IMPROVEMENT OF COTTON BY SEED SELECTION.

By HERBERT J. WEBBER,
Physiologist in Charge of Plant-Breeding Laboratory.

INTRODUCTION.

In 1902 there were grown in the United States, on 27,114,103 acres of land, 10,417,000 bales of cotton,\(^a\) worth $421,000,000. Cotton is the most extensive export crop grown in the United States at the present time, and the value of the total annual production is exceeded by corn alone. It is the principal crop of ten States, and in large areas of these it is almost the only product grown.

The average yield of cotton in the United States is only about 190 pounds of lint per acre, while on many large tracts carefully cultivated a yield of 500 to 800 pounds per acre is frequently obtained. The market for cotton fabrics is gradually increasing with the increase in population and with the growing demand for such goods in both old and new markets. There would thus seem to be no immediate fear of overproduction of this staple. The United States produces five-sixths of the world’s cotton crop at present, and there is within this domain but little opportunity for extending the industry into new regions, although a much larger acreage of cotton could be grown in the old cotton-producing States if necessity demanded it. The tendency, however, seems to be toward diversified farming, rather than further specialization in cotton production. The most important problem now before cotton growers seems to be that of increasing the production on the same acreage rather than extending the acreage itself. Cotton growing in other countries is capable of being considerably extended, but under the present conditions such extension will doubtless be slow and will only slightly affect the industry in this country. The American planter should strive by the application of improved methods and machinery and the use of improved varieties of cotton, yielding more and better staple, to keep well in advance of competitors in foreign countries where cheaper labor is available.

The factor which serves most to place the American grower ahead of his competitors in other cotton-growing countries is his readiness to adopt improved scientific methods and machinery and to bring intelligence to bear in every-day practical farming. The war of

---

\(^a\) Estimates of production in this paper are those of the Statistician of the Department of Agriculture (Crop Reporter, Vol. IV, No. 8, December, 1902).
competition, however, is a never-ending one, and only by the study and improvement of methods of culture will this country be able to maintain its supremacy in the cotton markets of the world.

The problem of primary importance in the cotton industry at the present time is to increase the production of cotton per acre; in other words, more cotton should be grown on the same land. In traveling through the cotton belt from the Carolinas to Texas, it is surprising how few good fields of cotton are seen, and the writer has talked with many people who have formed the impression that the cotton plant normally grows only to a height of about a foot or a foot and a half.

FACTORS OF SUCCESS.

While the character of the soil is of the greatest importance, still there is great opportunity of improving the industry on all lands, both good and poor. It is safe to estimate that the cotton crop could be doubled on the same acreage as now grown, by proper attention to the two factors so necessary to success, namely, the universal use of good seed and careful methods of tillage and fertilization. It is with the former of these, the production of good seed, that the present article will deal.

The writer has frequently been asked which of these two factors he considers of the greatest importance. It may be stated that both are of primary importance, and that no careful planter can afford to neglect either. The importance of good seed is probably more commonly overlooked than the matter of cultivation. It is too frequently a practice for planters to take any seed they can secure, regardless of whether it is adapted to their soil or climatic conditions, or whether it has been bred up to a high standard of productiveness. From observations in many parts of the cotton belt, the writer believes that fully half the cotton planters use seed taken at random from public gins, about which they know nothing other than that it was produced somewhere in the same vicinity. No planter can afford to be so negligent about any matter so essential to his success. As well might the breeder of fast-trotting horses introduce dray animals into his stables, or the breeder of intelligent hunting dogs introduce ordinary mongrel curs into his kennel. The use of good seed and its production by a regular system of selection is just as important a factor in the production of the crop as that of cultivation. No intelligent method of farm management disregards the production and use of good seed. The day when growers can afford to plant any sort of cotton seed is past. Only seed of a known variety, selected because of its desirable qualities and adaptability to local conditions, should be planted.

One reason why systematic seed selection is not more commonly practiced is that the impression prevails that the methods are costly and difficult of application. Planters connect the simple methods of
selection with the abstruse ideas of hybridization and cross breeding, and think that this work is something apart from ordinary methods of crop production, something for the scientific men only. The fact is, that the methods of selection are easy to understand, simple in application, and inexpensive. Every farmer has a method of cultivation which he pursues with little variation each year. In the same way, every farmer should use a definite method of seed selection and carefully follow it each year. If the object is to breed new and distinct varieties, the work is more difficult, and greater care must be given to all of the details, but even in this case the methods are comparatively simple.

It is the writer's object in this paper to discuss the salient principles on which the production of improved seed rests, and to describe both simple and complex methods of selection. By a careful study of these principles any grower should be able to formulate a method of seed selection with definite objects in view, and growers can not be too strongly urged to adopt some such method and rigidly adhere to its use every year. For many years the general belief has prevailed, though apparently in a large measure traditional, that an occasional change of seed is necessary if good crops are to be regularly secured. Advancing knowledge of the results of breeding are leading now to the opposite belief—that plants must be bred and adapted to soil and climatic conditions. Evidence is accumulating which shows that cotton and corn growers, if they are to obtain the best results, must select their seed in the locality where it is to be regularly grown. This has been forcibly brought out recently in the case of Professor Hays's highly selected wheats. After several years of careful selection at the Minnesota Agricultural Experiment Station a strain of Blue Stem was produced by Professor Hays which yielded from 4 to 5 bushels per acre more than any other of the many varieties tested. Nevertheless, when this wheat was tested at the Iowa and South Dakota experiment stations in comparison with certain standard varieties, its superiority was not so marked. This and many other illustrations emphasize the great advantages to be derived from selecting seed in the locality in which it is to be grown in order to adapt it to the particular soil and climatic conditions.

THE PRIMARY PRINCIPLES OF SELECTION.

THE INDIVIDUAL THE UNIT FOR SELECTION.

In general, plants reproduce their main characters unchanged, and the stability of cultivated plants and natural species depends upon this law of heredity. Plants, however, are not absolutely fixed and stable, but are very unstable and highly variable in minor characters. A careful examination of a field of cotton of any standard variety will show that the plants all differ from each other. Each plant in the field may look in the main like all the other plants, yet each has an
individuality, a facial expression, as it were, which distinguishes it from any other plant. Some plants branch low and some high, some have large bolls and others small bolls, some have long lint and others short lint, etc. It is these variations that furnish the means for improvement by selection. By selecting seed from those plants only which possess the desired feature in the greatest degree or to the greatest extent, that feature may be increased. Experience teaches that seed selected from the most prolific individual will in almost every case give a progeny having a tendency to produce more heavily; if a long staple is desired, as many plants as possible should be examined, and by taking seed from a very few which produce the longest lint the length of lint can be increased. (Pl. XLIII and Pl. XLIV, fig. 1.)

The principle here involved is well and widely known. If the largest individuals of a race are mated together the tendency will be to produce a progeny possibly below the parents in size, but above the mean average size of the race. The improvement of cotton by the continual selection of seed from those individual plants yielding the best or having the longest lint is in accordance with this well-recognized principle.

Aside from these ordinary slight individual variations which are within the limits of the race or species, there occasionally occur large and striking variations which are now known scientifically as "mutations," and which gardeners call "sports." If the selection is made with the view of creating new varieties or races, search should be made for these marked variations. If, however, the aim is simply to secure an improved strain with the same general characters, this can be accomplished by the selection of the slight variations that normally occur. The practical grower will hardly be able ordinarily to distinguish between these two kinds of variation, and the scientific breeder will have to admit that he can not tell where to draw the line between them. Fortunately, in practice it is not necessary to distinguish between these kinds of variation. The two main problems with which the cotton grower is concerned are the production of larger yields and better staple, and in his operations it is safe to select for seed the plants which produce the heaviest and give the best lint, these two ends being kept in view separately or in conjunction in the selection, as seems desirable.

SELECTING FOR ONE PRIMARY FEATURE AT A TIME.

While one can select to improve two features at once, as indicated above, this complicates the process of selection, and it is usually found desirable to select mainly for one object at a time. If attempting to increase the length of lint, it will probably be found that the plants with the longest and finest lint are lacking in productiveness, and that the most productive plants have short lint. Therefore, in selecting primarily to increase the yield, it is best to give attention
mainly to this feature, and simply give sufficient attention to the quality of the lint to see that it is up to the standard of the variety in length, abundance; strength, etc. In selecting to increase the length of lint, this should receive the main attention, care being taken simply to see that the selections do not deteriorate in production to such an extent as to render them unprofitable for culture. If very careful selections are to be carried out, it is necessary to judge each plant by a score card similar to those used in judging stock, each feature considered of importance being assigned a number of points in the score based on its relative importance.

TRANSMITTING POWER OF THE INDIVIDUAL.

What may be termed the transmitting power of the individual is a factor of prime importance in the improvement of any plant by selection. It is not enough to know that individuals have been selected that possess in the highest degree the desired qualities of yield or length of lint. To reap the full benefit of the selection it is necessary to determine whether the plant also possesses the faculty of transmitting this quality to its progeny. The plant's "projected efficiency," as Professor Hays expresses it, must be determined. Some individuals are very prepotent and have the power of transmitting their qualities to all or almost all of their progeny, while other plants lack in prepotency, and the progeny in a large measure fail to show in any marked degree the character for which the parent plant was selected. It is very important, if the greatest possible benefit is to be derived from the selection, that the seed from each individual be preserved separately and planted under the same label, so that all of the progeny from a selected individual may be examined to determine its transmitting power. If the transmitting power is weak and but few plants exhibit the improved character which distinguished the selected mother plant, all of the progeny should be discarded and no further selections made from among them. Further selections, the second year, should be made only from among the progeny of those plants which have the largest number of offspring showing in a high degree the quality for which the mother plant was selected. The variation of different individuals in the strength of their transmitting power renders it necessary to make a number of selections of superior plants in order to insure securing some having strong transmitting power, from which further selections and propagation may be made. It is absolutely necessary that a selected plant should have a high transmitting power, and if it has not it is valueless.

ISOLATION OF SELECT PLANTS AND THEIR PROGENY.

Many plants are normally cross-fertilized, and it is frequently necessary to pay strict attention to this matter at all stages of the work. All varieties and races of corn cross readily, and with this plant the
greatest care is therefore necessary to prevent selections from being pollinated with pollen from inferior individuals or individuals of a different type.

The cotton flower is large and attractive and is much visited by bees and other insects, so that the pollen is carried from one flower to another in considerable abundance; hence in the beginning of the Department's experiments on cotton breeding it was supposed that the danger of cross-fertilization would have to be carefully avoided. However, the flowers are abundantly self-fertile, setting seed normally when covered by paper bags that exclude all insects, and experience has shown that while there is some crossing the large majority of seeds that set are self-fertilized. In several instances varieties have been grown in single rows with other varieties all around them of such a kind that crossing, where it occurred, could be easily detected in the progeny. Plants grown from seed matured under such circumstances show but few crosses, indicating that the majority must have been self-fertilized. Judging from the observations thus far made, it would seem that ordinarily only from 5 to 10 per cent of the seeds are normally cross-fecundated. With cotton, therefore, it is not so important to grow the plants in an isolated location as in the case of corn. Nevertheless, practical experience has shown that when growers procure a small quantity of seed of an improved variety and grow this with other varieties to increase their stock of seed, usually the variety gradually deteriorates. This is probably due in considerable measure to cross-pollination with the ordinary cotton, though also doubtless in part to the fact that the seed received was probably highly selected, and deteriorated when selection was discontinued. While the effect of cross-fertilization is, therefore, not so great as in some plants, it is nevertheless of sufficient importance to justify certain precautions being taken.

After the selections have been made, it is desirable that they be grown together in a patch as far removed from all other cotton as possible, the seed from each select individual being kept together and plainly marked. The pollen of cotton is carried by bees mainly, and therefore it is practically impossible to secure absolute isolation in any cotton country, as this would require a distance of 5 to 10 miles from any other cotton. Practical isolation, however, may be secured by planting the special patch at a distance of a quarter or a half mile from any other cotton, particularly if the patch can be placed so that it is surrounded by woods. Planting in this way will insure that all of the seed produced in the selection patch will be fertilized by pollen from individuals having good mothers as all of the plants in the patch were grown from seed of carefully selected mother plants of the preceding year. In practical seed selection this precaution is all that it is desirable to attempt. If very careful scientific selection experiments are being conducted, it may be found desirable in some cases to be more particular and "rogue" out the patch as rapidly as the plants mature.
Stamm Egyptian Cotton, showing improvement produced in length and quantity of fiber by two generations of selection. (Natural size.)
FIG. 1.—ASHMOUNI EGYPTIAN COTTON, SHOWING IMPROVEMENT PRODUCED IN LENGTH AND QUANTITY OF FIBER BY THREE YEARS OF SELECTION.

[Natural size.]

FIG. 2.—FIELD OF HYBRID COTTON AT COLUMBIA, S. C., SHOWING MEN REMOVING ALL BUT THE BEST PLANTS.
Fig. 1.—Field of Hybrid Cotton at Columbia, S. C. (Same field shown in Pl. XLIV, Fig. 2), after first selection or roguing.

Fig. 2.—The same field shown in Fig. 1, after second and more careful selection or roguing, only the best plants remaining.
sufficiently to exhibit their characters. This is particularly true in selecting unstable hybrids to secure fixed types. In the experiments of the Department of Agriculture, where it is desired to take the greatest precaution against the crossing of the best plants with inferior ones, the field from which selections are to be made is carefully examined as soon as the lowest bolls open, and all plants are pulled up which do not show the desired qualities. (Pl. XLIV, fig. 2, and Pl. XLV, fig. 1.) The same field is carefully gone over again in a short time, each plant being examined, and those removed which on second examination do not hold up to the high ideal. (Pl. XLV, fig. 2.) All fields which are being selected to fix a variable hybrid are examined at least four times in this way and weeded out until only a few of the very best individuals remain. This careful process of "roguing" insures that the bolls set in the latter part of the season will be pollinated with pollen from excellent plants of the same type. This process of selection by the roguing out of inferior plants is too tedious and complex to be used except in the case of carefully conducted breeding experiments.

In the selection of seed of Sea Island cotton, which is practiced by all careful growers of this cotton, the seed from the select plants is ordinarily planted in a patch at some distance from, or on one side of, the general field. Even in planting under the latter condition the results obtained have proved very satisfactory, as will be explained later.

CARE OF THE SELECTION FIELD.

All evidence indicates that the seed produced by plants grown on good soil under the best conditions produces in its turn the best and most vigorous seed. It is thus desirable to plant the selection field on good rich soil of the same kind on which the crop is to be generally cultivated. If the general crop is to be grown on a light, sandy soil, it would of course be wrong policy to place the selection field on a rich, heavy loam. The soil should be of the kind used for the general fields, but unexhausted by previous cultivation. It is also desirable that the selection field should be well fertilized and cultivated, as every means should be used to develop the best plants and the best seed.

METHODS OF SELECTION.

A PRACTICAL METHOD OF SEED SELECTION FOR GROWERS.

OBJECTS OF THE SELECTION.—In general practice, as indicated above, the primary object is to secure increased yield, although it is also important in some cases to increase the earliness of ripening, the length of lint, or the size of the boll. Productiveness is the factor of importance in ordinary seed selection where the grower is not concerned with the production of new varieties, and it is to this that attention should be directed, giving in general only sufficient attention to other factors to keep them up to standard. If, however,
it is desired at the same time to secure improvement in any other
direction, the selection should be made with this object in view.

**First Year's Selection.**—The first selections should be made in
a large field of the variety which it is desired to improve. The field
from which the selections are made should have good soil and should
be thoroughly cultivated in order to insure a good development of
the plants and satisfactory conditions for making selections. Just
before the first picking, when some of the lower bolls are well open on
all of the plants, the field should be gone over and every plant
examined with reference to the productiveness, number and size of
bolls, vigor and shape of plant, earliness, etc.

It is desirable to mark more plants than are expected to be used,
because in going over and comparing the plants the first time it is
ordinarily found difficult to carry the characters desired in mind with
sufficient accuracy to enable a careful judgment to be made. There-
fore some fifty of the plants should be first marked and numbered,
so that these can be more carefully examined a second time and the
number reduced possibly one-half or more. The permanent numbers
should be placed only on the plants which are finally selected. Before
each picking a careful man should go over the field and pick the cot-
ton from each plant in sacks numbered to correspond with the num-
bers on the plants, in order that the different pickings from the same
plant may be kept together.

In the fall, after the close of the picking season, the seed cotton
from each individual plant can be more carefully compared and
weighed, and any of the plants which are found to have fallen below
the standard in production or in any other important feature should be
rejected. The remainder should be ginned, care being taken to have
the gin thoroughly cleaned out before beginning the process, so that
the seed from the selections will not become mixed with ordinary
seed. After ginning each individual plant, the seed should be care-
fully picked up and replaced in the numbered sack, so that all of the
seed from the same select individual will be retained by itself.

In describing the method of procedure, it is much clearer to base the
explanation on the selection of one superior plant each year, as the
process with one plant illustrates clearly what should be done with each
of the twenty-five or more which are selected in practice. (See fig. 38.)

**Second Year's Selection.**—The seed of the individual plant
selected the first year is planted in the spring of the second year and
plainly marked, in order to distinguish it from the seed of any other
plant selected. Each cotton plant yields from 500 to 2,000 seeds, and
therefore 500 or more seedlings will probably be produced. When
these plants reach the proper stage of maturity, the entire progeny
should be examined to see whether the plant selected the first year
has shown strong transmitting power. If a large percentage of the
progeny possess the desired qualities in a marked degree, showing
that the transmitting power is fairly strong, several selections of the best plants should be made from among them. If, on the other hand, the transmitting power has been weak, the qualities for which the plant was selected not having been transmitted, the entire progeny should be discarded.

The possibility of having to discard the entire offspring of a select individual is the principal reason for urging that a number of selections be made, instead of only one or two. The specially selected plants of this second generation should be carefully examined with reference to the particular qualities desired, and a single plant finally selected which is superior to all of the others. The seed of this individual should be preserved separately and handled exactly in the same way as the selection made the first year. The seed from the remaining plants produced by the single individual selected the first year should be ginned separately in order to avoid mixing, and retained to plant a seed patch of about 5 acres the third year, in order to obtain sufficient seed of a select strain to plant a general crop the fourth year.

**THIRD YEAR’S SELECTION.**—The seed from the plant selected the second year is planted by itself in the spring of the third year, care being taken again to mark the progeny of this plant so that it may be distinguished from the progeny of any other plants that may have been selected at the same time. Just before the first picking, all of the progeny should be examined, as in the second generation, to determine the strength of the transmitting power. If the progeny as a whole are found to have inherited the characters of the plant selected the second year, a few of the very best plants should again be selected and marked as previously. These should be more carefully examined, as in the above instances, and a single superior plant finally selected. The seed of the remaining individuals from the same number as the one selected, which will be about 500 in number, should be retained to plant a seed patch the fourth year, to give sufficient seed to plant a general crop the fifth year. The seed obtained in the third year from the seed patch of 5 acres planted from the progeny of the selection of the first year will this year furnish sufficient seed for the general crop the fourth year.

**FOURTH YEAR’S SELECTION.**—The seed from the specially selected plant of the third year is planted by itself and marked plainly to distinguish it from other selections, as in the previous year. From the 500 or more seedlings resulting, a particularly fine individual is again selected for further breeding, as in the preceding years, the same care being taken to determine the transmitting power to see that this is up to the standard. The other plants grown from the individual specially selected the third year will this year give sufficient seed to plant a 5-acre seed patch the fifth year. The seed used to plant the general crop of the fourth year is that from the seed patch of the
third year, grown from the unselected plants of the second year, and thus the general crop the fourth year is derived directly from the plant selected the first year, and so on through succeeding generations. The diagram (fig. 38) illustrates the above method of selection.

**Necessity of Selecting More Than One Plant.**—It is highly important in practice to select more than one excellent plant, as it not infrequently happens that a very fine plant is found having poor transmitting power, so that the progeny will be even below the general crop of the year preceding. It is impossible in a short article to lay out a general plan which will fit all cases. If the plantation is of moderate size, a sufficient number of individual plants could be selected each year, so that instead of the 5-acre seed patch represented in the diagram the entire plantation could be planted. According to this scheme, five plants selected the first year would in the third year plant 25 acres, and if 20 plants were selected the first year the seed patch of the third year, according to the diagram, would plant 100 acres. It is thus within possibility, on a moderate sized plantation, to select enough plants each year to plant the general crop from select seed the third year. The diagram (fig. 38) illustrates the method of selection pursued by planters of Sea Island cotton on James and Edisto islands.

**Methods Used in Selecting Sea Island Cotton.**

The methods of selection used regularly every year by certain growers of Sea Island cotton are almost exactly the same as those described above, with the exception that more careful attention is given to the quality of the lint, which is of great importance.\(^a\) The

\(^a\)For a careful description of the methods of selection employed by Sea Island cotton planters, see article on the "Improvement of plants by selection," by the writer of this paper, in the Yearbook for 1898, pp. 355-376.
methods used by these planters of Sea Island cotton on the islands off the coast of South Carolina are the most careful and painstaking known to the writer, and under their rigorous selection the fiber has gradually improved in length, fineness, and silkiness, until now it is the best produced anywhere in the world, and is sold at a special price much above that paid for ordinary Sea Island cotton. When Sea Island cotton was first introduced into this country from the West Indies it was a perennial plant, unsuited to the duration of the seasons of the latitude of the sea islands of South Carolina; but through the selection of seed from early maturing individual plants the cotton has been rendered much earlier, until now it is thoroughly adapted to the existing conditions. The fiber has increased in length from about 1½ inches to 2½ inches, and the plants have at the same time been increased in productiveness. The custom of carefully selecting the seed has grown with the industry and may be said to be inseparable from it. It is only by such careful and continuous selection that the staple of these high-bred strains can be kept up to its present superiority, and if for any reason the selection is interrupted, there is a general and rapid decline in quality.

A SHORT METHOD OF SEED SELECTION.

While the method of selection described above is recommended as the best for general purposes, there are some extensive planters who spend but little time on their plantations, and who may not be able to systematically carry out such a plan. For the use of such planters the following short method of selection is suggested: Select careful pickers that remain on the plantation continuously from year to year and train them to recognize the best plants, that is, those most productive, earliest in ripening, and having the largest, best-formed, and most numerous bolls. Each year before the second picking have these select pickers go over the field and pick the cotton from the best plants only. These pickers should be paid by the day and not for the amount picked. Preserve such seed cotton separately, gin it separately on a carefully cleaned gin to avoid mixing, and use the seed to plant the general crop the next year. If sufficient seed is not secured at the second picking, the same pickers can be sent over the field again before the next picking. In general, it is desirable not to use the seed of the first or last picking. It is generally recognized by growers that the seed of the middle pickings give the best results, although in some instances the difference is not very great. This method does not take into consideration the transmitting power of the individual; still, if carried out carefully and intelligent pickers are selected the yield can doubtless be greatly increased. The writer has talked with several growers who have used this method and recommend it as very satisfactory. It is applicable to any variety of cotton and to any locality.
SCIENTIFIC METHODS OF SELECTION USED IN THE ORIGINATION OF NEW RACES AND STRAINS.

The method of selection used by careful breeders in the production of new races and strains does not differ materially from the careful method of practical seed selection described above. The principal difference lies in the greater care which must be used at every stage in the process both in judging the individuals and in keeping careful records in order to determine accurately what advance is being made.

In careful breeding experiments the use of score cards similar to those used by breeders and judges of stock is of the greatest importance. The score card, however, must be a variable one, designed to serve the purpose of the breeder. In experiments in breeding cotton the score card has been found to be indispensable, but it has also been found necessary to use a different form of card for almost every experiment where the object of the breeding is to accomplish a different end. If the object is to secure a black-seeded, long-staple Upland cotton, the greatest importance attaches to the size of boll, yield, length of staple, and percentage of lint, and these characters should be assigned a higher value than other points which are of less importance. If an early, big-bolled, short-staple sort is desired, the qualities of earliness, size of boll, and yield should be especially considered, and should be given the highest number of points in the score.

The following is a score of points used in judging hybrids of Sea Island and Upland cotton, which illustrates the plan followed by the writer, the estimate being made on a basis of 100 points as perfect:

<table>
<thead>
<tr>
<th>Score of points used in judging Sea Island and Upland cotton.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size of bolls, 15 points</strong></td>
</tr>
<tr>
<td>Very large, 15 points</td>
</tr>
<tr>
<td>Large, 14 points</td>
</tr>
<tr>
<td>Medium, 12 points</td>
</tr>
<tr>
<td>Small, 8 points</td>
</tr>
<tr>
<td>Very small, 3 points</td>
</tr>
<tr>
<td>2 inches, 20 points</td>
</tr>
<tr>
<td>1 1/2 inches, 19 points</td>
</tr>
<tr>
<td>1 3/4 inches, 18 points</td>
</tr>
<tr>
<td>2 inches, 17 points</td>
</tr>
<tr>
<td>1 1/2 inches, 15 points</td>
</tr>
<tr>
<td>1 3/4 inches, 10 points</td>
</tr>
<tr>
<td>1 1/2 inches, 5 points</td>
</tr>
</tbody>
</table>

| **Length of lint, 20 points**                                 |
| Very fine, 10 points                                          |
| Fine, 8 points                                                |
| Medium, 6 points                                              |
| Coarse, 3 points                                              |
| Excellent, 20 points                                          |
| Good, 18 points                                               |
| Medium, 15 points                                             |
| Light medium, 10 points                                       |
| Light, 5 points                                               |

| **Uniformity in length of lint, 7 points**                    |
| Excellent, 7 points                                          |
| Good, 6 points                                               |
| Fair, 4 points                                               |
| Poor, 2 points                                               |

| **Strength of lint, 10 points**                              |
| Very strong, 10 points                                       |
| Strong, 8 points                                             |
| Medium, 6 points                                             |
| Weak, 3 points                                               |

| **Percent of lint, 18 points**                               |
| 33± per cent, 18 points                                      |
| 31–32 per cent, 17 points                                   |
| 29–30 per cent, 16 points                                   |
| 27–28 per cent, 15 points                                   |
| 25–26 per cent, 10 points                                   |
| 23–24 per cent, 5 points                                    |
The purpose of the experiment for which this score is used is to secure a variety of cotton for cultivation in upland regions which will have long staple, big bolls, opening well and easy to pick, and black seed. In this series of experiments, however, all plants not having black seed are rejected, so that no provision is made for judging on this point.

On the individual blank record sheets used for notes on the hybrid or selection, below each heading of the blank, two vacant spaces are left. The general notes are written in the upper space and the score record entered in the lower space. The following is a specimen record of this kind:

*Specimen individual record sheet.*

|---------------|---------------------|--------|---------------------|------------------|--------|----------|-------|----------|

|----------------|-------|----------------------|-----------------|-------------|

In what may be termed a scientific method of selecting cotton, the plants, which have been carefully compared and marked in the field, should be picked in separate marked bags; the seed cotton should then be taken to a convenient room, very carefully compared with reference to all important points, and accurately graded, the values being entered on a record blank. After the total score of each plant is computed a comparison is readily made. The one having the highest score should, of course, be the best plant, if the judgment in each case has been carefully made, and this plant should be selected and planted the next year, as should also several other of the plants having the next highest scores. The score card allows judgment to be made on a single point at a time, and avoids the confusion which would result from charging the mind with a mass of comparative data which it would otherwise have to retain and weigh. In careful breeding by either selection or hybridization the writer would urge the adoption as early as possible of a score card which will enable comparative judgment to be passed upon one character at a time.

Great care should be used to insure that the selection patch contains
only good plants, true to the ideal type which it is desired to establish. For this reason it is desirable to go over the field when the first blossoms begin to open and weed out such of the plants as are observed to possess undesirable characters of lateness, sterility, or habit of branching. When the first bolls begin to open, the plants should all be carefully examined again, and those showing unfavorable boll, lint, or seed characters pulled up (Pl. XLIV, fig. 2). If the selection patch is in an isolated situation, as it should be, this will insure that all seed that set after the inferior plants are pulled out will have been fertilized with pollen from at least a fairly good plant of the same general type. Thus the eradication of poor plants as rapidly as they can be discovered is of the highest importance where careful breeding experiments are being conducted. In the cotton-breeding experiments that are being conducted by the writer the selection fields are examined from two to four times and the unsatisfactory plants eliminated (Pl. XLV, figs. 1 and 2).

It may be urged by some investigators that in careful experiments, such as are now being considered, the blossoms desired for seed on each good plant should be hand pollinated with pollen from an equally good plant. This was the policy first adopted by the writer; but it requires a great expenditure of time, as many blossoms pollinated will not set bolls. It is believed that results can be obtained in a shorter time by doing the work on a more extensive scale and using the time that would otherwise be spent in hand pollinations in selecting from among larger numbers. As stated above, only a small percentage of the seeds are cross-fertilized, and if the plants developed from such cross-fertilized seeds are widely different from the desired type, they should be discovered and weeded out in the early stages of the selection, before they have had opportunity to influence the other plants to any very great extent.

In careful breeding, notes should be retained of each plant selected each year and a full record made of its transmitting power, as shown by a careful examination of its progeny the following season. This performance record, as it is sometimes called, of a select mother plant is of the highest importance. The select mother plant which has had a strong transmitting power in selections carried on through a series of years is pretty certain to be the progenitor of a valuable race. On the next page is a sample blank such as is used in the writer's experiments in keeping the notes on the progeny of select individuals:
IMPROVEMENT OF COTTON BY SEED SELECTION.

Progeny notes.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Columbia, S. C.</td>
<td>4/16</td>
<td>1,205</td>
<td>41</td>
<td>Early</td>
<td>5 feet</td>
<td></td>
<td>Good</td>
<td>Large</td>
<td>Good</td>
<td>14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium.</td>
<td>15</td>
<td>85</td>
<td>1½</td>
<td>White.</td>
<td>Fine.</td>
<td>Fair.</td>
<td>Good.</td>
<td>Good.</td>
<td>18</td>
<td>17</td>
<td>79</td>
</tr>
</tbody>
</table>

While in practical seed-selection experiments, where the object is simply to obtain good and highly productive seed for planting, it is not absolutely necessary to isolate the seed patch, yet in experiments to obtain improved races the select plants of a particular kind should always be grown by themselves in an isolated situation, where they will not be influenced in any way by crossing with other cotton.

SOME IMPROVEMENTS TO BE SOUGHT IN COTTON.

INCREASED YIELD OF FIBER AND SEED.

The possibility of increasing the yield of fiber and seed has been the main feature discussed heretofore in this paper, and need not be referred to here further than to state that numerous instances and experiments show that very marked improvement can be obtained by a few years of selection from the best-yielding plants. The result obtained by the writer in the selection of Egyptian cotton, to be described below, forms a good illustration of increase in yield produced by only three generations of selection. The gradual increase in the yield of Sea Island cotton since its introduction is also in part to be attributed to the careful selection to which it has been subjected, although improved methods of culture have contributed to the same result. In wheat, corn, and many other agricultural crops remarkably increased yields have frequently been secured by careful selection experiments, the exact results of which are in many places on record and can be examined by the student.

INCREASED LENGTH OF STAPLE.

In all varieties of cotton there is considerable variation in the length of the staple produced by different plants, and by the selection of seed from those plants having the longest staple, following the methods described above, the average length can be greatly increased.
Very remarkable results in increased length of staple of Sea Island cotton have been produced by the careful selection to which it has been subjected, as described by the writer in the Yearbook of the Department of Agriculture for 1898.

One of the most striking instances of improvement in both length and abundance of fiber that has come under the writer's observation is a selection of Stamm Egyptian cotton at Columbia, S. C. The few seed of this variety imported had the lint attached as when taken from the boll, and the average length was only about $1\frac{1}{4}$ inches. (Compare original imported seed, Pl. XLIII). The plants of the first generation in this country were very tall, some of them reaching a height of 8 feet, and very unproductive. Seed from several of the best plants, which were nevertheless inferior, were selected and preserved for planting the second season. The second season the lint from some of the plants was much longer, more abundant, and of better quality than that from plants grown from imported seed. (See Pl. XLIII, seeds marked first generation selection.) The progeny in the second year, grown from the first-year selection, were uniformly earlier, much more productive, and had longer and better lint. The lint on some plants was remarkably abundant and uniform, and in a number of instances reached the length of $1\frac{3}{4}$ inches. As a result of two years of careful selection in this country the character of the staple had thus been entirely changed and improved.

**Uniformity in Length of Fiber.**

Uniformity in length of fiber is a feature of primary importance, and long-staple cottons especially are capable of much improvement in this regard. This is one of the qualities regularly considered by the Sea Island planters in making their selections. Griffin, one of the best long-staple Upland cottons now grown, is lacking in uniformity, and should be carefully selected to improve this character. While the majority of the fibers range in length between $1\frac{1}{2}$ and $1\frac{3}{4}$ inches, the fibers near the point of the seed are frequently much shorter than those on the base and middle; and, again, some of the middle fibers are usually very long, frequently reaching a length of from 3 to $3\frac{1}{2}$ inches. This lack of uniformity in length could probably be corrected by a few years of careful selection. In selecting to secure uniformity it is not enough to judge simply by the regularity of all the fibers on the same seed. Seed from different bolls on different parts of the plant must be examined to see that the fiber on the different seeds is of the same length or nearly so. A general tendency to produce fiber of the same length throughout should be bred in the plant. If long-staple cotton is variable in length of fiber there is considerable waste in the process of manufacture, and the value of the staple is impaired. Careful attention must therefore be given to this point in the selection and improvement of all long-staple varieties.
Another essential consideration which has great weight in determining the value of cotton is the strength of the fiber, in which many varieties are lacking and to which careful attention should be given. The long-staple Upland cottons, especially those which have thus far been introduced, are very inferior in this quality. The majority, if not all, of these varieties were originated by crossing ordinary Upland cotton with Sea Island, and the almost universal tendency of such hybrids is to produce fiber deficient in strength, although it may be long and silky and approach Sea Island in these respects. Housewives in recent years complain of the weakness of thread, and this may be due in part to the lack of strength of long-staple Upland cotton, which is largely used in the manufacture of thread. In the selection of Sea Island cotton great care is given to the character of strength, and the fiber of this cotton when properly grown is probably as strong as that of any other cotton, unless it be properly-grown Egyptian cotton, which is also exceedingly strong. Sea Island cotton, because of its strength, has been selected after careful tests as producing the strongest and most durable duck cloth for United States mail sacks.

SEASON OF MATURING.

In all varieties there is considerable variability in the season of maturing, and this furnishes the means of securing modifications in this respect. If an early strain is desired, much can be accomplished by selecting seed always from the earliest plants, most of our early varieties having been produced in this way. In the case of the big-boll varieties, such as Truitt, Christopher, Russell, Texas Storm-Proof, etc., the season of maturity is so late that they are not profitable to grow in northern cotton sections. It is desirable that early strains of big-boll sorts be produced.

ADAPTATION TO SOIL AND CLIMATIC CONDITIONS.

Varieties which have been highly selected have by this selection been adapted to the soil and climatic conditions existing where the selection was carried out. If such plants are grown under different conditions they may fail to give equally good results and may require to be bred and reselected in order to adapt them to the new conditions. A pertinent illustration of this principle is furnished by the results that have been obtained in the introduction and breeding of Egyptian cottons in this country. Egyptian cotton is similar in most respects to Sea Island, being distinguished mainly by the character of the fiber, which is much coarser than Sea Island, very crinkly and woolly, and ordinarily of a light-brownish color. The yield in Egypt, as reported by Messrs. Kearney and Means, who have recently visited that country in connection with these experiments, is frequently from 600 to
800 pounds of lint per acre, being much more than is ordinarily secured from our best Upland cottons. When the best imported seeds of Egyptian varieties are planted in this country they almost invariably produce the first year very tall, spindling plants, which set very few bolls. The writer has had this experience with seed of Ashmouni, Abbasi, Mit Afﬁ, Gordon Pasha, Jannovitch, and Stamm, grown in South Carolina, Georgia, and Florida. The many attempts at growing Egyptian cotton in various parts of the cotton region of the United States have met with such poor success that planters have given it up as impracticable, and the impression prevails generally that the cultivation of Egyptian cotton in this country is a failure.

In 1899 the writer grew a few plants of Ashmouni Egyptian cotton at Columbia, S. C. They were, as above stated, very spreading and open, and set but few bolls the first year. The ﬁber also showed a tendency to lose its curliness and become whiter than the imported article. The most prolific and earliest plants showing the characteristic Ashmouni lint were selected. Seed of these were planted again in 1900 and selections of the best again made as in 1899. The same process of selection was repeated a third time in 1901. In 1902 the selections were transferred to Hartsville, S. C., where they were planted on similar soil. This season, the fourth in the United States and the third generation of the selection, they gave very promising results. A number of plants not true to type were pulled up and the total production was thereby reduced, yet a yield of 1,303 pounds of seed cotton per acre was obtained which gave 479 pounds of lint per acre. The ﬁber produced was typical Ashmouni in every respect observable, and proved on comparison to be slightly longer than the best samples of this variety obtained by Mr. T. H. Kearney in Egypt. It is markedly superior to the strain of Ashmouni used in starting the selection, both in quantity of lint on a seed and its length and uniformity (Pl. XLIV, ﬁg. 1). A field of Mit Afﬁ Egyptian cotton was grown on the same soil about a quarter of a mile distant, planted with seed directly imported. In Egypt this variety ordinarily gives a larger yield than Ashmouni, but at Hartsville, under the same conditions of soil and fertilization, it gave a yield of only 960 pounds of seed cotton and 346 pounds of lint per acre.

By selection in the same way Stamm Egyptian cotton has been very markedly improved in length and quantity of ﬁber, as described above (Pl. XLIII).

RESISTANCE TO DISEASE.

The apparent possibilities in the development of disease-resistant strains offer a promising ﬁeld for systematic breeding and selection. It has long been known that in various plants some varieties will resist certain diseases to which other varieties are susceptible. As an illustration, the sour orange is resistant to foot-rot, or mal di gomma, which is caused by a parasitic fungus, and the disease is
universally controlled by budding or grafting the susceptible sweet orange on the resistant sour-orange stock. A similar case of resistance among oranges to a disease caused by a surface-feeding mite has also been discovered by the writer. The Drake Star orange, a late variety of good quality but a light bearer, was found to be almost wholly resistant to attacks of the orange rust-mite, trees of this variety in the center of badly diseased sweet seedling groves producing fancy bright oranges, showing almost no effect of injury.

Experiments recently made by Mr. E. L. Rivers, of James Island, S. C., and Mr. W. A. Orton, of this Department, have shown conclusively that strains of both Sea Island and Upland cottons can be produced by selection which are resistant to the attacks of "wilt" or "black root," a serious disease of cotton which is causing great damage to the industry in South Carolina, Georgia, and Alabama. The method of breeding such immune strains is very simple, and it is easily possible for every planter having the disease on his plantation to breed a resistant strain. In fields of Sea Island or Upland cotton planted on soils badly infected with the wilt fungus almost every plant is killed by the disease before producing any cotton. Usually, however, a plant here and there will be observed which remains unaffected and produces a fair crop. By selecting seed from such immune plants and planting it again on badly infected soil, it has been found that the quality of immunity is usually transmitted to the progeny in a wonderful degree, and by carrying out such selections and planting each year on badly infected fields, Mr. Orton has been able to produce strains of both Upland and Sea Island cotton which are immune to the disease. Several varieties of Egyptian cotton tested in fields infected with the wilt fungus were found by Mr. Orton to possess a high degree of resistance. Jackson Limbless, one of the standard Upland varieties, was also found to be much more resistant to the disease naturally than any other of the ordinary Uplands, but was not so resistant as the Egyptian sorts.a

The Iron cowpea was found by Mr. Orton to be resistant to the cowpea wilt, a parasitic fungous disease, and by the writer, in conjunction with Mr. Orton, it was found also to be almost absolutely immune to attacks of the root-knot nematode (Heterodera radicicola). Sugar beets resistant to the sugar-beet nematode are also being bred by Wilforth, who has met with considerable success.

In the control of cotton diseases the breeding of immune strains bids fair to be of the greatest importance, as the evidence at hand indicates a considerable difference in the resistance of various individual plants in the case of several maladies, though in no case with

---


cotton other than in the cotton wilt has it been shown that this apparent immunity will be transmitted. In the case of the Mexican boll-weevil, which has overrun Texas and threatens to destroy the whole cotton industry if no check to its spread is found, there is some evidence to indicate that strains of cotton resistant to this insect may ultimately be bred. In examining fields of Upland cotton in different parts of Texas occasional individual plants were observed by the writer in badly infected fields which had set and matured almost all of their bolls, while adjoining plants were almost denuded of their bolls, except a few of the earlier maturing ones which had developed before the weevils had become abundant. Whether such plants possess a degree of resistance or not, and whether this possible resistance will be transmitted to the progeny, remain to be determined. It seems probable that some plants may be discovered and propagated which will be distasteful to the weevils.

In the seasons of 1901 and 1902 the writer, in conjunction with Mr. A. W. Edson, of this Department, grew patches of certain varieties of Egyptian cotton in several parts of Texas. As Egyptian cotton is noted for its freedom from diseases, the effect of the boll weevil on the several varieties was watched with considerable care. A patch of 2 acres of Jannovitch Egyptian, grown at Pierce, Tex., in the season of 1901, was very badly injured by the weevil, giving a yield of only 15 pounds of seed cotton on 2 acres. A small field of Ashmouni cotton at one place in 1902 was also badly injured, showing that this variety was probably as susceptible to attack as any other sort. A field of Mit Afifi cotton of 3 acres, grown at San Antonio, Tex., on the irrigated plantation of Mr. F. F. Collins, gave results which may indicate a degree of immunity, though further trials are necessary before the matter can be satisfactorily settled. The 3 acres of Mit Afifi were grown on land where the cotton crop had been destroyed by weevils the previous year. Near the Mit Afifi, about 200 feet distant, was a small patch of Upland cotton of a little over one-fourth of an acre in extent, a small patch of sugar cane intervening. The weevil did not appear on the patch of Mit Afifi until the middle of October, and when the patch was last examined by the writer the latter part of October the weevils had not yet become abundant. The weevil appeared on the patch of Upland cotton early in the season, and the crop was almost entirely destroyed, only a comparatively few of the early bolls maturing. Throughout the season the weevils were abundant on the Upland patch, while at no time did they become so abundant on the Egyptian cotton. The Egyptian variety gave a yield of 3,200 pounds of seed cotton, or about 1,066 pounds per acre, while the Upland variety gave a yield of 58 pounds of seed cotton, or about 200 pounds per acre. It has been found by investigators and planters that in general early varieties are less affected by the boll weevil than late varieties. When the weevils first appear they are
few in number, but gradually increase as the season advances. Very early varieties may set a large share of their bolls before the weevils become so abundant as to destroy all of the forms and young developing bolls. The Upland cotton was much earlier than the Egyptian and would normally be expected to produce a much larger crop in boll-weevil districts owing to this fact. The striking freedom of the Mit Afifi field from injury by the weevil would indicate that the plants may be in some degree distasteful or resistant to weevil attacks, although this can not be definitely determined without further experiments. Among the Egyptian plants a very few volunteer Upland cotton plants developed, and these, as a whole, remained fairly free from injury by the weevil until late in the season and gave a nearly normal yield. The Egyptian plants were about 2 feet taller than the Upland plants and entirely surrounded them. The fact that these few Upland plants in the field of Egyptian cotton produced fairly well led several persons examining the field to conclude that the absence of weevils in the Egyptian field was entirely accidental. While this may be the case, we are equally justified in assuming that the Egyptian variety, if distasteful and resistant, would in some measure protect from attack the few Upland plants which they surrounded and overshadowed.

If the Mit Afifi Egyptian cotton is in any degree resistant to attacks of the boll weevil, as is suggested by the above experiment, it would be of great importance in the investigation of the boll-weevil problem, for if it possesses any degree of immunity this could probably be greatly increased by a few years of careful selection. In view of the knowledge of the resistance of varieties of other plants to various insect and fungous diseases it would not seem at all impossible or improbable that a variety of cotton might be found that would be resistant to the boll weevil. In experiments of this kind, however, it must be remembered that a variety resistant to a disease under certain conditions, if these conditions are changed may become subject to attack.

Anthracnose, or boll rot, another serious disease produced by a parasitic fungus, is much worse on certain varieties than on others, and individual plants have been observed to vary considerably in degree of susceptibility. Here again there is evidence of an opportunity for the plant breeder to secure material for experiments in the breeding of immune varieties.

STORM RESISTANCE.

In many parts of the country where severe wind or rain storms are common, the cotton is torn and beaten out of the bolls, causing considerable damage. The form of the open bolls in certain varieties prevents the cotton from being blown or beaten out so easily, so that...
there are some so-called storm-proof varieties. There is opportunity for considerable improvement in this direction by systematically selecting seed from the plants suffering the least damage from this source.

CONCLUSION.

In this paper the writer has attempted to describe both simple and complex methods of selection, which may be used by cotton planters and breeders, and to point out some of the important improvements and results that can be produced by such means. It is impossible to overestimate the importance of seed selection to the planter. It is one of the fundamental principles of successful cotton growing, and planters are earnestly urged to give the matter careful consideration and adopt a systematic method of seed selection.

The writer has also pointed out a few of the many important improvements which could possibly be obtained by careful breeding, in the hope that some planters may be induced to carry out experiments looking to their accomplishment.