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B. T. GALLOWAY, *Chief of Bureau.*

TOBACCO BREEDING.

BY

A. D. SHAMEL

AND

W. W. COBEY,

IN CHARGE OF TOBACCO BREEDING EXPERIMENTS,

PLANT BREEDING INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., September 25, 1906.

Sir: I have the honor to transmit herewith a paper on "Tobacco Breeding," by Messrs. A. D. Shamel and W. W. Cobey, of the Plant Breeding Investigations of this Bureau, and would recommend its publication as Bulletin No. 96 of the Bureau series.

The tobacco-breeding work of the Bureau of Plant Industry has now been under way for several years, and results have been obtained which have attracted widespread attention and proved of very great value to practical tobacco growers. This bulletin is intended to summarize the results secured up to date and to place the knowledge obtained before growers in such a form that they will be able to understand it and apply it in the practical work of improving their crops. The experiments have shown that tobacco can be improved in many important ways, and the methods by which such improvements can be produced are here described in detail. The illustrations form a very important part of the publication and are necessary to enable the grower to understand clearly the character and improvements discussed in the text of the bulletin.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

B. P. I.—234.

TOBACCO BREEDING.

INTRODUCTION.

The growing importance of the tobacco industry may be realized from a brief summary of the estimates of the value of the crop in the United States in the season of 1906. About 796,099 acres of tobacco were grown, producing an average yield of 857.2 pounds to the acre, or a total of 682,428,530 pounds. The average value of the crop was 10.0 cents a pound, or a total of about $68,232,647. While it is almost impossible to comprehend the magnitude of the value of the manufactured products of tobacco, a glance at the total figures may convey some idea of the development of this great and distinctively American industry. In 1900 the total value of the manufactured products of tobacco was $283,076,546. These products may be divided into three general classes, of which the values were as follows: Cigars and cigarettes, $160,223,152; chewing, smoking, and snuff products $103,754,362; stemmed and rehandled tobacco, $19,099,032. In the manufacture of these products 142,277 people were employed, who earned a total wage of $49,852,484. In addition to the tobacco grown in the United States there was imported into the United States in the year ended June 30, 1906, $4,143,192 worth of tobacco in a manufactured condition and $22,447,514 worth of unmanufactured products, making the total value of the importations during this period $26,590,706. During the same time the exports of manufactured tobacco were valued at $5,410,480, and of unmanufactured tobacco at $28,808,367. In 1891 the tobacco industry furnished almost $50,000,000 revenue to the Federal Government, and the revenue from this source now amounts to about one-eighth of the Government's total net receipts.

The United States now grows by far the largest quantity of tobacco produced by any country in the world. While tobacco was grown by the first settlers in the colonies and was one of their principal cash crops, the extensive development of this industry has been a matter of comparatively recent years. The introduction of tobacco into the different sections of the United States, with their widely varying

conditions of soil and climate, has resulted in the production of types adapted to the soils and conditions of these sections, as well as supplying a product for the varied manufactures now demanded by the consumers of tobacco. Improvements in methods of culture, curing, and fermentation have resulted in the production of tobacco having an increased value, but the most important factor in the development of more valuable tobaccos has been the production of improved varieties by seed selection and breeding. The production of these improved varieties adapted to local soil and climatic conditions has made possible the rapid development of the industry and enabled the United States in a comparatively short time to rank as the foremost tobacco-producing country in the world.

The prosperity of the tobacco industry as a whole and of the growers in particular depends on the development of improved varieties of tobacco adapted to the demands of manufacturers and consumers. There is no crop which responds so readily to breeding as tobacco, as has been proved by the experiments of the writers, and it is further true that without careful selection and breeding there is no crop which so quickly deteriorates in yield and quality. The extent of the areas in the United States in which the conditions of soil and climate are suitable to tobacco culture is almost unlimited, so that it seems possible that by giving attention to the production of varieties adapted to those conditions this country can continue to produce an increasingly large yield of valuable tobaccos.

The experiments of the writers have shown that it is possible to increase the yield and improve the quality of the crop by seed selection and breeding. The methods of breeding worked out in the course of these experiments are simple and practical and can be carried out by every grower with little or no extra cost in the production of the crop. The fact that tobacco is perfectly self-fertile and that self-fertilized seed produces more uniform and better developed plants than seed resulting from cross-fertilization within the variety makes it possible by the adoption of proper methods of saving seed to make rapid progress in the improvement of the crop. Improvement in the shape, size, and quality of leaves or increase in the number of leaves borne by the individual plants, all of which can be attained by breeding, means increased profits to the growers and manufacturers, and therefore is of vital interest to all who are interested in the production, manufacture, and consumption of this crop.

The production of new varieties of tobacco by hybridization and selection is a most important phase of tobacco breeding. The new hybrids of native New England varieties with standard foreign-grown varieties, combining certain valuable characters of both par-

ents, described in this bulletin, are good illustrations of the use of breeding in the improvement of the tobacco crop. The making and testing of hybrids are matters of experiment and require considerable time and expense, but experience has shown that the results justify the necessary expenditure.

The production of improved breeds of live stock and varieties of fruits and cereals, in fact, of all crops, might be cited to prove the importance of applying the principles of breeding to the tobacco crop. It is only recently that systematic breeding experiments have been undertaken. It is hoped that the results of the experiments cited in this bulletin will serve as a means of creating general interest in this subject and of inducing investigators, breeders, and growers to turn their attention to the further improvement of their crops.

Tobacco growers in the sections where these experiments have been carried on have generally adopted the improved methods of bagging carefully selected seed plants and of separating the seed, and they are using the improved varieties of tobacco produced in the course of these investigations. In most of these districts certain men have become interested in the careful and systematic breeding of tobacco.

THE GREAT VARIABILITY OF TOBACCO PLANTS.

Under the intensive system of cultivation necessary for the production of profitable crops of tobacco, the condition of the soil, the fertilization, and the cultivation are fairly uniform so far as individual fields are concerned. In those tobacco-growing sections where the best grades are produced it is a common practise to grow tobacco year after year on the same field without rotation, instances being known where more than fifty consecutive crops have been produced on the same field. This system of cropping enables the growers to become thoroly familiar with the character of the soil in all sections of the fields, so that any inequality in fertility can be remedied by the judicious application of manures or commercial fertilizers, or by methods of cultivation. Notwithstanding these favorable circumstances for the production of uniform plants, a careful study of the plants in these fields reveals a great lack of uniformity as regards all characters. This lack of uniformity is particularly noticeable with respect to the variation in number, size, venation, shape, and habit of growth of the leaves borne by individual plants, the time of ripening of the leaves on the same plant and on different plants, the number and size of the suckers, and the structure and arrangement of the flowers and flower heads. From the practical standpoint, there is no more important problem in tobacco culture than the production of uniform crops. A lack of uniformity in the

crop not only results in a low yield, as a whole, and more especially of the best and most profitable grades of the cured and fermented product, but also increases the cost of sorting out the different types of leaves into their respective grades for market, the expense of which must be borne directly or indirectly by the grower.

The principal cause of the lack of uniformity in tobacco is cross-fertilization. In tobacco, as in all other crops, seed resulting from cross-fertilization produces many plants unlike either parent. Therefore such seed is undesirable for the general planting of a crop where uniformity is so important a factor. Where the tobacco seed plants are grown without protection from cross-fertilization some of the flowers are cross-fertilized by insects or other agencies. Desirable plants may thus be crossed with undesirable plants in the same field or in adjoining fields, and the plants grown from the seed thus produced are usually extremely variable, some of them resembling the desirable plants from which the seed was harvested, others resembling the inferior plants from which the pollen was carried for crossing, while the remainder are of an intermediate type, unsuited to the purpose for which the crop is grown, and therefore causing a loss to the grower. The writers have observed numberless cases in different tobacco-growing sections where several distinct and worthless new types appeared in the fields, the plants of which were grown from carefully selected seed. These undesirable types could only be accounted for by the accidental crossing of the seed plants the year preceding or at some previous time. The crossing of individual plants of the same strain, even if both are desirable plants, results in undesirable variations, many of which are apparently reversions to earlier and unimproved types of tobacco.

In those varieties of tobacco in which the buds are removed long before the flowers open on all of the plants except those saved for seed production, or where early topping is practised, the opportunity for the crossing of the flowers borne by the seed plants with other plants in the same field is almost wholly limited to the seed plants. However, it frequently occurs that late or diseased plants, or possibly sucker branches that have been overlookt, develop flowers which open at just the right time to allow insects to carry the pollen from these flowers to the seed plants and thus effect cross-fertilization. There is little doubt that many of the plants of irregular and unusual types are produced as a result of this kind of cross-fertilization.

An important cause of variation in tobacco plants is the use of immature seed. Many growers cut off or harvest the seed heads before all of the seed pods have turned brown; hence, before maturity. The writers have observed hundreds of instances where the

seed plants have been cut off while many of the flowers were still in bloom. On such seed heads seed pods in all stages of maturity can be found. Some of the pods are fully ripe and contain mature seed, while others have not fully developed. Much of the seed is immature and contains little food for the nourishment of the plantlet. These seed heads are frequently thrashed out with a flail or the pods are crushed by the hands in order to shell out the seed. In this way the immature seed is mixt with the ripe seed sown in the seed beds. In the seed beds the immature seed frequently sprouts earlier than the mature seed, and the early seedlings grown from such seed are naturally used for transplanting in the field. Such plants have a great tendency to vary, in some cases being very early, and as a rule having leaves that are small, coarse, and wholly undesirable for any purpose. These weak, immature tobacco seeds, according to careful and extensive observations by the writers, produce plants which are more subject to certain diseases, particularly the mosaic disease, than are plants grown from mature seed.

The excess of plant food in the soil where heavy applications of barnyard manure and commercial fertilizers are used is usually thought to produce variations in the plants. This variation is usually shown by an increase in the size of the leaves, which is generally correlated with changes in color, flavor, and other characters. In these cases there is usually a tendency for the type of plant to break up, so that the uniformity of the crop is disturbed. Where it is necessary to use large quantities of fertilizers in the growing of a profitable crop, the inclination to variation induced by this intensive system of cultivation must be controlled by the most rigid selection of seed from the type of plants best adapted for the purpose for which the tobacco is grown.

The change of soil and climatic conditions, particularly the taking of tobacco seed from southern or tropical conditions to the north, is a fertile source of variations in tobacco. The fixation of a uniform type in this case requires several years of acclimatization, supplemented by selection of seed from the desirable plants.

In the production of improved varieties of tobacco by breeding, variation in type can be secured by crossing, and by continued saving of self-fertilized seeds from plants most nearly reaching the growers' ideal of perfect plants uniform types can be fixt. Growers will frequently find plants that are markedly better than the rest of the plants in the field, so that by selecting these desirable variations a steady improvement in the yield and quality of the crop can be effected. Variation, therefore, is a basis for selection in an experimental way, but in practise every effort must be put forth in order to secure uni-

formity of the plants in the field and thus produce the most profitable crops.

The variations in tobacco plants may be divided into two general classes—variation in type and individual variability within the type. The causes of the variations in type, or striking variations, include crossing and change of soil and climatic conditions, particularly the change of seed from the Tropics to temperate regions. The causes of individual variations within the type include the fortuitous variations or inherent tendency to variability, methods of soil fertilization and cultivation, maturity of seed, and various local conditions. With an understanding of these conditions the grower can to a great extent control the degree of variability by methods of saving seed, systems of cultivation, and other practical methods of culture.

THE INTRODUCTION AND ACCLIMATIZATION OF VARIETIES.

The introduction of the seed of standard foreign-grown varieties of tobacco has been the source of increased wealth and prosperity in certain tobacco districts of the United States. In other regions such importations have resulted in great financial loss to the growers, which in most cases has been due to a lack of knowledge of the effect of the change of soil and climatic conditions on the particular type of tobacco grown. The writers have had an unusual opportunity in the course of their work to observe the behavior of crops grown in different tobacco-growing sections from imported seed, and have conducted extensive experiments in taking seed from one district to another, with a view to securing definite information on this subject for the benefit of the growers. The results of these observations are presented here for the guidance of tobacco growers who desire to use foreign-grown seed or who wish to change their seed.

The western Florida and southern Georgia Sumatra tobacco industry is an illustration of the successful introduction of a foreign-grown variety of tobacco. Tobacco growers in this region secured small samples of the seed of the Sumatra variety of tobacco from the island of Sumatra. At first small experimental crops were grown and seed saved from the best plants in these crops. In the course of this experimental cultivation it was noticed that the plants grown under the partial shade of trees in freshly cleared fields produced finer and more desirable leaves for cigar wrappers than the plants grown in the open. This fact led to the erection of an artificial shade over the fields, made of slats laid on a suitable framework. This method of growing tobacco was introduced about 1896 by Mr. D. A. Shaw, of Quincy, Fla. Later, other growers

used a coarse cheese cloth as a substitute for the slats. The shade method of growing tobacco in this region has developed rapidly, and at the present time several thousands of acres of tobacco are grown under either slat or cloth shade, and the industry has become established on a profitable and successful basis. During this time considerable attention has been paid to the production of a uniform type of tobacco adapted to the climatic and soil conditions of this section by the saving of seed from carefully selected plants of the Sumatra variety.

When Sumatra seed was first introduced into Florida the variety broke up into a number of different types, some of which were desirable, while others were undesirable. By reason of the small crops grown from such seed, the loss to the growers from the production of undesirable types of plants was not very great. The growers naturally saved for seed those plants which produced the most desirable types of tobacco, and as a result of continued selection of this kind a fairly uniform type of tobacco which was adapted to the local conditions in this section was secured. As the demand for this Florida-grown Sumatra tobacco developed, resulting in increased acreages, seed was at hand which was thoroly acclimatized for planting the larger area devoted to this crop. From time to time the tobacco planters in this region have obtained small quantities of seed from Sumatra, but in such cases this seed has been grown in a very limited way in very small fields until it has been acclimatized and uniform types have been secured by seed selection.

About the time of the Cuban revolution it became apparent that the supply of Cuban-grown tobacco for the use of cigar manufacturers in the United States might become limited by reason of the unfavorable conditions for tobacco growing then prevailing in Cuba. Under these circumstances it was thought to be a propitious time to introduce the growing of Cuban tobacco into southern Florida, where the conditions of climate and soil were believed to be similar to those of Cuba. Considerable public interest was aroused in this project, and as a result large quantities of Cuban-grown seed were secured and planted in certain sections of Florida. The crops raised from this seed proved to be a disappointment to the growers. The change of soil and climatic conditions resulted in the breaking up of the type of the Cuban variety into a large number of sorts, some of which were desirable, while others were undesirable. Many of the plants developed a branching habit of growth, bearing very small, undesirable leaves of poor quality, resulting in a very low yield of an inferior tobacco. One of the main causes of failure was the lack of understanding on the part of the growers of the effect of the change of conditions on the type of tobacco and their

neglect to appreciate the necessity of securing strains of plants by seed selection of the desirable types adapted to the particular conditions of soil and climate in southern Florida. If the acclimatization of these strains had been accomplished by seed selection in small fields, with little loss to the growers, the strains could have been grown on a more extensive scale with better chances of success.

In order to illustrate the necessity for the acclimatization of a variety of tobacco before it is grown on an extensive scale, the successful experiments of the Bureau of Soils in the introduction of Cuban tobacco in Texas may be cited. After a previous unsuccessful attempt by farmers in Texas to grow Cuban tobacco from freshly imported Cuban seed the Bureau of Soils began systematic experiments in growing small fields of tobacco and saving the seed of the most desirable plants according to the method described in this bulletin. In these crops certain plants were found which produced leaves possessing the flavor and aroma desired in a high-grade filler tobacco. The seeds from these plants were saved under bag, and their product has been found to possess the desirable characters of the parent plants. This tobacco has been sold at profitable prices, and the area devoted to the growing of this crop is being gradually extended in order to meet the demands of the manufacturers for this grade of filler tobacco. In northern Florida the tobacco growers, as a result of their experience with the imported Sumatra seed, experimented in growing, in the open, small fields of a cigar filler tobacco of a variety the seed of which was originally introduced from Cuba. This variety of Florida filler tobacco is now being grown extensively and profitably in that section.

The best illustration of the effect of a change of climatic and soil conditions upon the character of a variety of tobacco is found in the experience of tobacco growers in the Connecticut Valley in the planting of Florida-grown Sumatra seed and seed of the Sumatra variety imported from the island of Sumatra. As discust in an article upon the improvement of tobacco by breeding and seed selection in the Yearbook of the Department of Agriculture for 1904,[a] tobacco growers in the Connecticut Valley in the seasons of 1901 and 1902 grew extensive crops from seed introduced from Florida and Sumatra. In a careful examination of these fields it was found that the change in conditions had resulted in the breaking up of the type of the variety, so that several distinct types of tobacco were found growing in the same fields. Some of these types of plants produced well-rounded leaves, with fine venation and the elasticity, strength, gloss, grain, and other characters necessary in

[a] Shamel, A. D. Yearbook of the Department of Agriculture, 1904, pp. 435–452.

a high-grade cigar wrapper tobacco. However, many of the types of plants produced long, narrow, coarse, pointed leaves, wholly unsuited for cigar wrapper manufacture. In the case of another inferior type it was found that the leaves would not burn, altho the remaining characters were those of a desirable grade of tobacco. It was impossible to sort out this type, even by the most careful inspection of the crop, and, as a result, when the manufacturers wrapt cigars with leaves of this type and found that the wrapper would not burn, the quality of the entire crop was condemned. Certain other types of plants produced leaves of such thin texture or light body that when wrapt on cigars and allowed to dry out the wrapper frequently broke, or when the consumer carried the cigars in his pocket the wrappers were easily injured.

FIG. 1.—Belgian type of Connecticut Sumatra tobacco plant. These long, narrow leaves with oblique veins, coarse texture, burn very poorly, and after curing light green color are almost absolutely worthless for cigar-wrapper purposes. This type appeared in crops grown in the Connecticut Valley from Florida-grown Sumatra seed.

One of the most striking types of plants produced in the crops grown from this imported seed was the Belgian type, an illustration of which is shown in figure 1. In this case the plants bore leaves measuring from 30 to 46 inches long and only from 5 to 10 inches wide. These leaves, as shown in figure 2, were very pointed in shape, with coarse, angular veins, and as the cured tobacco lacked the appearance necessary for a cigar-wrapper tobacco its production was a total loss to the growers. The variation in type was accompanied by differences in time of maturity, so that the cost of the growing and harvesting of these crops was greater than in the case of uniform crops. The mixture of types was accompanied by great variation as regards the individual plants of each type. In many cases plants bearing 25 leaves were found growing by the side of plants producing 10 leaves. Marked variations in size and shape of leaves and in the number of suckers borne by the individual plants were observed, and as a result it was found that the comparatively small number of desirable types could not make up for the loss in the production of undesirable and worthless grades of tobacco. As a natural consequence of this condition the extensive culture of this variety of tobacco from imported seed has been abandoned, and the grow-

ers now have small fields and are selecting those plants producing the most desirable grade of cigar-wrapper tobacco with a view to securing strains which are adapted to the conditions of the Connecticut Valley. In the experimental fields of the Bureau of Plant Industry, covered with cloth shade, where seed of desirable plants has been saved under bag for three seasons, uniform strains, which are absolutely free from the unusual or distinct types observed in the fields from which the original selections of seed were made, have been produced.

FIG. 2.—Typical leaf of Belgian type of tobacco, showing the characteristic shape, venation, and other characters of this variety which are wholly unsuited for cigar-wrapper manufacture. The presence of such types of leaves reduces the value of the crop and is detrimental to the reputation of the variety of tobacco in which they are produced.

A few of the growers of the Sumatra variety in the Connecticut Valley introduced Cuban-grown seed and used it for planting their general crops. In these fields the breaking up in type was not so noticeable as in the case of the Sumatra variety, but the effect of change of conditions in the variety was shown in the production of so-called freak plants. These plants had a branching, or suckering, habit of growth, bearing very small, sharply pointed, coarse leaves that were worthless for cigar-wrapper purposes. In a careful study of the plants in these fields it was found that at least one-third of the entire crop consisted of these freak plants.

In one of these fields the writers made selections of seed plants of the most desired type, bearing the size, shape, and general character of leaves adapted for cigar wrappers. This seed was saved under bag, and a similar plan has been followed up to the present time.

In Plate I, figure 1, the original crop raised from freshly imported seed from which the seed selections were made is shown. In Plate I, figure 2, is shown a crop grown on the same field after two generations during which the seed was saved under bag. As can be seen from the illustrations, this method of seed selection and bagging has produced a uniform type of tobacco without the freaks and other undesirable types of the original crop. It is fortunate that on this farm the planter saved seed in the open for his own use from the same field. The crop grown from such seed was visited during the season of 1905 by the writers, in company with Dr. H. J. Webber and several tobacco growers, and was found to contain a large proportion of freaks; in fact, about the same proportion as the crop grown from

freshly imported seed. In other words, the seed saved under bag produced uniform strains adapted to soil and climatic conditions in this section, while seed saved in the open and subject to cross-fertilization with freaks and other undesirable types produced about the same proportion of freak plants as the crops grown from the freshly imported seed.

The writers during the past season planted in Florida Connecticut-grown seed of the Sumatra variety. It was found that while there was a noticeable change in the shape of leaf and in some minor characters in the Florida-grown tobacco, there was no violent breaking up of type or indication of unusual variability. This experiment and other observations have led the writers to believe that the effect of changing seed from the north to the south is not accompanied by such marked changes as when seed is taken from tropical conditions to northern latitudes.

In summing up the observations on this subject it can safely be said that it is a dangerous policy to plant large crops of tobacco with imported seed or with seed from a very different section. In most cases it has resulted in failure and caused considerable loss to the growers. The general crops should be planted from seed produced under the same conditions as the crop which is to be grown. If it is necessary to change the seed or desirable to test imported varieties, it should be done on a small scale, followed by a most careful selection of seed plants, and the seed should be saved under bag, safe from cross-fertilization.

THE STRUCTURE AND ARRANGEMENT OF FLOWERS.

A careful study of the tobacco flower is one of the most essential factors in the beginning of tobacco breeding. Successful results, particularly in the production of new varieties, can seldom be obtained until one becomes familiar with the structure of the parts of the flower and the manner in which these parts perform their several functions. A full realization of the ease with which crossing takes place can only be obtained in this way, and, as has been previously stated, the prevention of promiscuous cross-pollination is of first importance in the production of a desirable and uniform type of tobacco.

The tobacco flowers are arranged upon a branching determinate flower head, which appears when the middle leaves are about half grown and continues to develop and produce new flowers during the rest of the life of the plant. Figure 3 is a diagrammatic sketch of a tobacco flower, showing the parts of the flower and the general way in which pollination takes place. The calyx (*a*) is the outer, green, five-parted, floral envelop at the base of the flower which serves to

protect the flower in the bud. The corolla (*b*) is the delicately colored floral envelop inclosing the reproductive organs of the flower. Its color tends to attract insects, which are the principal agents in cross-pollination. Next inside the corolla are the five stamens, which are the male reproductive organs of the flower. Each stamen consists of the filament (*i*), supporting the anther (*j*) in which the pollen grains (*k*) are produced. The central organ is the pistil, or female part of the flower. The terminal enlarged portion (*g*) is the stigma. The pollen grains (*k*) adhere to the surface of the stigma (*g*) and germinate, sending an extremely minute tube (*l*) down thru the central conductive tissue (*h*) of the style (*f*). This tube extends into the cavity of the ovary (*d*) and finds its way into the ovule (*n*) thru a small duct or micropyle (*m*), where fertilization takes place. Other ovules (*e*) are fertilized by other pollen tubes. These ovules develop into seeds after fertilization. The ovary is two-celled, with a fleshy central placenta (*c*) on which the ovules are borne. The early capsules mature always before flowering ceases. The shape of the delicately colored corolla is somewhat tubular, or, perhaps, more nearly like an elongated funnel. It is comparatively small from the basal end to a point about two-thirds the distance to the terminal end of the flower. At this point it enlarges suddenly to more than twice the size of the basal part of the tube (fig. 3). It is composed of 5 petals, which coalesce to form the corolla tube, and separate only at the extreme end.

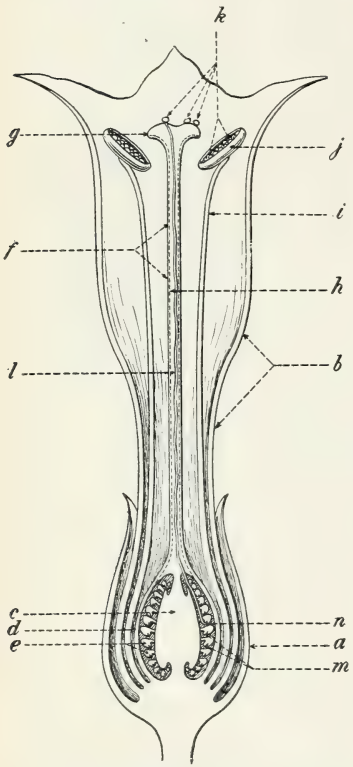

FIG. 3.—Diagrammatic sketch of tobacco flower.

The tobacco flower is symmetrical. The number of sepals and stamens is always the same as the number of petals, but these floral circles do not remain constant, varying rather indefinitely in different strains and even among individuals of the same strain. Trimerous flowers, or flowers with three parts in each flower circle, have been found growing on the same plants with pentamerous flowers, or those having five floral parts. This is the exception, however, and not the rule.

The tobacco flower is naturally self-fertile, and plants grown from

self-fertilized seed are always stronger and more vigorous than those from cross-pollinated seed when the crossing is within the variety. In Sprengel's discourse on the cross and self pollination of plants the statement is found that "nature seems to have wished that no flower should be fertilized by its own pollen." Later, Darwin stated that "nature abhors perpetual self-fertilization," but, unlike Sprengel, recorded a number of exceptions to this rule, and tobacco was among them. The experiments of the writers conclusively substantiate the findings of Darwin in this connection. They have found self-pollination in the case of tobacco to be most desirable in all cases.

A very interesting phenomenon of growth takes place in the filaments of the stamens immediately after the opening of the flowers, which can be taken as an evidence of the natural self-fertilizing habits of the plants. An examination of the flower just previous to the time of opening will reveal the fact that the pistil is longer and extends up beyond the stamens, but when the anthers open and the stigma becomes receptive a very rapid growth of the filaments takes place, which causes the open pollen sacks to be pushed up past the stigma, and in almost all cases they come in direct contact with the stigma in passing upward. This gives an opportunity for at least a portion of the pollen grains to adhere to the viscous surface of the stigma and for self-fertilization to take place, as shown in figure 3. It is just before this process occurs or while it is in progress that there is danger of, or opportunity for, cross-pollination. The open flower contains a small drop of nectar at the base of the corolla tube, which is sought by honeybees, bumblebees, and humming birds, as well as by many species of minute insects, all of which carry pollen from flower to flower and from plant to plant in their constant search for the honey-like substance secreted in the corolla tube. In passing in and out of the flowers the bodies of the bees and other insects and the beaks of the humming birds become dusted with pollen, which is transported by them to the pistils of the next flower visited. The ovules are as readily fertilized by pollen from the surrounding plants as by the pollen from the flower in which they are produced. This continuous crossing necessarily results in the introduction and intermixture of poor and undesirable varieties in our best strains of tobacco.

The observations of the writers plainly show the absolute necessity for protecting the flowers of the seed plants from cross-pollination. Careful experiments have demonstrated that in many instances the stigma of the tobacco flower remains in a receptive condition for three or four days. This condition results in a twofold disadvantage when no protection is used against cross-pollination. In the first place, it affords abundant time and opportunity for complicated

crossing, for each flower is visited many times a day by various insects and often by humming birds; and, secondly, it brings about conditions favorable for the production of seed of weak vitality. Previous experimenters have pointed out the fact that the best seed is not produced as a result of premature or late pollination, either of which is likely to occur in the case of tobacco flowers under natural conditions. When fertilized only by pollen of the same flower, the pollination takes place at exactly the right time, or when the stamens push past the receptive stigma, which results in the production of a superior grade of seed.

The readiness with which tobacco flowers can be cross-fertilized greatly facilitates the opportunity for producing new and valuable varieties by artificial crossing. In the course of the experiments here recorded it has been found perfectly possible to combine certain desirable qualities found in different strains and at the same time to eliminate some of the undesirable characters by producing hybrids between strains of tobacco.

FIG. 4.—Three tobacco flowers at proper stage for emasculation, and the scissors and forceps used in emasculating flowers. The corolla of the central flower has been opened in order that the anthers may be conveniently removed. The flower on the left has been emasculated preparatory to cross-pollination.

The method of cross-pollination used in the experiments of the writers is to remove all capsules, open flowers, and flower buds from the flower head except those which are in the proper stage of development to open within the following twelve or fifteen hours. In preparing these remaining flowers they must be carefully opened and emasculated by the use of a scalpel, small scissors, and a fine pair of forceps, as illustrated in figure 4. Great care must be taken in removing the anthers before they have dehisced, in order to avoid injury to the stigma. The emasculation should be done in the afternoon, after which all of the flowers must be carefully covered with a thin paper bag as a protection against insects or other agencies whereby pollen might be transferred to them. In the forenoon of the following day the emasculated flowers should be ready for pollination, but the exact time for applying the pollen must be determined in the case of each individual flower by the appearance of the viscid, sticky fluid on the surface of the stigma. The pollen from the male

parent plant can be best applied to the stigma of the female with the point of a scalpel or other sharp instrument. When applied with a brush there is danger of some of the pollen grains adhering to the hairs of the brush after each operation, resulting in considerable mixture of pollen, but where the scalpel is used there is no difficulty in removing all the pollen after each operation. The paper bag must be replaced over the flowers as soon as they have been pollinated, and must be allowed to remain until the seeds have set and all danger of crossing has past.

In crossing it is not essential that both of the parent varieties be grown in the same community. Pollen from tobacco flowers when thoroly dry will keep for several weeks or longer without deterioration. The writers have sent pollen thru the mails a distance of more than a thousand miles with perfectly satisfactory results. When not intended for immediate use, it should be harvested when perfectly dry and carefully taken off the anthers after they have dehisced and become dried out. These dry anthers may be put in small vials, and the pollen kept long enough for all practical purposes, provided the vials are carefully corked and kept dry.

The large number of seed produced in a single pod and on a single plant makes it possible to obtain definite results from selection or hybridization in tobacco much more quickly than in the case of most other plants. Careful counts show that from 4,000 to 8,000 seeds are produced in a single pod of normal size, and an estimate of the average number of pods on each plant shows that the ordinary tobacco plant produces from 500,000 to 1,000,000 seeds. In many cases the writers have secured from 1 to 1½ ounces of seed from a single plant when the seed has been saved under bag according to the method outlined in this bulletin. This large number of seeds gives an excellent opportunity for testing each selection or cross on a large scale. The quantity of seed produced varies inversely with the number and size of leaves on the plant. The production of a large number of good-sized leaves is almost invariably accompanied by the production of a small quantity of seed.

On account of the large quantity of seed produced by a single plant under normal conditions and the fact that the various characters of a tobacco plant are inherited so strikingly and uniformly by its progeny the following year when the seed is saved under bag, protected from cross-fertilization, it is possible for the tobacco grower to secure uniformity with a considerable degree of improvement in type, quality, and yield by one year's selection. One plant often furnishes enough seed for an entire crop, and the plants raised from this seed always produce a very uniform lot of tobacco when cross-fertilization is not allowed to take place.

THE NECESSITY FOR INBREEDING.

In the season of 1903 the writers, in company with Dr. H. J. Webber, visited the tobacco fields of the Connecticut Valley in response to a request of the growers for assistance in the production of uniform strains of tobacco by breeding and seed selection. During the survey of this region with a view to gaining an idea of the variability of the varieties of tobacco, it was determined to inaugurate a series of experiments in a practical way for the investigation of the methods of saving seed.

In view of the results of the investigations of Darwin and others on the comparative vigor of growth, seed production, and other characters of tobacco plants raised from seed obtained by cross and by self fertilization [a] the seed of select plants of the different types of tobacco was protected from cross-fertilization by inclosing the flower heads with a light but strong form of paper bag. Other seed plants were saved without such protection, as is ordinarily done by the tobacco growers. The seed harvested from these seed plants was saved separately, stored in small glass vials adapted to this purpose, and labeled according to the system now in use by the breeders in the plant breeding investigations of the United States Department of Agriculture. The record of the number of leaves, size, thickness, shape, and color of leaves, number of suckers, height of plant, habit of growth of leaves and plants, time of maturity of leaves and seed, and other characters was kept according to the system used by Doctor Webber, modified by the writers for use in keeping a pedigree of tobacco varieties.

The seed of the plants finally selected for experimental purposes was sown in ordinary seed beds, separated into many small sections by thin board partitions, each of which was capable of holding 500 seedlings. The seedlings from these separate seed-bed plats were transplanted to separate rows or plats in the experimental field, each row or plat being carefully labeled so that the plants could be traced directly back to the original seed plants. The manuring, or fertilization, and preparation of the soil in the experimental field and the transplanting, cultivation, and harvesting of the plants were all conducted with the greatest possible care to give all of the rows or plats equal opportunity for growth. For instance, the seed of all of the plants of a variety was sown the same day, and at the proper time the seedlings of this variety were all transplanted the same day. At the time of harvest the leaves of the individual rows or plats were primed or the plants cut on the same day, and the leaves or plants were hung in the curing shed, so as to get as nearly uniform condi-

[a] Darwin, Charles. Cross and Self Fertilization in the Vegetable Kingdom, pp. 203–215.

tions for curing as were consistent with the practical handling of the crop. The leaves of plants selected for seed were harvested separately and labeled so that the product of each plant could be intelligently used in comparative tests of the cured and fermented crop. This labeling process involved considerable extra work and attention in the field, curing sheds, and warehouses, but was absolutely necessary for a definite selection of seed plants for the next season's use, based on the character of the fermented tobacco.

The rows or plats of plants grown from seed of individual plants saved under bag, i. e., self-fertilized seed, showed remarkable uniformity in type, size, shape, and appearance of leaves, habit of growth, and all other characters, and conformed closely to the type of the parent plants from which the seed was saved.

Plate II, figure 1, shows a type of parent plant and Plate II, figure 2, the progeny of this plant, raised from self-fertilized seed. From this illustration it can be seen that the transmitting power of tobacco is most strongly marked and the progeny of plants raised from inbred seed remarkably uniform in all characters, every plant closely resembling the parents. In the hundreds of tests of this character which have been carried on by the writers during the past three seasons, not only in the Connecticut Valley but in Maryland and Florida, the benefits to be derived from using inbred tobacco seed have been confirmed and emphasized. It is true that some plants have the power of transmitting their characters to their progeny more strongly than others, but on the whole every case under observation has offered additional evidence of the value of the practise of saving tobacco seed under bag, free from possible cross-fertilization.

The continued saving of self-fertilized seed for three seasons has furnished no evidence of a decrease in the rate of growth or constitutional vigor of tobacco plants as a result of this practise. On the other hand, by reason of the selection of the best plants in the different varieties every season there has been a marked increase in the productiveness and the general vigor of constitution of the varieties under consideration. This conclusion is emphasized by the vigorous and productive strains of Connecticut tobacco shown in Plate III.

Self-fertilization is the closest possible degree of inbreeding, and it is the general impression that this practise is usually associated with a loss of vigor of growth, with a predisposition to disease, and other undesirable results. In tobacco, so far as our experience goes, this does not happen, and the exact opposite of this condition obtains, viz, that inbreeding is beneficial to the general development of the variety.

It is unfortunate that it is impossible to present tabular data at

the present time showing the behavior of plants raised from artificially cross-fertilized seed within the variety in comparison with plants raised from self-fertilized seed. The principal object of this work has been the achievement of practical results, so that the opportunity for scientific observations and experiments has been necessarily limited. However, the writers have had the privilege of making careful observations on the results of saving seed from plants grown under large field tents and comparing the plants raised from such seed with the plants raised from self-fertilized seed. Under these tents there is little opportunity for cross-fertilization with other varieties, except thru the small doors opening into these tents, which are kept closed all of the time when persons or teams are not actually passing thru them, so that there is little likelihood of bees or other insects passing in and out. The probability is that the cross-fertilization that takes place is wholly between the plants saved for seed in these tents or with other plants under these shades that are in bloom at the proper time for cross-pollination.

The comparison of the plants raised from seed saved under these field tents and exposed to cross-fertilization with the surrounding plants and of plants of the same variety raised from seed protected from cross-fertilization by paper bags shows that self-fertilized seed produces more uniform, vigorous, and productive plants than the open-fertilized seed, which is to a greater or less extent cross-fertilized between plants of the same variety.

It appears that the cross-fertilization of tobacco seed, even tho it occurs between good individuals, has a tendency to seriously break up the type. Along with the variability of type induced by cross-fertilization, it frequently happens that many freak plants resembling the wild species appear; these can only be explained with our present knowledge of the subject as reversions. Such freak plants are not usable for profitable manufacture, and consequently are a source of loss to the growers.

The size and weight of seed from the inbred plants are equal to and in most cases greater than the seed saved from open-fertilized plants. In a series of comparative tests of the two kinds of seed in the case of four varieties grown in the Connecticut Valley it was found that the inbred seed was heavier and larger than the cross-fertilized seed. The total quantity of seed harvested from the open-fertilized plants usually exceeded that of the inbred plants. This was due to the fact that in the case of the inbred plants more of the seed-bearing branches were removed than where the plants were allowed to set seed under natural conditions, in order to adapt the seed head for the best possible development under the paper bags. Where an equal number of seed pods was examined for

yield of seed the inbred seed equaled or exceeded in quantity the cross-fertilized seed in the variety. In the case of hybrids or in the crossing of two distinct strains or varieties the yield of seed, as well as rate of growth of the hybrid plants, was greater than that of the inbred seed and plants. It is true that some of the improved inbred strains produce but little seed compared with unimproved types of the same variety. Inbred strains have been selected for increased yield and number of leaves, which seem to be correlated with lessened seed production. The same correlation holds true where open-fertilized strains have been selected for increased number and total yield of leaves.

The rate of germination of the inbred in comparison with the cross-fertilized seed was thought to be slower in some of the experiments carried on in the season of 1904. However, further comparisons have failed to bear out this conclusion, and it is the belief of the writers, based on careful observations on this subject, that the inbred seed sprouts as rapidly as the cross-fertilized seed. It seems probable that in the cases observed by growers in 1904 a difference in moisture content of the rotted apple-tree fiber, the medium used for sprouting, was the cause of the apparent differences in time of sprouting. So far as the writers' observations go, the inbred seed produces more rapidly growing plants than the open-fertilized seed, and consequently earlier plants for transplanting. There is no doubt, further, that the inbred seed produces a larger proportion of seedlings for transplanting at one time than the open-fertilized seed, which is an important matter to the tobacco grower, who is frequently forced to wait for seedlings on account of the lack of uniformity of plants in beds sown with open-fertilized seed.

Darwin's conclusions on the comparison of tobacco plants raised from inbred and cross-fertilized seed for three years are as follows:[a]

> Taking the plants of the three generations altogether, the crossed show no superiority over the self-fertilized, and I can account for this fact only by supposing that with this species, which is perfectly self-fertile without insect aid, most of the individuals are in the same condition as those of the same variety of the common pea and of a few other exotic plants which have been self-fertilized for many generations. In such cases a cross between two individuals does no good; nor does it in any case, unless the individuals differ in general constitution, either from so-called spontaneous variation or from their progenitors having been subjected to different conditions. I believe that this is the true explanation in the present instance, because, as we shall immediately see, the offspring of plants which did not profit at all by being crossed with a plant of the same stock profited to an extraordinary degree by a cross with a slightly different subvariety.

[a] Darwin, Charles. Cross and Self Fertilization in the Vegetable Kingdom, p. 210.

These conclusions of Darwin were based upon greenhouse and garden tests, where, of course, it was not possible to study and compare the characters of quality or the value of the tobacco from the inbred and cross-fertilized seed. The observations of the writers upon tobacco grown in the field under normal conditions in the different tobacco-growing sections bear out the conclusions of Darwin on this subject, and show, further, that the inbred seed produces more profitable crops of tobacco than the seed resulting from open or cross fertilization within the variety.

THE IMPROVEMENT OF THE SHAPE OF LEAVES.

The shape of the leaves is a very important factor in determining the value of all classes of tobacco, and is of first and particular importance in cigar-wrapper varieties. Many varieties which possess some of the most desirable characteristics of high-grade wrappers are totally valueless for this purpose on account of the narrowness of the leaves. From such leaves it is impossible to cut cigar wrappers economically. The manufacturer of cigars demands a leaf which is wide and well rounded at both ends. This shape admits of the best opportunity for cutting into wrappers of the desired shape and size with the least possible waste, while the long, pointed leaf will yield very few wrappers, and a very considerable proportion of it must be consigned to the waste pile.

The long, pointed leaf is not only undesirable because of its shape, but the texture toward the basal end is poorly adapted for cigar wrappers and the grain is usually unevenly distributed. In such cases a large part of each leaf can be utilized only for binders or low-grade fillers. A striking example of leaves of this character may be found in the case of many strains of Connecticut and of Pennsylvania Broadleaf varieties. When working these varieties the manufacturer expects to cut wrappers from the middle portion and tips of the leaves only, while the remainder of the leaves, often half or more, must be used as binders or for filler purposes. A wider leaf and one which is more nearly round would yield many more wrappers to the pound and would be proportionately more valuable.

In addition to being wide, with well-rounded tips, the best wrapper leaves must have small, fine veins which are widely separated and which form an obtuse or right angle with the midrib. The veins in narrow leaves extend along down the leaf toward the tip, are coarse, and present a very unattractive appearance when wrapt on cigars, while in the case of wide leaves the veins usually extend out toward the edge of the leaf and are almost perpendicular to the midrib, smaller in size, and wider apart. In some of the strains of

Broadleaf tobacco which have been improved by careful seed selection and breeding the veins are sufficiently wide apart to allow wrappers for cigars of standard size to be cut between the veins. Such wrappers have a very smooth, attractive appearance on cigars, and where they can be cut in this way the waste material from each leaf is exceedingly small. Figure 5 illustrates the superior value of the wide over the narrow form of leaf for cutting wrappers economically. Attention is also called to the character of venation

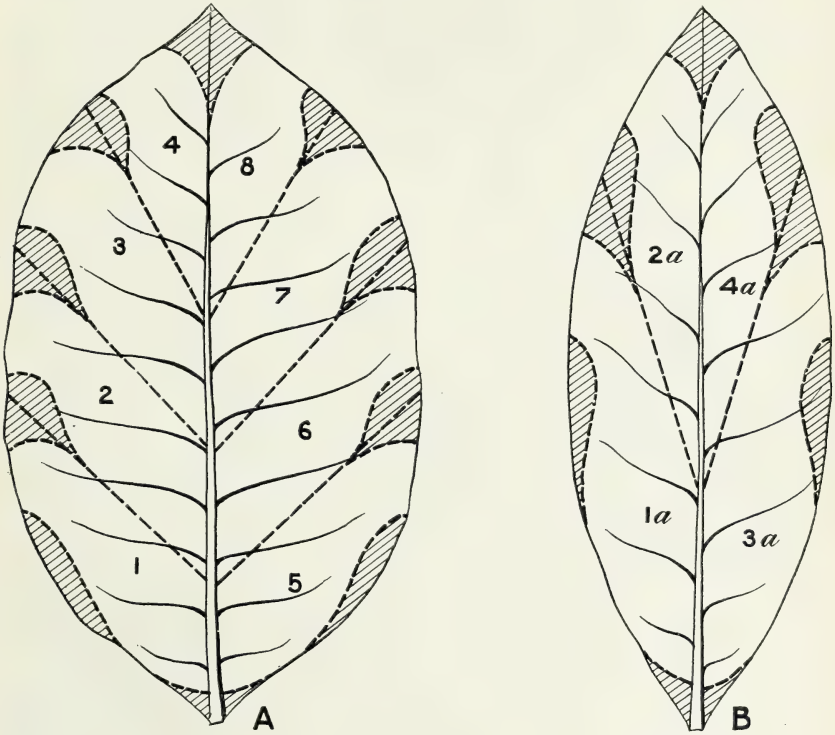

FIG. 5.—Diagrams showing the superiority of broad over narrow leaves for cigar-wrapper purposes: A, broad leaf; wrapper cuts numbered 1, 2, 3, 4, 5, 6, 7, and 8. B, narrow leaf; wrapper cuts numbered 1a, 2a, 3a, and 4a. Waste indicated by hatching. Not only do the broad, round leaves yield more cigar wrappers, but on account of the venation and other characters they produce wrappers of superior quality.

in the two leaves shown. It will be observed that the veins extend out almost directly toward the edge of the leaf from the midrib in the case of the wide leaf (A), while in the case of the narrow leaf (B) the veins run upward, and, consequently, when used as wrappers injuriously affect the appearance of cigars.

The variability of the plants in the field in respect to shape of leaf is found upon close observation to be more striking than the variability in many other characters. The variability of strains of

tobacco grown from the seed of the same variety and under similar conditions as respects shape of leaves is shown in Plate IV. It is very important that this variability be reduced to the minimum, and the writers have found that it is possible to greatly reduce the variability by systematic seed selection. Plants producing leaves which are very long and narrow are frequently found growing beside others with well-rounded leaves of a desirable length. Plants bearing leaves of the ideal cigar-wrapper shape and those that were totally worthless on account of their shape, as well as many gradations between these extremes, have been found growing side by side. In the case of a field of Florida tobacco grown from freshly imported Sumatra seed a similar variability was observed in the summer of 1905. The production of leaves of undesirable shape results in a direct loss to the grower and manufacturer alike. The cost of production to the grower is no greater where the leaves are all of uniform size and shape, and the cost of grading is greatly reduced.

In nearly all varieties of cigar-wrapper tobacco, most of the leaves are small and narrow near the basal end and this portion of the leaf is seldom wide enough for wrapper purposes. Figure 5, A, shows a leaf wide at both ends, from which wrappers may be cut down to the extreme basal end, thus avoiding the waste which can not be avoided in the form of leaf shown in figure 5, B. It is important to produce the form of leaf shown in figure 5, A, not only because it will yield more wrappers to the pound and necessitate very much less waste in cutting, but because more wrappers to the acre may be obtained.

The variability in the shape of leaves on the same plant is often very marked, and may be as readily corrected by proper methods of seed selection as the variation among the individual plants in the field. The size and shape of the individual leaves on almost all plants vary more or less, but on some much more than others. An occasional plant will be found on which the leaves are comparatively the same size and shape from the top to the bottom of the plant, while in other cases there are marked differences in this respect. Where this uniformity is found the top leaves are seldom as thick or heavy as where there is a lack of such uniformity, and therefore a larger percentage of the leaves is adapted for cigar-wrapper purposes.

By selecting for seed the plants possessing leaves of the most desirable shape from top to bottom and protecting them from cross-fertilization, it is possible to produce a crop which will be uniformly like the parent plant. It can be plainly seen that this will result in a larger yield to the acre of much more valuable tobacco because of the uniformly well-shaped leaves, best adapted to cigar-wrapper

purposes, and this may be accomplished with no additional expense to the grower.

The shape of the leaf in certain types of smoking tobacco largely determines its adaptability to both soil and market conditions. In Maryland it has been found generally true that a broad leaf gives best results on very light sandy soil, and is best adapted to the demands of the German market, while a somewhat narrower or longer leaf is more desirable on heavy clay soil; from this latter type the highest grades of red tobacco are produced to meet the requirements of the markets of France. In the case of Maryland tobaccos the shape of leaf is usually correlated with the number of leaves, there being more leaves to the plant where they are narrow than in cases where they are broad. The writers have observed many exceptions to this rule and have found that by keeping this point in mind when selecting seed plants it is possible to find round-leaved plants producing a large number of leaves, and to procure varieties from these plants which will produce a large number of uniform leaves and at the same time a grade of tobacco which will be adapted to the demands of the market for which it is grown.

It is within the power of the tobacco grower to produce the shape of leaf best adapted to the purposes for which his tobacco is grown, and to continually improve the shape and gradually bring it up to the ideal of a perfectly shaped leaf, by carefully selecting seed plants year after year which produce leaves most nearly approaching this ideal. In all cases if uniform types are to be produced cross-pollination must be prevented, in order that the progeny the following year may inherit only the characters of the desirable parent plants.

THE MODIFICATION OF THE SIZE OF LEAVES.

The modification and control of the size of tobacco leaves is of almost equal importance to the improvement of their shape, and the size is so intimately associated with the shape that both features can be dealt with along the same lines in the improvement of tobacco by breeding and seed selection.

The purpose for which the crop is grown must always determine the most desirable shape and size of the leaf, and the individual grower must decide for himself what size and shape will be best adapted to the local market demands. The importance of producing a comparatively definite and uniform size of leaf is well recognized by the manufacturers of all classes of tobacco. In the case of the Maryland Smoking tobacco grown for export purposes it is difficult to procure a leaf which is too large for the highest market demands, especially when it is grown for the French market. In most cases

the leaves are too small. This defect may be remedied to a considerable extent by selecting for seed those plants which have the largest leaves, and at the same time this will result in a material increase in the yield of the crop. When grown for plug wrappers, the size of the leaf is as important and worthy of as careful consideration on the part of the grower as when grown for cigar wrappers. In the manufacture of certain brands of plug tobacco the entire side of the leaf is used for one wrapper, which method is often preferable to using large leaves which have to be cut into two or more wrappers. Where this system is followed, leaves are demanded which are comparatively narrow and of sufficient length to cover the standard size of plug with the least possible waste.

A careful study of the size of wrapper desired by the manufacturer will give the grower a very definite idea of the most desirable size of leaf to produce, and by selecting plants having this style of leaf for seed the grower is enabled to produce uniformly the type of tobacco which will be best adapted to his market conditions.

In cigar-wrapper varieties of tobacco the size is of as much importance as the shape of the leaf. A short, wide leaf is always the kind most in demand, and has the advantage of being much less susceptible to injury in the curing barn. The manufacturers of certain brands of cigars prefer to cut only two wrappers from each leaf, and for this reason demand a very small, round leaf. Most manufacturers prefer a leaf sufficiently large for cutting two or more wrappers from each side, for the reason that nearly all classes of cigar-wrapper tobacco may be used more economically in this way. The size of Sumatra leaf most desired at present is about 16 inches long and sufficiently wide to admit of the most economical cutting. When leaves become very much larger than this there is danger of coarse venation, altho this can be very largely controlled by selecting for seed only those plants which produce leaves that have small, fine veins.

The question of venation is very intimately associated with both size and shape of leaf, and a certain correlation seems to exist between these characters. The writers have been able to produce types having leaves of desirable shape and size in which the venation is fine and in every way desirable. The experiments that have been conducted with this end in view prove beyond a doubt that these important characters may be successfully correlated and largely controlled by methods of selection and saving seed.

In curing tobacco in the barn the size of the leaf has been found to be an important factor. This has been clearly shown in the breeding experiments in the Connecticut Valley during damp curing seasons. One of the objects sought in Connecticut has been to secure a shorter

and rounder leaf than is now being produced in the Havana Seed and Broadleaf varieties. Numerous crosses have been made and hybrids produced with this end in view, and considerable progress has been made in securing a rounder leaf in the native varieties by careful seed selection. It has been invariably observed that these round-leaved varieties and strains have suffered much less injury from pole-sweat than the old standard varieties. This difference is attributed to the fact that in the case of the old long-leaf varieties the leaves after wilting hang down close around the stalk and adhere to one another, thus preventing the proper circulation of air when it is most needed for successful curing; while in the shorter, round-leaf types, the leaves stand out from the stalk, do not adhere closely together, and admit air freely to all the leaves on the plant, thus preventing in a large measure the injurious effects of pole-sweat or house-burn. The importance of the size of leaf from this standpoint can not be too strongly emphasized. The loss in the Connecticut Valley, as well as in many other sections of the country, due to pole-sweat often takes away the profit of the crop and is keenly felt by tobacco growers. The best crops are occasionally totally ruined by pole-sweat after they have been grown successfully and put into the barn in good shape. Therefore it can be plainly seen that the production of shorter, rounder leaved varieties in sections of the country where pole-sweat is disastrous will result in great profit to the tobacco growers and packers. Crops which have been badly injured in the barn are a source of endless trouble, and are very expensive to sort and pack successfully.

For cigar-filler purposes a comparatively small, short, and thick leaf is demanded. The small leaves are usually thicker and have better body and a very much better aroma and flavor than large, thin leaves. It has been definitely demonstrated from observations made by experimenters on the island of Cuba and from the observations of the writers made in certain filler districts of the United States that the best and most aromatic fillers are always obtained from plants producing comparatively small leaves. Plants which in a way seem to represent dwarf types or strains almost invariably produce leaves which have a much higher aromatic flavor than can be obtained from plants of the same variety producing larger and finer leaves.

In an attempt to improve the aroma of some of our domestic filler types thru breeding and selection the Department of Agriculture is endeavoring to produce new types of Cuban tobacco with very small leaves, with the belief that such types will have a superior aroma and will excel the filler grades which are now being grown in this country. These experiments have not advanced far enough to admit of any very definite conclusions, but they have indicated very clearly

that it is possible to produce better fillers by originating and perpetuating small-leaved varieties of tobacco. The yield from such types has been comparatively small, but by setting the plants closer together it is believed that there will be very little decrease in the yield to the acre in the production of small leaves uniformly thruout the crop.

The great variation in the size of leaf which is found in nearly all tobacco fields makes it possible to breed up and fix varieties which will produce uniformly the size of leaf most desired to meet special market demands. Plants producing small leaves are found growing along with those producing large leaves when all are, as far as we know, of exactly the same variety and grow under equal and uniform conditions. This variation is undoubtedly due to promiscuous accidental cross-pollination which has taken place in preceding generations. This variation in size as in shape of leaf also occurs much more strikingly on some individual plants than on others. Plants may be found in all tobacco fields with leaves of comparatively the same size and shape from the top to the bottom of the stalk, while in the majority of instances they are much smaller near the base and top than the middle of the stalk. By selecting seed plants that produce leaves which are uniformly of the desired size and shape from top to base of plant and by covering the flower heads with light paper bags, leaves very uniform in this respect may be grown the following year from seed saved in this manner.

Any tobacco grower will recognize immediately the advantages to be gained by producing types of tobacco in which the leaves on all of the plants are uniform in size and shape and where the leaves on the individual plants are likewise uniform in this respect from the top to the bottom of the plant. The yield of the crop will be materially increased, as will the value of the tobacco, while the cured product from such fields will be much more uniform in the packing house and the cost of handling proportionately reduced. The writers have already secured striking uniformity in some of the best strains of cigar and smoking tobaccos grown from seed which they have selected carefully and systematically for three years, and have found a considerable increase in the yield and value of the crop grown from such varieties.

A recognition of the importance of producing this uniformity is emphasized by the great number of demands made upon the writers for seed of these improved strains. It is easily within the power of tobacco growers to improve their present strains of tobacco in the shape and size of leaf, as well as in other characters, by selecting for seed the plants which are most nearly perfect in these respects and by saving the seed under bag according to the methods outlined

in this bulletin, in this way preventing intermixture with undesirable strains by accidental cross-pollination.

THE CONTROL OF THE NUMBER OF LEAVES ON INDIVIDUAL PLANTS.

The variation in the number of leaves borne by individual plants is just as marked as the variation in size and shape, but the size and shape are not always correlated with the number of leaves. In a general way it has been the observation of the writers that in cigar-wrapper tobaccos the plants which produce the best-shaped leaves usually produce more than the average number of leaves. The variation in the number of leaves on individual plants grown in the same field may be almost invariably attributed to the lack of systematic seed selection, to crossing, and to the use of a large proportion of light, weak seed in planting. The variation may be correlated with the height of the plants or the length of the internodes, or both. Different strains of the same variety are extremely variable in respect to the number of leaves produced, and until pure strains are developed no very great degree of uniformity in the number of leaves borne by individual plants in the crops may be expected. The production of strains true to type and uniform in the number of leaves, as well as other characters, is made possible by the careful selection of seed.

The control of the number of leaves is directly associated with the yield of the crop, and bears a very important relation to success in the handling and curing processes. The possibility of procuring a larger number of desirable leaves on each plant thru careful selection of seed is no longer doubtful, as is clearly borne out by experiments in tobacco breeding. An increase in the production of leaves borne by individual plants has been effected without any increase in the height of the plants and with no detriment to the quality of the tobacco. The reduction in the height of the plants is especially important in Sumatra tobacco grown under shade. It is difficult to prime or pick the top leaves from plants over 7 or 8 feet high, and it would not be advisable for the grower to produce plants which must be topt above that height. The most convenient height for a tobacco shade is about 9 feet. A tent higher than this would be difficult to build, and would be more liable to damage from severe windstorms; hence the necessity for keeping plants below this height by growing more leaves on each plant or by producing plants bearing shorter internodes. The Sumatra and Cuban varieties have a tall habit of growth, with long internodes, but respond readily to methods of breeding in the production of shorter stalks and shorter distances between the leaves.

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In all the varieties of tobacco which the writers have improved by seed selection and breeding the internodes are short and the number of leaves proportionally greater in the improved strains. In a careful count of the number of leaves to the plant in a good field of Sumatra tobacco the average was found to be between 19 and 20, while the records made in the breeding plats of strains of tobacco originally grown from the same seed as the general field where these leaves were counted show that the number of leaves was increased by two years' selection to an average of between 23 and 24. The breeding plats and the general field were grown under exactly the same conditions in order to eliminate any influences outside of the results of careful seed selection for the production of a greater number of leaves. The leaves produced on the plants giving an increased number were equal in size and more desirable in shape than those from stalks producing a smaller number.

The increase in yield due to the production of a greater number of leaves on individual plants and to shortening the internodes may be secured by systematic seed selection with no additional cost to the grower. Aside from the increase in yield, the quality of the leaf when there is a large number of leaves borne by the stalks is usually better than when the stalks produce but few leaves. This is particularly true in cigar and high-grade smoking tobaccos. None of the improved types of Sumatra tobacco have leaves sufficiently close together to cause any deterioration in the quality or texture of the leaf during the curing process. In the case of certain types of export and plug tobaccos and in some of the northern-grown cigar-tobacco varieties an increase in number of leaves is not desirable, for the reason that it is conducive to pole-sweat when the crop is being cured. It is further true in the case of these varieties that if the number of leaves is increased without shortening the internode, the plants will become too tall for expeditious handling. Therefore, it is necessary in certain varieties of tobacco to keep the leaves down to a certain definite number, with a desirable length of internode.

It is entirely possible for the grower to control largely the number of leaves by careful seed selection and in this way produce uniformly the plants which give the number desired. Care must always be taken in selecting for a large number of leaves not to increase the number at the expense of leaf uniformity. Only plants having leaves uniform in size and shape should be selected for seed purposes, and this selection must be kept up with unremittent persistency from year to year in order to hold constant the characters of improved strains of tobacco after they have been produced.

A large number of leaves to the plant is almost invariably closely correlated with a much lessened tendency to sucker and with de-

creased seed production. The plant food in such cases goes to the leaves, where it is most needed, and not into the production of suckers and of seed, which would be a loss to the grower. A large growth of leaf greatly retards the growth of suckers, and in some instances types have been produced which were comparatively suckerless—i. e., types which produced only very few and small suckers. These types are desirable not only from the standpoint of an increased leaf production, but the expense of suckering is in a large measure eliminated.

The habit of growth of the leaves, whether erect, or at right angles to the stalk, or drooping, greatly influences the number of "sand" or ground leaves obtained from the crop. When the leaves are drooping or pendent on the stalk the tips of a number of the lower ones come in contact with the ground and are often covered with sand or beaten and bruised by heavy rains, and are therefore partially or totally damaged. This loss of the lower leaves of the stalk can be very largely overcome by carefully selecting for seed those plants on which the leaves have an upright or erect habit of growth. This very important point in the habit of growth of the plant is often overlookt, but can be easily controlled by systematic selection. In view of the fact that the sand leaves are not nearly so valuable as those which have not been injured in this way, it is highly desirable that this habit of growth of the plant be kept constantly in mind when selecting plants for seed purposes.

The number of leaves on plants of a drooping habit of growth is sometimes greater than where the leaves grow erect or in an upright position, but where a large number of the lower leaves are badly damaged a larger number of the best grade of wrappers may be obtained from plants producing a somewhat smaller number of leaves, but all erect. Individual plants producing a large number of the desirable erect leaves may be found, however, and such plants should be saved for seed under bag in order to propagate the strain the following year.

THE PRODUCTION OF NONSUCKERING TYPES.

The number and size of suckers borne by individual tobacco plants are subject to considerable variation. In making selections of seed plants in many tobacco fields the writers have found plants bearing from 8 to 12 large suckers, and in the same fields other plants producing only one or two small suckers. In Plate V are shown two plants growing side by side in the field, at about the same stage of maturity, one of which bore five large suckers, while the neighboring plant bore only one small sucker. Instances of this kind are common in most tobacco fields. As can be seen in the illustration the nonsuckering plant has a larger number of more rounded leaves

than the suckering plant, which condition is usually true in all such cases.

The production of many large suckers is usually correlated with the development of few, heavy, dark, and usually narrow, pointed leaves. This condition is explained on the ground that the large sucker branches take from the plants the elements of plant food which otherwise would be utilized in the development of many broad, round leaves. The possibility of securing nonsuckering types of tobacco was suggested in the course of a series of experiments in the improvement of cigar-wrapper tobaccos. In the selection of seed plants great care was exercised to pick out those bearing the largest number of rounded leaves with fine veins. In the course of the study of the progeny of these plants it was observed that few suckers were produced by the most desirable types of plants. The continued observations on this subject have confirmed the conclusions that there is a correlation between the number, shape, and character of the leaves borne by individual plants and the number and size of suckers produced by these plants.

The number and size of the suckers produced by the plants in all tobaccos is an important practical problem from several standpoints. Owing to the dwarfing and otherwise injurious effect of the suckers it is necessary to remove them by breaking them off, or to "sucker" the plants, as the process is commonly called. There is great danger of breaking, tearing, or injuring the leaves during the suckering process, and this causes much loss in cigar-wrapper varieties, as the injured cigar-wrapper leaf is rendered practically worthless. A careless laborer frequently causes great loss to the grower during the process of suckering the plants. Owing to the fact that the suckers do not develop on all of the plants at the same time and consequently can not all be removed at once, it is necessary to go over the field several times during the season in order to remove all of them.

The cost of suckering is one of the important items of expense in the cultivation of tobacco. Therefore the production of nonsuckering types is an economic problem of great importance, not only by reason of the reduction in the cost of growing the crop, but from the fact that the nonsuckering types usually produce a larger yield of a more desirable quality of tobacco than the suckering types.

It has been found possible to produce uniform strains of different varieties of tobacco having but few and small suckers by saving the seed from nonsuckering plants under bag. As an illustration of the possibility of the growers producing such types the experience of one of the writers in the improvement of the Connecticut Broadleaf tobacco may be cited. In these experiments desirable plants were selected for seed in 1903, producing round leaves of fine, silky texture

and few suckers. The crops raised from this seed were found to produce but few suckers, the progeny of the different plants varying somewhat in this respect. From the strains producing the best type of leaves and bearing the least number and smallest size of suckers nonsuckering plants were again selected and the seed saved under bag in 1904. In the season of 1905 it was found that the progeny of these selections were almost free from large suckers. In one strain in particular only a few very small suckers, none of which grew more than 4 inches in length, were produced. The plants raised from ordinary seed of the same variety in the same field produced many large suckers, and as usual it was necessary to sucker the crop several times during the season. The remarkable difference in the suckering and nonsuckering habit has become so well fixt in this particular strain that a limited distribution of the seed was made for testing during the season of 1906.

It has been suggested that by saving seed from sucker branches strains of tobacco are developed which produce an increasingly large proportion of suckers; in other words, that sucker seed tends to produce suckering types of tobacco. In experiments with plants raised from seed saved from the central flower cluster the writers have observed little or no difference. As a rule, however, it has been found that the seed pods in the central flower cluster contain more large and heavy seed than the pods borne by the sucker branches, so that where seed is not carefully separated in order to secure only heavy seed for planting it is probably the best practise to save seed from pods borne by the central flower cluster of the seed head.

THE PRODUCTION OF EARLY VARIETIES.

Early maturing varieties of tobacco are of particular importance to northern tobacco-growing districts. Owing to the fact that frost kills the plants it is necessary for northern farmers to grow varieties which will mature between the time of the last frost in the spring and the first frost in the autumn. After the tobacco crops have been harvested and hung in the barns the curing processes are carried on most favorably during warm weather. The length of time required for the completion of the curing varies with the variety grown, the purpose for which the tobacco is to be used, and the weather. Under normal conditions, however, the natural curing period extends from four to eight weeks. It can readily be seen, therefore, that early-maturing varieties are likely to have more favorable conditions for curing than late varieties, as has proved to be the case in the experience of the tobacco growers in northern districts.

Another fact of importance in this regard is the likelihood of late-maturing varieties being injured in the field by autumnal storms. The earlier the crops can be harvested, the less is the probability of injury by severe rain, wind, or hail storms. In one district of the Connecticut Valley in the season of 1905 a severe hailstorm at about the usual time of harvest completely destroyed all except the early-maturing tobacco, which had been harvested and hung in the curing sheds. This experience is common to other northern tobacco regions and emphasizes the value of early-maturing varieties.

The uniformity in time of maturing of the individual plants in the fields is an important practical matter. In those districts where the tobacco crop is harvested by cutting off the plants near the ground all of the plants in a given section of the field must be cut off at one time. The immature plants can not be left to ripen and the early-maturing plants can not be harvested before the rest of the plants in the field. Overripe or underripe tobacco is likely to be of poor quality. In cigar-wrapper varieties the overripe leaves lack elasticity, gloss, and strength. The underripe leaves are likely to have uneven color and are susceptible to injury by various fungous and bacterial diseases. It is very important, therefore, that the individual plants in the field ripen uniformly, so that they can be harvested at one time without loss or injury.

The lack of uniformity in the maturity of leaves borne at the base, middle, and top of the plants is a cause of loss in value of the crop to the growers. As a rule the bottom or so-called "sand" leaves ripen first, the middle leaves next, and the top leaves last. In the varieties of cigar-wrapper or smoking tobaccos, especially where the entire plant is harvested at one time, the overripe sand leaves and the immature top leaves on such variable plants are inferior in value to the middle leaves. As stated, the color of these sand and top leaves is usually poor and undesirable, and there is also generally a corresponding inferiority in the texture and quality of these leaves. A careful study of the plants in tobacco fields at the time of the harvest has shown that individual plants bearing leaves that ripen uniformly from the bottom to the top of the plants can be found. In the experiments with the production of improved types of Connecticut Sumatra and Connecticut Cuban tobacco it was found that by selecting these uniformly ripening plants and saving the seed under bag uniform strains of these varieties could be produced.

The common practise of harvesting these varieties is to prime or pick off the lower ripe leaves first; then a few days later prime the middle leaves, and finally harvest the top leaves. In the case of the improved strains selected with the object of obtaining uniformly maturing plants practically all of the leaves can be primed at one

time. This improvement not only reduces the cost of harvest, but results in a more uniform crop of tobacco.

The differences in rate of growth of the individual plants in tobacco fields, resulting in varying times of ripening of the plants, is illustrated in Plate VI, figure 1. This degree of variability could be found in all the tobacco fields visited by the writers. In Plate VI, figure 2, are shown two rows of plants of the same variety treated exactly alike from the time of sowing the seed to harvest, one grown from the seed of the late and the other from the seed of the early plant shown in Plate VI, figure 1. The difference in time of ripening in this case was seven days; in other words, the early strain was ready for harvest one week before the late strain.

The experiments which have been conducted for the purpose of improving the different varieties of cigar wrapper and filler varieties and of smoking varieties of tobacco have demonstrated that it is possible for tobacco growers to improve the earliness of maturity of their varieties wherever such improvements are desirable. This improvement can be practically carried out by a careful study of the habits of growth of the plants in the field and the selection of the earliest and best plants for seed, saving the seed of these plants with precautions to prevent cross-fertilization. The production of earlier varieties requires several years of systematic selection and must be accompanied by a careful study of the quality and character of the product of the early strains. The practical limitation of earliness or the process of shortening the period of maturity depends on the effect of such change on the quality and yield of the early varieties.

Other things being equal, early-maturing varieties of tobacco are desirable, especially in northern sections, and can be produced by the growers thru the systematic selection of early seed plants. Uniformly maturing plants in a field and uniformly maturing leaves on the same plant are of great importance and can be produced by similar practical methods of seed selection.

THE IMPROVEMENT OF THE BURNING QUALITY.

The nature of the "burn" presents to the grower of cigar, cigarette, or pipe tobacco a most vital question, and, in the case of poor-burning tobaccos, an obstacle which is very difficult to overcome. All previous researches looking toward the solution of this problem have been confined to studies of the conditions of soil, fertility, cultivation, and fermentation, and their relation to the character of the burn of the tobacco, and thru the efforts of those who have carefully investigated these subjects improvements have been made in the burn of most of the varieties of tobacco. A thoro understanding of these phases of this question, however, does not wholly solve the

problem, nor does the improvement in methods of culture exhaust the possibilities in the production of uniformly good-burning tobacco. There are no cases on record of previous efforts having been made to improve by breeding and seed selection the combustibility of the varieties of tobacco. Believing it possible to produce better burning varieties in this way, the writers have endeavored in the course of their experiments during the past three years to produce strains of cigar-wrapper varieties which will burn more freely and uniformly than those which are grown at present.

Sufficient progress has been made to show very clearly that the variability in burn of tobacco produced by different plants is not altogether due to favorable or unfavorable conditions of soil, variations in kind or quantity of fertilizers, or to methods of fermentation, but that the individual plants themselves possess some innate character which bears a marked relation to the nature of the burn of the leaves. It is not definitely known whether this is due to the capacity of different plants to take up and assimilate the chemical constituents of plant food in different proportions or whether it is due to the difference in the physiological constitution of the leaves. To the practical tobacco grower it is of little interest to know the exact reason for this variability, but it is of most vital interest to him to know that it does occur, and that the good or poor burning quality of the plant is uniformly transmitted to its progeny, so that the nature of the burn can be largely controlled by seed selection. A difference in the soil or fertilizer, or in the treatment of the crop, always has a greater or less influence on the burn of tobacco, and must be taken into consideration; but in ordinary crops of tobacco, where all conditions are as nearly equal as possible, this marked variation in the burning quality of the individual plants still occurs.

The writers have found plants belonging to the same variety growing side by side under uniform field conditions which showed the widest variation in the nature of the burn. The product of one type of plant would burn freely and evenly, while that of another type had a very poor combustibility. This variation in burn can not be explained on the ground of any difference in soil or cultural treatment, but can only be understood by assuming that there are innate differences in the individual plants in this respect. The writers have proved beyond a doubt that this innate character does exist and is hereditary. Experimental plots of tobacco grown from the seed of the good and poor burning plants have shown that this character is extremely uniform in the progeny, provided other conditions are equal. Plate VII shows two rows of tobacco growing side by side, one of which produced a tobacco that burned very satisfactorily, while the product of the other was very deficient in com-

bustion under ordinary conditions. Taking this variability as a basis, it has been possible to produce by careful seed selection strains of tobacco possessing greatly improved burn without any change in the soil or in the method of handling the soil or the crop.

In the case of one variety of Sumatra tobacco to which the greatest objection was its poor burn, strains have been produced in the course of these experiments which burn in a perfectly satisfactory way without coaling or flaking. Even the top leaves in these particular strains have a free, even burn and good capacity for holding fire.

The production of improved burning strains requires more detailed experimental work than the improvement of shape, size, or number of leaves. No field character of the plant has been closely enough associated or correlated with the nature of the combustion of the cured leaves to make possible the selection of the best burning plants in the field. Consequently they can only be determined by actual burning tests of the tobacco after it has past thru the processes of curing and fermentation. For this reason the leaves of each seed plant must be carefully harvested separately and labeled in a manner to correspond with the label designating the seed saved from the same plant. It is always desirable that each priming of leaves be numbered or marked so that it may be identified after curing and fermentation. This enables the experimenter to make a test of the uniformity of the burn of the top, middle, and bottom leaves of each individual seed plant. There is considerable variability in the degree of uniformity of the burn of leaves borne on different parts of the plant, and therefore it is desirable to secure seed from plants which show a good burn in all the leaves, in order to produce a strain with uniformly good combustion. The leaves of all the seed plants should be cured and fermented under conditions as nearly normal as can be obtained in order to admit of a fair competitive test and to eliminate the possible influence of irregular conditions.

Where large numbers of samples are to be tested specially constructed apparatus is necessary to secure accurate results. A simple form of apparatus has been devised by Dr. W. W. Garner, of this office, for making these comparative tests. It consists of a series of glass tubes so arranged that each tube will smoke a cigar in very much the same manner as it is smoked by an individual, but with more regularity and uniformity. This apparatus is operated by means of an intermittent flow of water which subjects all the cigars to exactly uniform conditions. A carefully adjusted aspirator draws the proper intermittent current of air thru the cigars, and is so connected with the tubes that exactly the same strength of current is drawn thru each cigar. A paper has been prepared by Doctor Gar-

ner[a] which describes this apparatus and method of laboratory tests of the burn of tobacco in detail. By smoking several cigars at the same time by the use of this device it is possible to make very close and accurate observations on the rate and evenness of burn, color of ash, and other characteristics of the tobacco from different plants.

Cigars are prepared for this test from all the samples to be tested from the different plants and are allowed to dry out under natural but uniform conditions. The method employed by the writers in determining the comparative combustibility of the leaves from each seed plant is as follows:

One cigar is made wholly from the leaves of each plant, using the top leaves for filler, those next to the top for binder, and one side of a middle leaf for the wrapper. The other half of the wrapper leaf is reserved for a supplementary test, which will be described later. The object in making the entire cigar from the same plant, whether it is a filler or a wrapper type, is to eliminate the possible influence of any other tobacco upon that which is being tested. After the cigars have dried sufficiently, they are placed in the apparatus for smoking and all drafts excluded from the room to secure absolute uniformity of conditions. While the cigars are burning they are scored on the several points which go to make up a good or poor burn. The differences in character of burn of tobacco from the different plants when smoked under these uniform conditions is very surprizing, and shows clearly the variability of the quality of burn in tobacco produced by different plants grown under uniform conditions.

The rate of burn is carefully determined, and the degree of uniformity or evenness noted. Some cigars will burn down on one side and go entirely out on the other, while others burn completely and evenly. Some will burn much more rapidly than others and with greater evenness. In many cases the wrapper puckers or swells just ahead of the fire, and often a shiny, metallic, black ring will appear just back of the burning tobacco. Sometimes both of these phenomena are present, and in this case the black ring, which indicates what is known as a metallic burn, appears between the fire on the cigar and the ring caused by the puckering or swelling of the leaf. These rings indicate a poor burn and are invariably associated with poor-burning tobacco and very frequently with an undesirable or bitter taste.

The comparative degree of coaling, i. e., a swelling of the wrapper at the burning point leaving a black ash, can be readily determined and noted in these tests. The character of the ash is also considered very important, and in case it flakes badly or is of a very dark, dull

[a] Bulletin No. 100, Part IV, Bureau of Plant Industry, U. S. Department of Agriculture.

color the seed from plants producing such tobacco is discarded. The seed from only those plants which produce tobacco that burns evenly, closely, and holds fire well, with no coaling and with a white, close, compact ash, is selected for further planting in the production of good burning types.

In the case of cigar-wrapper tobacco an additional test is made in which some standard filler and binder tobaccos are used and only the wrappers are taken from the plants to be tested. This gives an opportunity to observe the effects of other tobaccos on the burn of the wrapper and gives a test which may be compared to the testing of the wrapper in the ordinary way on cigars. A good, uniform grade of filler and binder is used in these tests. The wrappers from the best burning plants burn a little ahead of the filler, but hold fire well and burn evenly around the cigar.

These tests are further supplemented by another and more delicate one for bringing out the fine points of difference in the wrapper leaves from the individual seed plants without the possible influence of any other filler or binder, or of poor workmanship. Wrappers taken from the half leaf left in making the cigar test are placed on prepared forms, the shape and size of an average cigar, just as they would be placed on a cigar, and are allowed to dry on these forms. The forms are removed after the wrappers are thoroly dried, leaving the wrapper in the shape of a tube, just as it would be if it could be removed from the cigar in a dry condition. One end of this wrapper tube is placed over the end of a glass tube, upon which it fits closely. A current of air is then drawn thru the glass tube, entering at the end on which the wrapper was placed and of sufficient strength to give the best conditions for burning. The end of the wrapper is then lighted with a spreading flame, and accurate notes are taken on the length of time the tobacco holds fire and the character of the burn. The wrappers from the best burning leaves will burn up evenly, but where the combustion is at all deficient it is clearly brought out in this test. In many cases instead of burning evenly the fire will run in streaks about the leaf or will go out when it reaches a vein. Some of the leaves will scarcely burn at all under these conditions, while others will burn in a very satisfactory way. This final, delicate test is used more especially for cigar wrappers than for any other class of tobacco. In all cases a final test is made by smoking a cigar made from the tobacco under test.

Whether the grower uses the methods which we have described in testing the burn of his tobacco or not, it is comparatively easy for him to make a definite test of the combustibility of the leaves from all the plants which he selects for seed, and in this way gradually

breed up good burning types of tobacco in which the burn will be uniform thruout. This uniformity in type can only be secured by saving the seed of the plants producing the good-burning type of tobacco, these having been protected from cross-pollination according to the method described in this bulletin.

THE SELECTION OF SEED PLANTS.

The successful improvement of tobacco varieties by selection depends on the characters of the plants saved for seed production. Too much emphasis can not be given to the necessity for great care in the selection of seed plants. The history of the production of the valuable varieties of tobacco by seed selection is sufficient evidence of the importance of this subject. The running out or deterioration of the established varieties where careful seed selection has not been followed and the consequent deplorable financial condition of the growers of these inferior tobaccos is additional argument for the adoption of the most improved methods of saving seed by all growers. Inasmuch as any improvement in the yield or quality of tobacco means that much additional profit to the growers and manufacturers, attention to seed selection is a matter of direct financial importance as well as scientific interest.

The development of highly specialized means for manufacture and the increasing demand by the consumers for a variety of manufactured tobacco products are important reasons for the most careful study of seed selection as a means for producing tobacco adapted for the manufacture of special grades. In fact, a survey of the conditions of the tobacco growers in different sections shows that in those regions where a systematic attempt is made to produce a type of tobacco adapted to the specialized market requirements the prosperity of the tobacco growers is much greater than where no such attention is given to the improvement of the crop. It can be safely stated that the tobacco grower of the present day and of the future must either keep pace with the demands of the market or be forced out of business. Owing to the increased general prosperity and wealth of the United States, tobacco consumers are constantly demanding a higher grade of tobacco, a demand which, if taken advantage of by the producer, means greater profit and better prices for the specialized crops.

The common practise in selecting tobacco seed plants in many tobacco-growing regions is to save a group of a dozen plants, more or less, depending on the acreage of tobacco grown, in some convenient corner or section of the field where they will interfere least with the harvesting of the crop. A visit to any tobacco-growing region in the United States shortly after the crop is harvested will show these clumps of plants which have been left for seed. It is

usually the practise of the best growers to save portions of one or more rows producing the best plants, but frequently even this care is not given to this most important factor of tobacco growing. On the large tobacco plantations the writers have frequently observed a section of the field set apart for seed production. In some cases the poorest plants in such sections have been topt, while in others this practise has not been followed. This method of selecting seed plants is not as desirable as that employed in saving seed in most farm crops. It means that the growers do not take advantage of the variability of the individual tobacco plants in the field, and consequently lose the benefits to be derived from using the best plants as the parents for the next year's crop. After carefully studying the plants in hundreds of tobacco fields, the writers have found that the best plants do not grow in groups, but in different parts of the field, and can only be found by diligent search and careful observation of the crop, plant by plant, from the time the plants are set out in the field until they are topt. As soon as the benefits to be derived from seed selection and breeding have been demonstrated in tobacco-growing communities the growers are usually quick to take advantage of the improved methods of saving seed.

It has been frequently urged that change of seed is beneficial. In the light of recent investigations and observations on this subject this contention is believed to be incorrect in the case of tobacco. In other words, seed should be saved on the farm or field where the crop is to be grown. A change of seed is always experimental, and, as pointed out in the discussion of the introduction and acclimatization of new varieties, such change when necessary should be made only after carefully testing the seed for several years and securing by selection a strain which is adapted to the local soil and climatic conditions. In some tobacco-growing sections growers frequently buy their seed or obtain it from some other source than their own crop. While it may be true that this practise may be advisable in some cases—for example, when the seed is procured from tobacco-seed breeders having the same general soil and climatic conditions as the growers—this plan is not a good one to follow as a regular source of seed and is not practised by the most successful tobacco growers. The experience of the best growers and of scientific investigators of tobacco, as in the case of other farm crops, such as corn and cotton, goes to prove that the best policy is for every grower to save his own seed from the best plants in his crop. Instead of the varieties of tobacco running out by reason of having been grown under the same conditions continuously, it has been demonstrated that they are improved by the adoption of simple and practical methods for the selection of seed plants and the saving of seed.

In order that the grower or breeder may select seed plants intelligently it is necessary for him to form an ideal of the type of plant which it is desirable to grow. Without a clear conception of the type of plant desired any improvement by seed selection will be accidental, and as a rule the efforts in this direction will be unsuccessful. It is also necessary in forming the ideal to keep in mind the purpose for which the tobacco is produced in order to develop a type which will meet the demands of the market. For instance, in the growing of cigar-wrapper tobaccos a broad, round leaf, adapted for the cutting of the largest possible percentage of wrappers, is most desirable, so far as the shape of the leaf is concerned. The production of a high-yielding type must be governed in all cases by the effect of such change in the size and number of leaves upon the quality of the tobacco. The information necessary for the intelligent selection of desirable plants for seed can only be gained by a careful study of the plants, the cured and fermented product, and the market demands.

The plan of selection of seed plants followed by the writers is to examine with greater or less care, several days before topping, every plant in the field from which selections are to be made. As indicated before, it is always advisable to study the plants from the time they are set out, whenever this plan is practicable, with a view to picking out the best plants for seed. Such plants, when found, can be marked with a tag, string, or heavy rag, so that they can be readily identified when the final selection is made. Some characters, such as time of maturity, are more easily observed in the young plants than later; hence the importance of marking the plants showing the characters desired whenever they are found.

The size of at least three leaves in apparently desirable plants should be measured—one at the bottom, one near the middle, and another at the top of the plants. These measurements can easily be made with an ordinary yardstick, taking the length from the point of attachment of the leaf to the stalk to the tip and the width at the broadest point. The development of the top leaves by reason of further growth can be taken into consideration, tho in most tobaccos well-developed top leaves are correlated with early-maturing plants and always with uniformity of leaves on the same plant. The shape, size of veins, color, texture, and other characters of the leaves should be taken into consideration.

The number of leaves should be counted, also the number of suckers, and observations made, and, if possible, recorded of the uniformity of the shape, size, and other characters of the leaves in different portions of the plants, the presence of rust or other fungous or bacterial diseases, the height of the plants, and the space between the leaves, or length of internodes. The transmission of these charac-

ters from parent plants to progeny is shown in Plate VIII. A detailed estimate of the plants in the field in respect to these characters is valuable only as a guide to the selection of the best type of plants for a particular or a pedigree record, but must always be of secondary importance to the judgment of the grower as regards the general type of the plants and their adaptability for successful and profitable production.

In cigar-filler, smoking, and other varieties an intelligent selection can only be made by the study of the cured and fermented leaves. In this case it is necessary to save of plants that show in the field the general physical characteristics desired several times the number that will be necessary for seed. The leaves of these plants must be primed and kept separate, properly labeled, hung in the curing shed with the remainder of the crop so as to get normal curing conditions, and carried thru the processes of fermentation with the bulk of the crop. After the fermentation or sweating process has been completed, the samples from the individual plants can be tested, the seed from the poor plants discarded, and the seed from the best plants saved for planting. A description of the apparatus which has been devised in the Office of Plant Breeding Investigations for testing the burn or combustibility of cigar wrappers and for assisting in the comparison of the quality of cigar-filler and smoking tobaccos has been published, as previously stated. In the study of the samples from the individual seed plants it is absolutely necessary that they all be brought under uniform conditions of moisture, heat, and other conditions affecting the character of the leaves before the tests are made. Final tests must always be confirmed by the use of the tobacco in cigars, pipes, or by other means of consumption for which the tobacco is adapted.

RECORDS OF BREEDING WORK MADE IN THE FIELD.

The form of record blank used in the breeding work of the writers, together with the directions for note taking and definition of terms, is given here for the benefit of those who may wish to carry on systematic breeding work and keep a pedigree record of the parent plants and their progeny. This plan of record keeping is being constantly revised as the knowledge on the subject increases, but up to the present time the plan described has been found to be very useful and valuable, covering the most important characters and points necessary for an adequate record. The plants finally selected for seed are usually given a number for identification, this number being written on a small, strong tag attached to the top of the plant below the paper bag with a short piece of flexible wire.

The following form for note taking in the field is printed on a large shipping tag:

Tobacco } No_____
U. S. P. B. }
Date _____
Type _____
Leaves:
Number _____ Length_____
Width _____ Thickness_____
Shape _____ Color _____
Uniformity _____ Rust_____
Spots _____ Gum_____
Maturity _____ Position_____
Venation _____
Stem:
Height _____ Circumference _____
Length of internodes_____
Suckers:
Number _____ Size _____
Position _____
Seed:
Number of pods_____
Date of picking_____
Harvest:
1st 2d 3d

The directions for note taking for use in making field notes adopted by the Office of Plant Breeding Investigations of the United States Department of Agriculture are as follows:

In order to secure uniformity in nomenclature and note taking and promote uniform methods of classification in the tobacco-breeding experiments the following system has been adopted and should be closely adhered to by those conducting these experiments and applied to all records made in the course of these investigations:

NOMENCLATURE.—The word *variety* should be used to designate distinct, well-recognized, and established kinds of tobacco; as, for example, Sumatra, Connecticut Havana, White Burley, and Zimmer Spanish.

The word *strain* should be used to designate a slight local modification of a variety in which some intrinsic quality has been bred, such as tendency to produce a heavier yield, improved shape of leaf, or better adaptability to local conditions, as, for example, Cooley's Connecticut Havana, Connecticut Sumatra, or Jones's Zimmer Spanish.

The word *type* should be applied to new varieties which are selected for experimental purposes and have not come into commercial use.

TYPE NUMBERS.—In the fields where selections are made several distinct types may be found, and a number of seed plants should be selected for experimental purposes in each type. A number should also be given each type, and in all records of experiments with this type it should be referred to under this number. When a new type is found the list of existing type numbers should be consulted, so that no two types may be given the same number. For example: *Variety*, Sumatra; *strain*, Connecticut Sumatra; *type*, *1* (Crumple). Wherever it may be desirable the type may be further

identified by a distinctive name, as for example, in the case of the Connecticut Sumatra strain, *type, 2* (Green leaf); *type, 4* (Broad leaf).

SELECTION NUMBERS.—The individual plants selected for propagation should be given numbers which will serve to identify them, as well as the type and the generation to which they belong. Each plant is represented by a combination of numbers, the first one representing the series and usually corresponding to the type in which the plant belongs. Each succeeding number represents the individual parent plants in that generation, the last being the number of the individual selection in the last generation. For example, in the experiments with the improvement of Connecticut Sumatra tobacco in the second generation of selections the following numbers have been used: 1–5–6. The first number (1) refers to the series, and, in this case, to type 1 in the Connecticut Sumatra strain; the second number (5) refers to the number of the seed plant selected and used for planting the second generation; the last number (6) refers to the seed plant saved for planting the third generation selected from the crop raised from plant No. 1–5; while 2–3–8 refer to a selection of the green leaf Connecticut Sumatra type, plant No. 3 of the first generation, and plant No. 8 of the second generation selected from crop raised from No. 2–3.

HYBRID NUMBERS.—The general plan of assigning numbers to tobacco hybrids is similar to the system followed in the selections except in the case of the type number, which consists of a figure and a letter. The letter is added to the figure in order to distinguish the hybrids from the selections and may be used to identify the individual hybrids of similar parentage. A different type number should be given to each series of hybrids, and a different letter to each hybrid within the series, as, for example, 41a, 41b, and 41c refer to individual hybrids between Connecticut Havana and Connecticut Sumatra; 42a to hybrids between Connecticut Havana and Connecticut Cuban, and 43a to hybrids between Connecticut Broadleaf and Connecticut Cuban, respectively. The hybrid numbers should not be duplicates of the selection numbers.

ASSIGNMENT OF NUMBERS.—In order to prevent confusion arising from using the same numbers in different sections, it is proposed to assign certain numbers to each natural center of breeding experiments. These numbers should be consulted before new numbers are given to types or hybrids. The numbers from 1 to 100, inclusive, are assigned to the Connecticut Valley experiments; 101 to 200, inclusive, to the Florida experiments, and 201 to 300, inclusive, to the Maryland experiments.

The names of the established varieties of cigar-wrapper tobaccos grown in the Connecticut Valley are (1) Connecticut Havana; (2) Connecticut Broadleaf; and the varieties introduced in an experimental way which are grown to a limited extent under cloth shade are (1) Sumatra and (2) Cuban. A number of distinct strains of Sumatra and Cuban varieties grown from imported seed have been produced and are recognized as modified types of the Sumatra and Cuban tobaccos, so that in order to distinguish these types from the imported varieties they should be known as Connecticut Sumatra and Connecticut Cuban tobaccos. The types which have been selected for experimental purposes are as follows: Connecticut Sumatra type: 1, Crumple; 2, Greenleaf; 3, Sumatra; 4, Broadleaf; 5, Belgian; 6, Abnormal; 7, Smoothleaf; 8, Freak; 9, Mosaic; 10, Mongrel; 25, Holcomb Hollow; 27, Resistant; 28, Diseased. Connecticut Cuban type: 11, Cuban; 12, Dark Green; 13, Havana; 14, Freak. Cuban: 20, Imported Cuban. Connecticut Havana: 36, Cooley. Connecticut Broadleaf: 50, Brewer; 55, Favorite.

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The principal variety of tobacco grown in Florida for cigar-wrapper purposes has been developed from imported Sumatra seed and is commonly known as Florida Sumatra tobacco. The Florida Sumatra types which have been selected for experimental purposes are: 101, Lott; 102, Attapulgus; 103, Ovalleaf; 104, Greenleaf; 105, Shortstem; 106, Prolific; 107, Spiralbud; 108, Corry; 109, Fain; 110, Bell; 111, Gregory.

The variety of tobacco grown in Maryland for smoking purposes is commonly known as Maryland Smoking. The types which have been selected for experimental purposes in this variety are: 201, Sasser; 202, Satin; 203, Thickset; 204, Narrowleaf; 205, Red Clay; 206, Hill; 207, Holland; 208, Drury; 209, Long Red; 210, Wilson.

Measurements of stems.—The height of the stem of seed plants should be measured from the surface of the ground near the base of the plant to the last 12-inch leaf at the top which would be left after topping. The height of stem-topt plants should be measured to the leaf that will be highest after topping, so that in all cases the length of internodes may be determined by dividing the height of the stem by the number of leaves borne by that plant. The measurements should be made at the time of the first priming or just before cutting.

The circumference of the stem should be measured half way between the point of attachment of the middle leaf and the one next below, just before harvest.

Measurements of leaves.—The third leaf from the bottom (1), the middle leaf (2), and the third leaf (3) from the top should be used for determining the size of leaves. The length should be measured from the point of attachment to the tip of the leaf. The width should be measured at about the middle of the leaf at its widest point.

The number of leaves counted for record should include all except those top leaves under 12 inches in length which would be cut off in topping.

Descriptions of leaves.—Definitions of the terms used in the description of leaves are given below:

Shape:

Linear. Narrow; several times longer than broad.
Lanceolate. Tapering; several times longer than wide.
Oblong. Nearly twice as long as broad.
Elliptical. Oblong, with flowing lines.
Oval. Broadly elliptical.
Ovate. Like section of a hen's egg.
Cordate. Heart-shaped.
Obovate. Larger at tip than at base.

Uniformity:

Very good. All leaves alike from top to bottom of plant.
Good. The midddle leaves alike.
Medium. Irregularity not marked.
Poor. Irregularity marked.
Very poor. Very undesirable irregularity.

Position:

Erect. Makes sharp angles with stem.
Partly erect. Between erect and horizontal.
Horizontal. At right angles with stem.
Drooping. Tops of leaves drooping.
Pendent. Hanging downward.

Venation:

Coarse. Large midrib and veins; veins spreading over entire leaf into margins.

Medium. Large veins in central portion of leaf.

Fine. Small midrib and veins; veins not prominent in the margin of the leaf.

Rust:

None. Absence of rust.

Slight. A few spots on few leaves.

Injured. Parts of the leaves destroyed.

Destroyed. Most of the leaves rusted.

Leaf spots:

None. No spots present.

Incomplete. Part of the leaves evenly spotted.

Complete. All of the leaves evenly spotted.

Irregular. Part of the leaves irregularly spotted.

Amount of gum:

Slight. Very little gum present.

Medium. Deficient.

Normal. The desirable quantity.

Excessive. More than desirable.

Maturity:

Very early. About two weeks earlier than medium.

Early. About one week earlier than medium.

Medium. Usual time of maturity.

Late. About one week later than medium.

Very late. About two weeks later than medium.

Thickness:

Thick. Very coarse and heavy.

Medium. Usual thickness.

Thin. Light and thin.

Very thin. Very thin texture.

Color in field:

Very light. Pale yellowish green.

Light. Pale green.

Medium. Green.

Deep. Concentrated green.

Dark. Dark green.

Very dark. Very dark green.

Yellow. Yellow green.

Very yellow. Deep yellow green.

Color in warehouse:

Very light. Very light brown.

Light. Light brown.

Medium. Most desirable brown.

Dark. Dark brown.

Very dark. Very dark brown.

Elasticity:

Strong. Leaf stretches without tearing.

Medium. Between strong and weak.

Weak. Does not stretch and tears easily.

DATE OF GERMINATION, ETC.—In making notes on the date of germination and date of coming up the following outline may be used:

Date of germination:

Very early. Most vigorous and early.

Early. Vigorous and large percentage sprouted.

Medium. Medium early.

Late. Few sprouted.

Very late. Very few sprouted.

Date of coming up:

Very late.

Late.

Early.

Very early.

DATE WHEN CURED, ETC.—The date in column headed *Cured* (in the record form for field notes) is the time of taking down the leaves in the sheds. The date in column headed *Bulked* is the time the tobacco is put in bulk and fermendation begun. The date in the column headed *Fermented* indicates the time that the tobacco has finished fermentation in bulk and is ready for sizing and assorting. *Yield* is the weight of each grade as assorted for trade conditions.

PERMANENT RECORDS OF BREEDING WORK.

A convenient way for making a permanent record of the individual notes on the parent plants and their progeny is shown in the following form, which is printed for the Office of Plant Breeding Investigations on sheets kept in a "loose ledger" cover adapted for this purpose:

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Tobacco selection.

Individual sheet.

P. B. Form 25.

Tobacco Selection No. .....

Parent variety ..... U. S. P. B. No. .....

Locality ..... Field ..... Type ..... Date ..... Experimenter .....

Individual notes:

Seed.						Leaves.														
Date sown.	Date of germination.	Date sown in seed bed.	Date of coming up.	Uniformity of young plants.	Date transplanted.	Number.	Length.	Width.	Thickness.	Shape.	Uniformity.	Position.	Rust.	Spots.	Amt. of gum.	Maturity.	Color. F.	Color. W.	Elasticity.	Venation.
							1													
							2													
							3													

Stem.			Suckers.		Type.	Seed pickings.			Harvest.			Cured.	Bulked	Fermented.		Yield.			Total score.
Height.	Circumference.	Length of internode.	Number.	Size.					1	2	3					1	2	3	
																4	5	6	
																7	8	9	
																10	11	12	

Progeny notes:

Seed.							Leaves.														
Date sown.	Date of germination.	Per cent of germination.	Date sown in seed bed.	Date of coming up.	Uniformity of young plants.	Date transplanted.	Number.	Length.	Width.	Thickness.	Venation.	Shape.	Uniformity.	Position.	Rust.	Spots.	Amt. of gum.	Maturity.	Color. F.	Color. W.	Elasticity.
								1	1												
								2	2												
								3	3												

Stems.			Suckers.							Maturity.	Harvest.			Cured.	Bulked.	Fermented.	Yield.			Total score.
Height.	Circumference.	Length of internode.	Number.	Size.							1	2	3				1	2	3	
																	4	5	6	
																	7	8	9	
																	10	11	12	

In the breeding work conducted by the writers a portion of the seed from the plants saved for seed is sown in small sections in the seed beds and the plants are subsequently transplanted to separate rows in the field. From the rows of plants producing the best type and quality of tobacco further selections of seed plants are made. In this way the productive capacity of the individual seed plants can be tested and a record of their performance made by the breeder. Usually 100 plants are grown from the seed of each seed plant in the individual rows in the test plats.

The sections of the seed beds necessary for producing this number of plants at one time for transplanting are usually 3 by 3 feet in size, boards one-half inch in thickness and 6 inches in width being used for making the partitions. These boards are usually sunk in the beds about 2 inches to prevent mixture of seed between the different sections. Necessarily the quantity of seed required to sow these sections is very small, about 1 gram being used for this purpose, which should be taken from the general seed product of the individual plant. The seedlings from these sections can be transplanted by hand, care being taken not to injure the roots, and sufficient water supplied to start the plants under favorable conditions. This plan of testing the individual seed plants may not be practicable for the grower of a small crop, but can be used to advantage by tobacco breeders.

After the seed plants have been selected in the field the flowers should be protected from cross-fertilization and the seed saved in accordance with the directions given under the head of methods of saving seed.

METHODS OF SAVING SEED.

The absolute necessity of saving seed free from cross-fertilization was recognized by the writers in the beginning of the tobacco-breeding experiments. The readiness with which tobacco flowers are cross-pollinated has been shown in a previous section, giving a description of the flower, and has been emphasized all thru this bulletin. The securing of pure, unmixt seed is necessarily of the first importance in developing improved strains of tobacco which are sufficiently uniform to meet the requirements of the manufacturers. After trying various methods of keeping the seed pure by covering the flower head of the plant it was found that the most practicable and efficient way to protect the flowers from cross-pollination was by the use of a light, strong manila paper bag, which serves to keep out all agents whereby pollen may be transferred from plant to plant and from flower to flower, and at the same time does not interfere with the proper development of the flower head and the seed. This method impresses

all growers at first as being impracticable, but it has been found by the writers and by many growers who have adopted it to be thoroly practicable and in every way effective. Nearly all the growers in the Connecticut Valley, where the work was first begun, are saving their seed in accordance with this method, which is sufficient evidence of its adaptability to practical farming conditions. The form of bag used must not be thick or heavy enough to affect the natural transpiration and growth of the plants. The kind which has been adopted for general use is the lightest grade of manila bag that can be procured at the grocery or country stores. There is greater liability of the seed being injured under southern or tropical conditions by using a bag which is too heavy than there is in the North. In order to prevent any possibility of injury from this cause, the writers have adopted the method of puncturing the bag with a large number of very fine holes, which will admit air and at the same time are not large enough to allow insects to pass through and carry the pollen from plant to plant.

FIG. 6.—Tobacco seed plant at proper stage of maturity for the application of a paper bag. The bag should be placed over the seed head just before the first flowers open. The top leaves and sucker branches should be removed before arranging the bag, in order that nothing may interfere with the development of the seed head.

The bags may be punctured by using a sewing machine and arranging the bags as in sewing ordinary cloth. The sewing-machine needle of course must not be threaded for this purpose. For the average tobacco plant the paper bag of 12-pound size has been found to be the most satisfactory. When the plants to be bagged are of a small variety, the 10-pound bag may be large enough, but it will not allow sufficient room for the proper development of the seed head on a tobacco plant of average size.

The proper time for bagging is just before the first flowers open and are ready for pollination. At this time the stem of the flower head is sufficiently strong to support the weight of an ordinary paper bag without injuring the plant in any way. When the bags are applied earlier than this, the operation is more difficult and the tender top of the plant is liable to be broken off or bent by the weight of the bag. When the growing plant has reached the proper stage for bagging, all branches just below those which form the main flower head

and all small leaves should be carefully removed. The accompanying illustration, figure 6, shows the earliest flowers just ready to open, which indicates the right stage of development for bagging. After the flower head has been carefully prepared, as indicated, the bag should be inverted, placed over the flower head, the mouth gathered closely around the stem just below the flower branches and tied loosely enough to allow sufficient room for further growth, as shown in figure 7. At this stage of the plant's development the flowers bloom rapidly, and a corresponding rapidity of growth takes place in the flower head. This condition makes it necessary to visit the bagged plants in the course of five or six days in order to take the bags off and remove all superfluous growth in the nature of small leaves, so as to give as much room as possible for the development of the flowers. The bag must be replaced immediately, before insects have an opportunity to visit the flowers and transfer pollen. This process should be repeated two or three times during the season and the bag elevated each time in order to allow for the rapid growth of the stem.

FIG. 7.—Tobacco seed plant showing arrangement of a paper bag for the protection of the flowers from cross-fertilization. At this stage of development a tobacco plant increases in length very rapidly; consequently, the bag should be tied loosely so that it can be easily pushed up the stalk.

After a sufficient number of pods have set seed to produce the normal quantity of seed, the bag may be removed to prevent any possibility of mold during continued periods of rainy weather. When this is done all late buds and flowers must be broken off, leaving only the pods which have been fertilized to produce seed. It is also desirable to remove all seed pods which are poorly developed, in order to eliminate some of the seed which is likely to be light and undesirable.

When all the pods are mature the plants are cut in the ordinary way and hung to dry in a barn or other place having a free circulation of air. In order to catch the seed of pods which open during the process of drying, it is customary to put new bags over the seed heads at the time the plants are cut. Thoroly dry seed may be shelled and stored in glass vials or bottles with perfect safety, and can be kept almost indefinitely in this way. The fully matured

and dry tobacco seed will retain its vitality when kept dry for ten years, or, as has been observed in several cases, a much longer time.

The seeds saved in accordance with the methods here outlined are larger, heavier, and of higher vitality than those saved in the ordinary way. Self-fertilized seeds are free from the introduction of hereditary tendencies from surrounding plants, and the characters of a single plant are transmitted to the progeny with almost as great uniformity as in the case of vegetative reproduction or propagation from cuttings.

This method of saving seed requires very little more time than the old method, and at the same time gives the grower an opportunity to study the types of tobacco in the field by coming in closer contact with the seed plants themselves. He will of necessity make closer observations as to the points of perfection or imperfection in individual plants, and by protecting the flowers from cross-pollination it is entirely possible for him to produce a pure and uniform strain of tobacco after selection for two or three years, to improve his tobacco in every way, and to weed out the undesirable and unprofitable types which occur so frequently in the general tobacco field.

SEED SEPARATION.

The special value of large, heavy seed in the production of general farm crops has long been established. Careful farmers and seed growers have used various methods for selecting this grade of seed for planting. Experiments with light and heavy seed in this and other countries have demonstrated clearly and conclusively that larger yields are obtained from heavy, plump grains than from small, light seed. Live-stock breeders do not breed from weak or poorly developed parents, and it is just as important that plants be bred from heavy seed with strong parentage as to use the best animals in the production of improved breeds of live stock.

The writers have found this principle to be strikingly emphasized in the production of tobacco from different grades of seed. The plants from large, heavy seed not only grow more vigorously, but have greater resistance to certain bacterial and fungous diseases and show greater uniformity in the field and warehouse than plants produced from inferior seed. Thus it can be seen that the specific gravity of individual seeds has a very important bearing on some of the main factors in the production of profitable crops of tobacco. The reason for this is very evident when we consider the fact that the heavy seeds contain a larger supply of food for the development of young plants than the light seeds. It is not always true that the heavy seeds germinate first, or that the plantlets from such seeds make the most rapid growth in early stages of development, but they always

make a healthier, more strudy, and stronger growth, and produce much better plants in the end. The comparative size, production, earliness, and other characters of plants raised from light and heavy seed are shown in Plate IX, figure 1. It frequently happens that the light seed are the first to germinate, and in some cases the young plants from the light seed are first to reach the proper stage for transplanting. However, after they are about half grown they show freaky tendencies and are very susceptible to various diseases, are unstable, and of little value to the tobacco grower. They sometimes bloom earlier and mature before the average well-developed tobacco plants in the field, but are deficient in yield and other important qualities. Such plants are, of course, undesirable from every standpoint and should be eliminated before being transplanted to the field, so as to give place to vigorous plants grown from heavy seed.

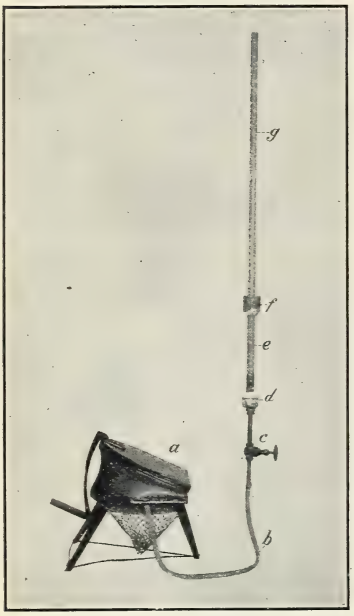

FIG. 8.—Tobacco seed separator. This apparatus separates the light, immature, and poor seed from the heavy seed, and can be so regulated as to furnish any degree of fineness of separation desired. It is now being used extensively by tobacco growers.

It is almost impossible to select and discard in the seed bed the weak plants produced from light seed, so that it must be done, if at all, before the seed is sown. Doctor Trabut, in his experiments with tobacco, sought to make a separation of tobacco seed according to different degrees of specific gravity by throwing the seed upon water and discarding those that continued to float after a certain length of time. This process effects a partial separation, but it is incomplete. The extremely small size of tobacco seed makes this method rather impracticable, for the reason that minute air bubbles will adhere to the seed for a considerable time and hold many of the heavy seed on the surface, while some of the lighter ones will lose the air bubbles first and sink to the bottom with the heavy seed. Notwithstanding the incompleteness of this method, Doctor Trabut found a great difference in the growth and productiveness of the seed which sank to the bottom of the vessel first, and he brought to light new and vital facts regarding the importance of using heavy seed.

In order to secure a more complete separation of the light from the heavy grade of seed, the writers have devised a simple and practical

wind-blast apparatus, shown in figure 8, for separating tobacco seed into heavy and light grades. This apparatus has already come into general use by tobacco growers in the United States and other countries. It was described by Mr. A. D. Shamel in the Yearbook of the Department of Agriculture for 1904. The seed separator here illustrated is a slight improvement over the original apparatus as described by Mr. Shamel.

The improved apparatus consists of a foot bellows (*a*), connected with a globe valve (*c*) by means of a rubber tube (*b*). The valve (*c*) is connected directly with the seed receptacle (*e*). The seed receptacle consists of a 1-inch glass tube (*e*) about 14 inches in length, cemented in the reducer (*d*) with plater of Paris. At the extreme bottom of the glass tube *e* and just above the top of the valve (*c*) a fine wire gauze is fastened. The object of this gauze is to prevent the seed from falling into the valve from the receptacle, and therefore it is necessary to use a wire gauze with very small mesh. An ordinary gas pipe coupling (*f*), about 3 inches in length and slightly larger than the tube *e*, is firmly cemented to the top of the tube to serve as a support for the tube *g*. The tube *g* is of glass the size of tube *e* and about 6 feet in length. The apparatus can be supported by a convenient frame, which may be fastened to the wall or set up wherever desired.

The bellows and tubing for this apparatus may be procured from any chemical supply house, and the remaining parts from hardware stores. They can be easily put together and the apparatus set up in the proper manner by anyone who wishes to use it. A complete device of this nature should not cost more than $5, a very small sum compared with the benefits to be derived from getting rid of the light and undesirable seed. In the successful operation of this apparatus the following method should be employed: Pour about 1 ounce of the tobacco seed to be separated into the seed receptacle, and by means of the foot bellows pass a current of air of sufficient strength thru the entire apparatus. The strength of the current of air may be regulated by the globe valve so as to blow out the desired proportion of the light seed. The light seed is blown out thru the top of the tube and the heavier seed falls back into the seed receptacle. The degree of separation may be controlled accurately by means of the valve, the length of the tube, and the working of the foot bellows. A much more complete separation may be made by the use of a long tube than where a short one is used.

This simple apparatus serves to completely eliminate the evil results associated with the use of light and inferior seed. It is thoroly practical in every way, and delicate enough in its operation to separate the smallest kinds of seeds according to their individual speci-

fic gravity. One apparatus is sufficient to separate seed for an entire community, a plan which is being followed in some cases. A pound of seed may be separated in less than half an hour. Thus it is seen that the apparatus and cost of operating are very small and not sufficient to prevent any tobacco grower from eliminating all light and poorly developed seed, in this way not only increasing the yield, but also improving the uniformity and quality of his crop.

DISEASE RESISTANCE.

In practically all fields producing diseased tobacco plants where the writers have made observations some degree of immunity has been noticed in individual plants which have been found growing among badly diseased plants on infected soil. These cases of immunity could not be explained on the ground of any differences in treatment, but their resistance to disease was evidently inherent in the individual plants. The same conditions have been found by other investigators and workers in other farm crops, and from these resistant individuals many immune strains have been developed. Among the most notable are the variety of wilt-resistant cotton, improved by Mr. W. A. Orton and Mr. Rivers, and the Iron cowpea, which is resistant to root-knot caused by nematodes, improved by Dr. H. J. Webber and Mr. W. A. Orton. The transmission of this immunity found in individual plants has made it possible to develop immune strains, and in that way to produce thoroly healthy crops on disease-infected soils.

In most cases where immune plants occur, if seed is saved from a large number of such plants some of them will be found to transmit their resistance to the progeny uniformly and thus give rise to the easiest known method for the control of certain plant diseases.

In the case of tobacco, the seed of the immune plants must be saved, with precautions to avoid cross-pollination, to insure the best results. In the season of 1903 the writers made selections of plants in several tobacco fields in the Connecticut Valley which showed immunity to the tobacco wilt. These plants stood out very plainly and strikingly in the diseased sections of the field, making a normal growth, and were apparently not affected by the wilt in any way, while plants growing all around them were so badly diseased that they produced no tobacco, and many of them died before maturing seed. Seed was also saved from some of the diseased plants that reached maturity. Two rows were planted the following year on the infected soil, one from seed of a resistant plant and the other from seed of an immune plant, with the results shown in Plate IX, figure 2. In this instance, by reason of the foregoing and other observations, it was found that complete resistance to the wilt was obtained by one year's selection.

A wilt in tobacco occurs in North Carolina which is evidently a parallel case with the one found in Connecticut, and in all probability could be controlled in the same way.

One of the most serious diseases affecting tobacco at present is the root-knot caused by nematode worms. Tobacco seems to be particularly susceptible to the attacks of nematodes, and many crops are more or less seriously affected by this enemy. There is no known remedy for this pest that is applicable in a practical way to field conditions. Soil-sterilization methods are used successfully in plant beds or in greenhouses, but such treatment is rather too expensive to be used on large fields. The most practicable method for the control of this disease seems to be in the way of securing immune strains of tobacco by seed selection and breeding. The writers have selected a large number of individual plants that showed immunity in the field, and the seed of these selections will serve as a basis for experiments in the production of nematode-resistant types. The complete success of other workers in obtaining resistance to nematodes in varieties of sugar beets and cowpeas is good evidence that similar results may be obtained in their efforts to obtain resistance to this enemy in tobacco. The Iron cowpea shows strong resistance to the nematode when planted on badly infected tobacco fields, and for this reason can be highly recommended to tobacco growers for use in this connection.

The mosaic disease causes very serious injury in tobacco fields in many parts of this country. The writers believe, from indications observed during the past two years, that it will be possible to develop strong, vigorous strains of tobacco which will be largely resistant to this disease. In the case of some Maryland selections, resistance to the mosaic disease seems to have been transmitted in a large degree to the progeny of certain vigorous strains. In two plats grown side by side under uniform conditions, one from seed of a parent plant affected with mosaic disease, the other from a perfectly healthy one, the following results were obtained: Plat 1, grown from the seed of the mosaic plant, showed 80 per cent of diseased plants in the field; plat 2, grown from the seed of a perfectly healthy plant, showed less than 20 per cent of diseased plants. It may be impossible to entirely eradicate this disease by the production of immune varieties, owing to the peculiar nature of the malady, but these figures, which have been duplicated many times, show very conclusively that by the development of stronger and hardier types of tobacco, especially where heavy seed is used for sowing, it will be possible to gradually reduce the percentage of mosaic plants in ordinary tobacco fields.

There are numerous tobacco diseases which the writers believe may be largely eradicated by producing immune strains. It is the intention of the Office of Plant Breeding Investigations to take up work with as many of these diseases as seems practicable and endeavor by selection to produce resistant types wherever it is possible to do so.

FIG. 9.—Typical plant of Uncle Sam Sumatra tobacco, originated by the Department of Agriculture in the Connecticut Valley from Florida-grown seed and now being extensively grown for cigar-wrapper production. The shape, size, venation, stretch, color, gloss, and other characters are specially well suited for cigar wrappers. This variety yields a large number of the best grades of wrappers, and is very uniform in all characters. It is a vigorous-growing plant, of early maturity and small seed production.

A NEW VARIETY PRODUCED BY SEED SELECTION.

UNCLE SAM SUMATRA.

The original plants from which the variety of tobacco known as Uncle Sam Sumatra has been produced by seed selection were grown under shade on the plantation of the Connecticut Tobacco Corporation, near Tariffville, Conn. The first selections were made in the season of 1903 on this plantation in a field the plants of which were grown from seed originally brought from Florida. The Florida seed was produced by plants which were grown from seed originally imported from the island of Sumatra. In a careful study of the Connecticut-grown Sumatra crops in 1903 a number of distinct types were discovered, some of which were evidently very undesirable, while others were apparently desirable. A striking illustration of two of these types is shown in Plate VIII. The seeds of typical plants of these types were saved under bag and tested in 1904 in an experimental field of 4 acres on the Indian Head Plantations, at Granby, Conn. Further tests of the Uncle Sam variety in the season of 1905 in the Indian Head Plantation experimental field and in other fields in the Connecticut Valley and of plants of this variety grown in Florida from Connecticut-grown seed have demonstrated the value of this variety for growing under shade for the production of cigar wrappers. The original plants of the Uncle Sam variety showed striking variations from the generally accepted type of Sumatra tobacco, but were believed to more nearly approach the ideal of a desirable cigar-

wrapper variety than other types. In the experimental stages the plants belonging to this type were classed as type 3 and called Sumatra to distinguish it from the other types. As soon as its commercial importance was established it was decided to call it the Uncle Sam variety. This name was considered appropriate from the fact that it is probably a striking variation produced by the effect of the change of climatic conditions consequent on the introduction of Sumatra-grown seed into the United States, and while it was discovered in the Connecticut Valley it appears probable that it can be successfully produced under shade in Florida.

FIG. 10.—Typical leaf of Uncle Sam Sumatra tobacco, showing the ideal shape for cigar-wrapper manufacture. The veins are small and stand out almost at right angles to the midrib, which is very important for the economical cutting of wrappers.

The striking characteristics of this variety are extremely round leaves of fine texture, small fine veins growing at right angles from the midrib, the large number of leaves borne by the individual plants, and the wonderful uniformity of size and shape of leaves from the base to the top of the plants. In crops raised from the seed of this variety a large proportion of light-colored wrapper leaves are produced, which when wrapt on cigars have a smooth, glossy appearance. The leaves show uniformly a good burn in all practical and experimental tests, and there is no undesirable taste or flavor present or noticeable when the wrappers are smoked on cigars. The leaves have a peculiar and very characteristic habit of growth, standing out almost at right angles near the stem, and then drooping slightly near the tips. The quantity of seed produced by plants of this variety is very small, and very few and small suckers develop at any time during the growing season. In figure 9 is shown a typical plant of this variety, while figure 10 shows a typical leaf of this variety grown from self-fertilized seed.

The pedigree record of the original plants and their progeny shows an average production of 21 leaves to the plant, having an average length of 20½ inches and a width of 14½ inches. The average number of suckers is three and the size small. The average height of plants is 6 feet, and the average period from the date of setting out the plants in the field to the time of harvest is ninety days. The length of internode is 3½ inches and the circumference of stem 3½ inches. The plants have been particularly free from the attacks of fungous diseases, and the leaves have the necessary stretch, or elasticity, and strength to cover the cigar well without injury. The yield of wrappers in the manufacturing process has been exceedingly large and of the best quality.

FIG. 11.—Typical plant of the Cooley Hybrid tobacco. Connecticut Havana Seed, female parent; Sumatra, male parent. The hybrid retains the habit of growth and adaptability to Connecticut Valley conditions of the mother parent, combined with the improved shape, size, venation, and other characters of the male parent.

NEW VARIETIES PRODUCED BY HYBRIDIZATION AND SEED SELECTION.

THE COOLEY HYBRID.

The history of the origin of the Cooley Hybrid is as follows: Select plants of the Havana Seed variety grown by Mr. D. P. Cooley, Granby, Conn., were used as mother parents. Several flowers on these plants were emasculated at the proper time and pollinated with pollen produced by plants grown from Connecticut Sumatra seed in the season of 1903. From the plants grown from this seed, selections of the most desirable were made in 1904. From this crop typical seed plants were again selected, and the plants raised from this seed in 1905 showed as great uniformity as ordinary crops of the mother Havana Seed variety, so that the hybrid can be said to be fixt, and seed in small samples has been distributed to interested growers. An illustration of the Cooley Hybrid plant is shown in figure 11, while a leaf of this variety is shown in figure 12. Illustrations of the Cooley Hybrid tobacco grown under shade are shown in Plate X.

The Havana Seed variety has long, rather pointed leaves with large veins. Only the tips of these leaves are suited to cigar-wrapper manufacture, the middle and basal portions lacking the necessary quality for good wrappers. This portion of the leaves is used for binders and in some cases for blending with cigar-filler tobacco. Inasmuch as the value of the tobacco depends on its capacity for producing cigar wrappers, it is highly desirable and important that as much of the leaf be utilized for wrapper purposes as possible. By crossing this acclimated variety with the standard Sumatra variety a hybrid was secured which produces short, broad, well-rounded leaves with fine veins. In other words, the hybrid combines the hardy and acclimated characters of the Havana Seed with some of the important characters of the Sumatra variety. From the variations in the plants of this hybrid it has been found possible to produce about the type of plant that is best suited to cigar-wrapper manufacture which can be grown under the soil and climatic conditions of the Connecticut Valley.

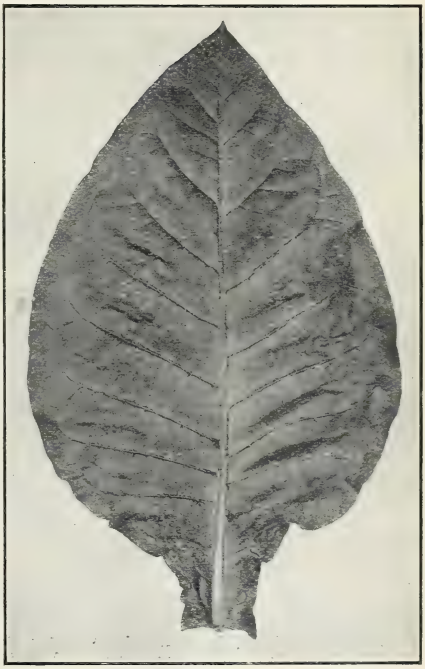

FIG. 12.—Typical leaf of the Cooley Hybrid tobacco. Connecticut Havana Seed, female parent; Sumatra, male parent.

The general characters of the Cooley Hybrid distinguishing it from the mother Havana Seed variety are increased number of leaves; shorter, broader leaves with very small, fine veins; reduced seed production, and more even texture of leaf from tip to base. The average number of leaves is 16; length, 27 inches; breadth, 17½ inches; shape, very round; number of suckers, 2; size of suckers, small; height of plant, 29 inches; circumference of stem, 2¾ inches; length of internode, 2 inches; time of maturity, ninety-five days.

It is necessary that the seed of this hybrid be saved under bag to avoid the possibility of cross-pollination. If the seed is crost with other plants, particularly with plants belonging to other varieties grown in a region, it is probable that there will be considerable breaking up in type and consequent deterioration of the

value of the variety for cigar-wrapper production. It is likely that more or less variation will be developed in crops of this variety for several years, but that this variability will not be very marked. Small crops ought to be grown at first, even in the Connecticut Valley where the variety was produced. From these crops selections can be made in accordance with the directions given in this bulletin under the head of "The selection of seed plants," whereby acclimated strains of this variety adapted to local conditions, which will be an improvement over the present variety, can be secured.

THE BREWER HYBRID.

The history of the origin of the variety known as the Brewer Hybrid is as follows: Plants of the Connecticut Broadleaf variety raised from seed of the strain grown by Mr. N. S. Brewer, Hockanum, Conn., were crost in 1903 with pollen secured from plants grown in the Connecticut Valley from imported Cuban seed. Many crosses were also made in 1904. The plants raised from the hybrid seed in 1904 showed that a marked change had been effected by hybridization. The hybrid plants produced short, broad leaves of fine, even texture with small fine veins, an increased number of leaves with little increase in the height of the plants and, in some cases, a much improved type of plant for cigar-wrapper production.

FIG. 13.—Typical plant of the Brewer hybrid tobacco. Connecticut Broadleaf, female parent; Cuban, male parent.

Selections from the crop of 1904 were grown in 1905, and one strain in particular showed such fixity of type that it may be considered ready for distribution to growers.

In the Connecticut Broadleaf tobacco the large size of the leaves is correlated with large veins and rather coarse and inferior basal portions of the leaves. These basal parts of the leaves are only suitable in most cases for cigar binders and for blending with fillers. As

in the case of the Havana seed variety grown in this valley, the tips of the leaves produce the high-grade wrappers. It has long been recognized that a most important problem was the production of a smaller leaf with more uniform texture adapted for cigar-wrapper manufacture.

The Brewer Hybrid possesses many important characters that are distinct improvements over the Broadleaf variety. The average number of leaves is 21; length of leaves, 27½ inches; width, 19¾ inches; shape, very round; height of plants, 42 inches; circumference of stem, 2½ inches; length of internode, 2 inches; number of suckers, 2, of medium size. The time of maturity is eighty-five days. The suckering habit of the hybrid is rather unsatisfactory at the present time, for it seems to inherit the suckering tendency of the Cuban tobacco; but as some of the plants in this variety have been found to be comparatively free from suckers there is little doubt that nonsuckering strains can be developed by seed selection.

FIG. 14.—Typical leaf of the Brewer Hybrid tobacco. Connecticut Broadleaf, female parent; Cuban, male parent. The broad, very round leaf, fine venation, and other desirable characters of the Cuban tobacco are evident. These characters are combined in the hybrid with the burn, body, and taste of the Connecticut Broadleaf, the mother parent.

An illustration of the Brewer Hybrid is shown in figure 13. The typical shape and size of leaf of the hybrid are shown in figure 14.

In the case of both the Cooley Hybrid and the Brewer Hybrid the tobacco can be sold by the growers and utilized by the manufacturers as improved Havana seed and Connecticut Broadleaf tobacco, respectively. In this way their production will not disturb the established market standards, but simply meet the demands of the market for improved wrapper and binder tobaccos to the benefit of both the grower and the manufacturer.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. FIG. 1.—A field of tobacco raised in Connecticut from imported Cuban seed. The result of using unselected Cuban-grown seed in the Connecticut Valley can be seen from a careful examination of this illustration, which shows a typical instance of the breaking up in the type of tobacco, due to the abrupt change of soil and climatic conditions. The branching type of plants bearing small leaves, constituting about one-third of the total number of plants in the field, was absolutely worthless for cigar-wrapper production, and many of the other variations from the normal Cuban type were of inferior quality, thus greatly reducing the yield and value of the crop. Fig. 2.—This uniform field of tobacco was produced by carefully selecting for seed production the best plants in the field shown in figure 1, and protecting the flowers from cross-pollination by the use of paper bags for two seasons. The undesirable types of plants were eliminated by this practise, and a uniform and desirable type secured, adapted to the soil and climatic conditions in Connecticut.

PLATE II. Fig. 1.—This type of plant found in Connecticut fields grown from freshly imported Cuban tobacco seed was selected for propagation. Fig. 2.—The progeny of a single Connecticut Cuban seed plant, similar to figure 1, showing the uniformity of type of plants grown from self-fertilized seed, and the marked similarity of every plant to the type of the parent seed plant.

PLATE III. The two uniform types of tobacco shown in this illustration were produced by sowing the seed of typical plants of these types growing in the same field and under similar conditions, free from cross-fertilization. These types of tobacco have been improved by careful selection of the best individual plants from year to year adapted to the purpose for which each type is produced. This experiment has demonstrated that the size, shape, venation of leaves, and other characters of tobacco plants can be propagated uniformly every year by judicious selection of seed plants of the type desired and the saving of the seed under bag.

PLATE IV. The introduction of Florida-grown Sumatra tobacco seed in the Connecticut Valley was followed by a breaking up of the type of this tobacco. Among these types, few of which were desirable, and many undesirable, the two types shown in this illustration were found. The seeds of typical plants of these types were saved under bags, from which uniform strains were produced the following season. Both of these types of tobacco are valuable for growing under shade, and the two rows, one of each type, growing side by side, offer incontrovertible proof of the value of the methods of seed selection described in this bulletin in the production of uniform types of tobacco.

PLATE V. The two plants shown in this illustration, one bearing few small suckers, and the other many large suckers, represent the average variability of tobacco plants as regards the sucking habit. The plants are of the same variety, grow side by side in the row, are of the same age, and were grown under similar conditions in every respect. The leaves of the plant bearing few suckers are uniformly wide and round, while the leaves of the plant bearing large suckers are long and pointed, and have a tendency to vary markedly in size from the top to the base of the plant. This character is hereditary and consequently the suckering tendency may be controlled by tobacco growers by seed selection.

PLATE VI. Fig. 1.—The characteristic variability of tobacco plants as regards time of maturity, as shown in this illustration, is a matter of common observation in tobacco fields. The difference in the time of ripening of the leaves in the individual plants is of special importance in the tobacco crop, from the fact that in most cases all of the plants in the field are harvested at one time, and overripe or underripe leaves are inferior in quality. For this reason it is desirable that the plants mature uniformly thruout the field. Fig. 2.—The two rows of tobacco plants shown in this illustration demonstrate the possibility of securing uniform early or late strains of tobacco by seed selection. The two rows were grown under the same conditions.

PLATE VII. The character of the burn of leaves of individual tobacco plants varies in a marked degree, even among plants of the same variety grown under the same conditions and treated alike in the curing and fermenting processes. The two rows of plants in this illustration were grown from the bagged seed of two plants of the same field, growing side by side, one a plant producing good and the other poor burning leaves. These two progeny rows inherited uniformly the character of burn of the parent plants, demonstrating that it is possible to improve the quality of burn in a variety of tobacco by seed selection.

PLATE VIII.—The Connecticut-grown Sumatra tobacco produced a number of types of tobacco very different in all characters. The two rows of plants shown in this illustration are the progeny of two representative plants of these types, grown under the same conditions and showing the striking uniform inheritance of the characters of the parent plants.

PLATE IX. Fig. 1.—The row of tobacco plants in the left in this illustration, raised from heavy seed, shows the more vigorous growth, earlier maturity, and greater uniformity of plants raised from heavy seed, compared with the less vigorous plants raised from light seed shown in the row on the right. Fig. 2.—The row of small plants shows the dwarfing effect of the root-rot in Connecticut Sumatra tobacco, while the row of vigorous plants shows a resistant strain secured by seed selection.

PLATE X.—The two rows of the Cooley Hybrid tobacco shown in this illustration were grown under shade in the Connecticut Valley. The uniformity of plants and the shape, size, and character o fleaves shown in these rows are characteristic of this variety of tobacco. There is no decided breaking up in type following hybridization, as is the case in other plants.

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FIG. 1.—CONNECTICUT CUBAN TOBACCO PLANTS RAISED IN 1903 FROM UNSELECTED FRESHLY IMPORTED SEED, SHOWING GENERALLY UNDESIRABLE TYPES.

FIG. 2.—CROP OF CONNECTICUT CUBAN TOBACCO PLANTS RAISED IN 1905 FROM SEED SAVED FROM BEST PLANTS SELECTED FROM THE FIELD SHOWN IN FIGURE 1, SHOWING UNIFORMLY A DESIRABLE TYPE.

FIG. 1.—TYPE OF CONNECTICUT CUBAN TOBACCO PLANTS SAVED FOR SEED PRODUCTION.

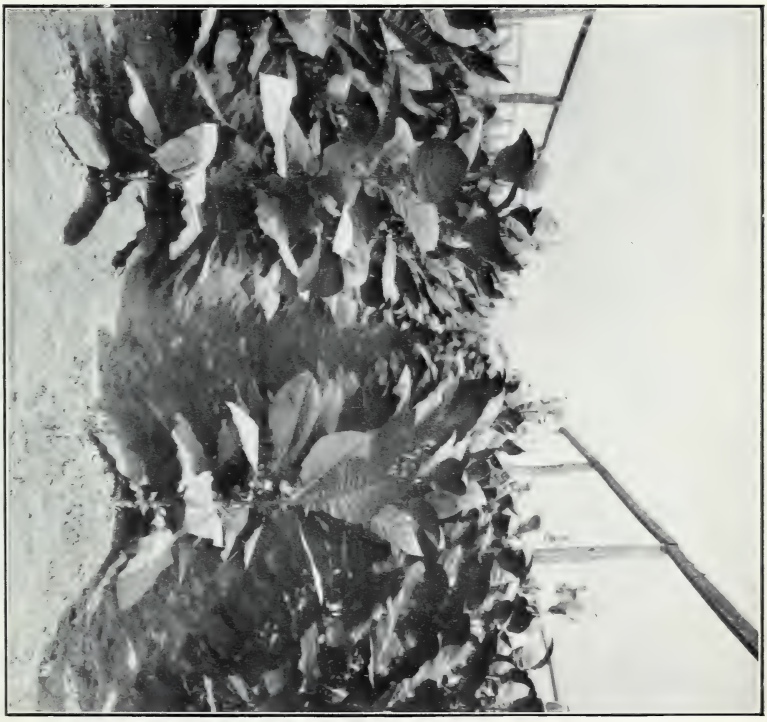

FIG. 2.—THE PROGENY OF A SINGLE PARENT PLANT OF CONNECTICUT CUBAN TOBACCO RAISED FROM SEED SAVED UNDER BAG.

TWO TYPES OF CONNECTICUT CUBAN TOBACCO WHICH HAVE BEEN INBRED FOR THREE YEARS, SHOWING THE VALUE OF THE PRACTICE OF INBREEDING IN TOBACCO.

TWO ROWS OF CONNECTICUT SUMATRA TOBACCO SHOWING VARIATION IN TYPE. ROW ON RIGHT, GREENLEAF TYPE; ROW ON LEFT, SUMATRA TYPE.

TWO TOBACCO PLANTS OF SAME AGE SHOWING VARIABILITY IN THE PRODUCTION OF SUCKERS.

FIG. 1.—FOUR TOBACCO PLANTS OF THE SAME AGE, SHOWING VARIATION IN TIME OF MATURITY.

FIG. 2.—TWO ROWS OF CONNECTICUT BROADLEAF TOBACCO, SHOWING THE POSSIBILITY OF THE PRODUCTION OF EARLY STRAINS. ROW ON RIGHT RAISED FROM THE SEED OF AN EARLY PLANT, AND ROW ON LEFT FROM SEED OF A PLANT MATURING AT THE USUAL TIME.

TWO ROWS OF CONNECTICUT SUMATRA TOBACCO GROWN UNDER UNIFORM CONDITIONS. ROW ON RIGHT, POOR BURNING TYPE; ROW ON LEFT, PERFECT BURNING TYPE.

TWO ROWS OF CONNECTICUT SUMATRA TOBACCO SHOWING VARIABILITY IN TYPE. ROW ON RIGHT, BELGIAN TYPE; ROW ON LEFT, CRUMPLE TYPE.

FIG. 1.—TWO ROWS OF TOBACCO PLANTS SHOWING THE RESULTS OF THE USE OF HEAVY AND LIGHT TOBACCO SEED. ROW ON LEFT, RAISED FROM HEAVY SEED; ROW ON RIGHT, FROM LIGHT SEED.

FIG. 2.—A ROW OF CONNECTICUT SUMATRA PLANTS AFFECTED WITH WILT IN COMPARISON WITH A ROW OF PLANTS OF THE SAME VARIETY GROWN FROM RESISTANT SEED.

TWO ROWS OF COOLEY HYBRID TOBACCO GROWN UNDER SHADE.