connecticut-grown Sumatra tobacco is shown in figure 58. Pointed leaves are undesirable for wrapper purposes on account of the small number of wrappers that can be cut from them, seldom more than two wrappers from each leaf. The wide leaves with rounded tips and bases yield from four to six wrappers. The tip is usually the most desirable portion of the leaf for wrapper purposes, having the best grain and appearance, and for this additional reason a rounded tip is specially desirable. In fact, it has been conclusively proven that any shape of leaf desired, which is produced in a given locality, may be fixed and transmitted uninterruptedly to the succeeding crops by selection of the parents having the desired shape of leaf and saving the seed of such plants under bag.
Uniformity of Belgian Type of Sumatra Tobacco Produced from Seed Saved Under Bag.
Fig. 1.—Variation in number and size of leaves produced on Sumatra tobacco plants.

Fig. 2.—Variation in length of internodes of Connecticut Cuban tobacco plants.
The number of suckers produced on the different plants was found to vary in the same way as the number of leaves and other characteristics. In selecting individuals free from suckers and saving the seed under bags, it was found that the crop produced from these suckerless plants produced proportionately few suckers, while the plants selected with a large number of suckers transmitted this suckering habit uniformly to all of their progeny. The grower can thus select plants free from suckers, or showing a tendency to produce fewer suckers, and by saving the seed from individual plants of this type produce strains that develop but few suckers. Seed from suckerless plants produced also the best progeny as regards the number, size, quality, and shape of leaves and other characteristics which go to make up desirable types of tobacco.

The size of leaf, it has also been found, can be controlled by the selection of seed plants having the desired size. In the selections of Connecticut Sumatra tobacco, parent seed plants were saved having leaves 35 inches long by 22 inches wide, and in the same type other selections were made of plants having leaves 15 inches long and 7 inches wide. It was found that the crop produced from these selections possessed uniformly about the same size of leaf as that selected in the parent plants. In the first case a crop was secured having an average leaf about 35 inches long by 22 inches wide, and in the second case the leaves were on an average about 15 inches long by 7 inches in width. An illustration of the difference in the size of leaves produced by two Sumatra plants is shown in Plate LXII, figure 1. In all of the selections the size of leaf of parent plants was reproduced in marked degree in the crop grown from the seed of the individual plants.

The size of leaf has an important bearing on the value of the crop in all varieties of tobacco, but more particularly in the cigar-wrapper types. Other things being equal, the greater the number of wrappers that can be cut from each leaf without waste, the greater the value of the crop to the manufacturer and the higher the price obtained by the grower. In some varieties, as the Havana seed and Broadleaf wrapper sorts, the leaf is very large and only a small portion is adapted for wrapper purposes, the remaining portion of the leaves being used for binders and fillers in low-priced cigars. In the crops of these varieties a small number of plants are found producing leaves of the proper size to better adapt them to the purposes for which this kind of tobacco is grown. The selection of seed from plants of this character is a means of controlling the size of leaves in the crop. It has been commonly supposed that the size of leaf is influenced primarily by the soil and climatic conditions. In the experiments bearing on this point the results clearly showed that the character or size of leaf was transmitted from the parent plants to their progeny with unfailing regularity, and by seed selection large and small leaved types were produced uniformly in the crop under similar soil and climatic
conditions and methods of cultivation. It is possible for the grower, then, to develop types producing leaves of the most desirable and profitable size by selecting seed from plants bearing leaves uniformly of the desired size.

In all varieties of tobacco there is considerable variation in the time of ripening of the individual plants in the field. In a tobacco crop which is harvested all at one time, the early plants remain in the field until they deteriorate in quality, while the later ones do not mature, and when harvested do not cure properly. In a similar manner the leaves on many of the plants mature irregularly, those at the top requiring from ten days to two weeks longer than the bottom leaves to reach the stage of maturity necessary before the crop can be harvested. In all of these crops some plants are found in which the leaves ripen more uniformly than in others, and by the selection of seed from such plants uniform types can be secured in which all of the leaves are ripe and ready for harvesting at one time. In 1903 a Sumatra plant was observed which ripened several days before the general crop was ready to be primed. The seed of this plant was saved under bag and the progeny set out in a separate plat the following season. The plants in this plat were ready to be harvested about two weeks earlier than the remainder of the field of the same variety. In a number of selections of plants made to secure uniformity in the time of ripening of leaves on the same individual, the progeny exhibited the characteristic uniformity of the parent plants. The crop from these plants was harvested in two primings, while the ordinary crop required three or four primings in order to secure the leaves at the desirable stage of maturity. In the varieties of tobacco in which all the crop is harvested at the same time, the uniformity in ripening reduces the expense of sorting and the loss from overripe and immature leaves, while the uniformity of ripeness in varieties which are primed materially lessens the expense of harvesting.

In improving the quality of tobacco one must be guided by the requirements of the manufacturers. In wrapper varieties the leaves must have good burning quality, texture, grain, elasticity, and strength, so as to cover well and without breaking on the cigar, present an attractive appearance, and have no disagreeable taste. The color of the leaves should be uniform in order that the grower may obtain a large percentage of high-grade wrappers and the manufacturer secure the quality of tobacco necessary for his brands of cigars without waste.

The plants bearing the largest number of leaves of uniform size and shape produce the largest proportion of leaves of uniform color. In order to determine the grade of color produced by the plants, it is necessary to compare the leaves after curing and fermentation have been completed. The shade of color of leaves on the plant in the field is correlated with the color after fermentation, light green types producing light grades and dark green shades developing the dark grades
of wrappers. The proportion of the standard grades of the best quality may be increased by taking seed from plants which develop leaves of desirable color and other characteristics. The improvement of all other varieties in the qualities for which they are produced can be carried out by the application of the general methods of seed selection.

**THE METHODS OF SELECTION.**

The first step in the selection of tobacco is a careful study of the individual plants in the fields from which the selections are to be made, before any plants have been topped. It is necessary for the grower to make a preliminary selection of a large number of plants at this time in order to give an opportunity for a final selection after the cured product of these plants has been carefully compared in the warehouse. The differences in quality of the product of the individual selections can be determined only by a careful study of the cured leaves. The type or general form of the plants, the number, uniformity, and shape and size of the leaves, the number of suckers, the height, and the time of ripening of the plants should be kept in mind and the plants carefully examined with regard to these points. It is of the greatest possible importance that the grower have a clear and well-defined ideal of a perfect plant best adapted to the purposes for which his crop is grown, and that the individuals selected as seed plants conform as nearly as possible to this ideal type. In a given variety of tobacco the increase in number and the improvement in shape and size of the leaves are usually correlated with a corresponding improvement in other important characteristics peculiar to the type. A large number of leaves is associated in most cases with few suckers, leaves of fine venation, elasticity, strength, and other desirable qualities.

The tobacco plant is naturally self-fertile, but is frequently cross-pollinated by insects or other agencies carrying the pollen from one plant to another. The writer has observed that under natural conditions most of the flowers on tobacco seed plants are cross-fertilized. Darwin found that self-fertilized tobacco seed produced plants superior to seed cross-fertilized within the variety, and accounted for this condition by supposing that this species is similar to the common pea and a few other exotic plants which have been self-fertilized for many generations. The variation in types and individual plants within the variety may for the most part be attributed to cross-fertilization, and uniform types and plants can only be secured by preventing this crossing. Immediately preceding the complete development of the tobacco flower, the funnel-like corolla and the stamens increase in length with great rapidity. At this time a considerable quantity of a sweetish, honey-like liquid is secreted in the base of the flower, and a number of species of insects, including the common honey bee, visit the flowers to obtain this nectar.

The anthers, which contain a large quantity of the dust-like pollen,
open below the receptive portion of the stigma. A few hours after the flowers open the stamens increase in length so that the anthers are in a position to allow a part of the pollen to fall on the stigma, and at this time fertilization takes place. The period between the time of the opening of the flower and the contact of the anthers with the stigma gives an opportunity for cross-pollination by insects or other means. The insects entering the flower at this time, after having visited other flowers in like condition, naturally brush some of the pollen from their bodies over the receptive portion of the stigma, which is in condition for pollination. Furthermore, on entering the corolla the insects are again covered by pollen from the freshly opened anthers, so that this pollen is carried from flower to flower and from plant to plant. In this way most of the flowers on the seed plants are cross-fertilized. In view of the superior value of self-fertilized seed, it is highly important that the growers use some means of protecting the seed plants from cross-fertilization. This peculiar characteristic of the tobacco plant renders the selection of seed and improvement of the variety a simple process as compared with that in the case of other crops. The grower in making the selection of seed plants need only take into account the characteristics of one parent, while in most other crops the influence of both the mother and father plants has an effect upon the character of the progeny.

SAVING SEED UNDER BAG.

A simple and effective means of protecting the tobacco flowers from the injurious effects of cross-fertilization is by covering the flower cluster with a paper bag before the flowers are ready for fertilization. This bag should be made of light but strong and durable paper, which will not injure the plant or flowers by bending the plant out of its natural position, and will not be easily torn or destroyed by rain or wind storms. The common manila bag, which can be secured at most hardware or grocery stores, is admirably adapted for this purpose. In the seed selections made by the writer in the Connecticut Valley a parchment-paper bag was used, which has the advantage of lightness and durability, and is impervious to water. The most convenient size of bag will depend upon the variety of tobacco and the size of the seed head, but in general it should be about 9 inches wide and 15 inches long. The shape of the bottom of the bag is important, from the fact that the square-bottom style does not shed water as readily as a roof-shaped bottom. A properly bagged Florida-grown Sumatra seed plant is shown in Plate LXIII, figure 2.

The center cluster of flowers in the seed head should be used for seed production, and all suckers or other seed-bearing branches should be removed before the bag is applied. The preparation of the stalk for the bag is shown by Plate LXIV, figure 2. The cluster of flowers on
Fig. 1.—Plants from diseased and resistant strains of Sumatra seed.

Fig. 2.—Florida Sumatra seed plant, with bag covering flowers.
FIG. 1.—FLOWERS AT PROPER STAGE OF MATURITY FOR BAGGING.

FIG. 2.—INFLORESCENCE WITH SUCKER BRANCHES AND TOP LEAVES REMOVED, READY FOR BAGGING.

INFLORESCENCE OF SUMATRA TOBACCO PLANTS.
a single plant will usually produce from 300,000 to 500,000 seeds; therefore it is unnecessary to save the inferior capsules produced by the suckers or lateral branches in order to secure sufficient seed for planting. The plants should be bagged before the earliest flowers begin to open and the bags moved up the stem every two or three days, as the plants increase in height, in order to allow sufficient space for the development of the seed head without crowding. The proper condition of flowers is shown in Plate LXIV, figure 1. When most of the capsules have begun development, indicating that fertilization has been completed, the bags may be removed temporarily and all late flowers cut off, so as not to interfere with the further development of the seed in the early and most desirable capsules; after which the bags should be replaced and allowed to remain on the plants until the seed heads are harvested. The seed saved under bag in this manner is larger, heavier, lighter in color, more free from mold, and has stronger vitality or germinating power than seed saved without bagging. After the capsules have turned brown, indicating maturity, the seed stalks should be cut and hung in a dry place where there is a free circulation of air, and allowed to remain until the seed has become thoroughly dry. The vitality of the seed can best be preserved by storing in glass jars; thoroughly dried out.

TEST OF INDIVIDUAL SEED PLANTS.

The individual tobacco plants vary in transmitting power to such an extent that it is advisable for the grower to test the selected seed plants in this respect. The object of the test is to determine the plants which most uniformly transmit the desirable characters to their progeny. In order to ascertain the prepotency of the seed plants the seed from individual plants should be saved separately and sowed in separate plots in the seed bed the following season. A careful record of the important characteristics upon which the selection of parent plants is based is a valuable aid in the study of the progeny of these plants. This record should be made in the field, as soon as the plants have reached maturity, on tags attached to the individual seed plants. The form of record varies with the type of tobacco and the purpose of selection. The outline on page 450 is a convenient form of record which has been used for cigar-wrapper varieties.

The tags bearing this record should remain attached to the seed heads until the seed is harvested. The seed from each plant should be shelled separately and kept in glass vials. Each vial should be numbered to correspond with the number of the plant from which the seed was saved. The tags should be carefully preserved as a part of the pedigree record of the plant and its progeny.

About 100 plants from each selection should be set out in a separate row in the field and each row labeled with the number of the parent plant. In the careful improvement of a variety of tobacco, it is
desirable to keep a record of the progeny of each parent plant in order to measure the advance made by breeding and selection. This record consists of notes on the development of each progeny row in the field and the yield and value of each grade of cured tobacco. The plan shown on page 451 may be taken as an illustration of such a form of record. The seed plants for the general crop should be selected from the progeny rows which produce the largest number of plants possessing the characteristics for which the parent plants were selected.

### Variety: Connecticut Sumatra

<table>
<thead>
<tr>
<th>Plant Number</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>August 7, 1904</td>
</tr>
<tr>
<td>Type</td>
<td>Green-leaf</td>
</tr>
</tbody>
</table>

**LEAVES:**
- Number: 28
- Width: 11¾ in
- Shape: Oval
- Uniformity: Good
- Spots: None
- Maturity: Early
- Venation: Very fine

**STEM:**
- Height: 3½ feet
- Circumference: 2½ in
- Length of internodes: 4 inches

**SUCKERS:**
- Number: 3
- Size: Small
- Position: Top of plant

**SEED:**
- Number of pods: 95
- Date of harvesting: September 19, 1904

**DISEASE-RESISTANT STRAINS.**

The development of disease-resistant strains of tobacco will probably become one of the most important features of tobacco breeding. In the case of a root disease attacking the Sumatra variety of tobacco,
Individual plants were found by the writer in 1903 which were apparently resistant to this disease. In the affected fields most of the plants succumbed and only a few produced marketable leaves. The seed from the resistant plants was saved under bag, with the object of securing a resistant type of this variety. The progeny from these plants were resistant to the disease and produced a profitable crop of tobacco, while the plants grown from other selected seed were as seriously injured as in the previous year. Plants from the resistant and semiresistant strains of seed are shown in Plate LXIII, figure 1. Similar cases of resistance have been observed in Porto Rico and other tobacco regions. This evidence, considered in connection with the production of disease-resistant strains in other crops, suggests the possibility of breeding types of tobacco resistant to many of the common tobacco diseases.

**Progeny notes.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Connecticut Sumatra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of selection</td>
<td>7—1</td>
</tr>
<tr>
<td>Date</td>
<td>1905</td>
</tr>
<tr>
<td>Type</td>
<td>Green-leaf</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SEED.</th>
<th>PLANTS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date sprouted.</td>
<td>Date of germination.</td>
</tr>
<tr>
<td>April 4.</td>
<td>Late.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LEAVES.</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>LEAVES.</th>
<th>STEMS.</th>
<th>SUCKERS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early.</td>
<td>Deep.</td>
<td>Good.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DATE.</th>
<th>YIELD.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrappers:</td>
<td>1. Light, 2 lbs.</td>
</tr>
<tr>
<td>2. Medium, 3 lbs.</td>
<td></td>
</tr>
<tr>
<td>3. Dark, 2 lbs.</td>
<td></td>
</tr>
<tr>
<td>4. Seconds, ½ lb.</td>
<td></td>
</tr>
<tr>
<td>5. Fillers, ¼ lb.</td>
<td></td>
</tr>
</tbody>
</table>
The production of uniform types of established varieties of tobacco can only be secured by using the seed from self-fertilized plants, but new strains of varieties adapted for special purposes can be produced most readily by crossing different varieties. The production of new types of the hardy native varieties by crossing with the standard imported varieties may result in the development of new races, combining the hardiness and yield of the native with the desirable qualities of the imported tobacco. In Algeria, Dr. Louis Trabut crossed the best races of the acclimated varieties with foreign tobaccos and secured a number of types which were a great improvement over the native varieties. These new varieties, in which were united the desirable qualities of the native and foreign tobaccos, were distributed to planters and gave very satisfactory results.

The experiments of Darwin show that while crossing within a variety is detrimental, the crossing of different varieties produced seed of stronger vitality, more rapid growth of the young plants, earlier flowering of the mature plants, and a greater yield than the self-fertilized seed. He says:

When the flowers of one variety were crossed with pollen from a somewhat different variety, which had grown under somewhat different conditions, that is, by a fresh stock, the seedlings derived from this cross exceeded in height and weight those from the self-fertilized flowers in an extraordinary degree.

Similar results have been obtained by Dr. Leonard Angeloni in a series of experiments with the crossing of a large number of Italian and foreign varieties of tobacco.

In the season of 1903 crosses were made with the native and imported varieties of cigar tobaccos. The progeny from these crosses showed a great improvement in quality, vigor of growth, and yield over the native types. The shape of leaf was materially modified, particularly in the case of the hybrids of Havana seed and Cuban, and Havana seed and Sumatra. This modification in shape and type of leaf by hybridization is illustrated in Plate LIX, figure 2. These hybrids produced very round leaves with regular and uniformly fine veins from the tip to the base. These leaves were of finer and more elastic texture than the Havana seed and better adapted for cigar-wrapper purposes. In the case of the crosses in which the Broadleaf variety was used as the mother parent, results were even more striking. The selection of seed from the desirable individual plants will, doubtless, result in the general improvement of quality and increase in yield. All other crosses showed similar results, and led to the belief that by the judicious blending of the foreign and native varieties it will be possible to produce strains possessing the desirable qualities of imported tobacco, together with the hardiness and yield of the native varieties.