START
COTTON IMPROVEMENT THROUGH TYPE SELECTION, WITH SPECIAL REFERENCE TO THE ACALA VARIETY

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GENERAL PROBLEMS OF SELECTION IN COTTON

NEED FOR CONTINUED SELECTION

The problem of selection, as applied to the breeding and preservation of varieties of cotton, is more complex than current theories have recognized. Selection is the approved means of keeping a variety uniform and of maintaining its productiveness; methods of selection must be employed that will serve the intended purpose. Account must be taken of many more features or forms of diversity than have been considered formerly in order to preserve the essential characters of varieties by continued selection. Theories of selection must be reexamined, as these have been largely responsible for the methods of breeding used in the past. Changes in methods are suggested by facts that have come to light in recent years through the study of the varieties of cotton.

It is plain that the need of selection does not cease with the discovery and separation of a superior type of cotton any more than with a superior breed of animals. If selection is relaxed there is ...
no assurance that varieties will be maintained in a condition to produce cotton of good quality. Essentially the same problems arise in keeping up the plant varieties as with the breeds of animals, but less knowledge has been current regarding plants, and ideas of plant breeding are entertained which plainly would not apply to animals. More theories have been developed in connection with plant breeding, perhaps because the facts are less intimately known. Animals are dealt with as individuals, whereas plants are handled in bulk, as though individual and family characteristics were lacking.

Plant breeders are engaged largely in developing new varieties, whereas animal breeders are chiefly concerned with keeping up old and well-established breeds. New breeds of animals are seldom introduced, and then in most cases are imported from foreign countries where they have existed for long periods. Valuable breeds of animals have seldom been originated by crossing different species or by selecting peculiar individuals having strikingly unusual characteristics, which are the favorite methods among plant breeders for obtaining new kinds, although the "novelties" produced by these methods often are distinctly inferior to varieties already in use.

Stock raisers do not question that the best animals must be used in each generation, to keep up the standards of the good breeds. Cotton growers are led to believe that selection at intervals of several years is sufficient and that a "running out" of varieties after a few generations is natural and inevitable. After a bad season it is customary with many farmers to change the seed. Both of these popular beliefs among cotton growers are found to be erroneous, though widely and confidently accepted. Experience shows that selection must be applied continuously, and that varieties of cotton can thus be maintained for long periods. The notion of frequently changing the seed has been popularized by commercial breeders and seed merchants in advertising high-priced novelties.

In view of the limited quantities of seed that are bought by the farmers at fancy prices, there is little prospect of the cotton industry being supplied adequately through commercial channels, especially when catering to the supposed demand for novelties. In Texas 28 firms were reported in 1928 as producing registered, certified, and recertified cottonseed; more attention being given to the production of good seed than in most of the cotton-growing States, yet less than 5 per cent of the cotton acreage in Texas was planted with seed of this quality (47).  

An adequate selection or breeding system is needed for maintaining the seed stocks after superior varieties of cotton have been discovered and established in cultivation. The frequent introduction of new varieties is most decidedly not in the interest of improved production in the cotton industry. The search for new varieties is only a part of the problem of improvement, and it has no beneficial effect if good varieties are not maintained and utilized. Production that is based on inferior seed stocks is extremely wasteful and inefficient.

Methods and facilities for maintaining the production of good seed are essential to any substantial improvement of production in the cotton industry.  

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1 Italic numbers in parentheses refer to Literature Cited, p. 69.
COTTON IMPROVEMENT THROUGH TYPE SELECTION

Cotton industry, and study has been directed for several years to this problem. The lack of good seed is the underlying cause of the poor and irregular quality of much of the American cotton crop, and the multiplicity of varieties is largely responsible for the deficiency of seed supplies. Efforts toward improvement in other phases of production can not be really effective until adequate supplies of pure seed are established. Keeping up the seed stocks of superior varieties, rather than the creation of new types, is the essential breeding problem.

On account of the use of the fiber in textiles, a special need for uniformity is recognized in the breeding of cotton. The more uniform the plants can be made, the more uniform will be the fiber that they produce, the better the fiber will be adapted to manufacturing processes, and the greater its commercial value. Uniform fiber has less waste to be separated in spinning, and the cost of factory operation is lower, as the threads are more even and are broken less frequently in spinning or weaving. Finer threads can be made from uniform cotton, and the fabrics are stronger and more durable. The limited production and widely fluctuating prices of superior fiber have restricted its use. If regularly available at moderate prices, vastly larger quantities would be used than are now to be obtained. Substitutions of shorter or less uniform fiber are forced upon the manufacturers when the supplies of good fiber become too inadequate and uncertain and prices run so high as to become prohibitive. Cotton of the character that can be produced from the Acala variety would be used in enormous quantities if adequate supplies were assured.

Cotton still is the largest export product of the United States, and the low quality of the American cotton crop is a serious national handicap. The failure to establish a standardized production of good varieties of cotton in the United States not only invites injurious competition in foreign markets but limits American textile manufacturers to irregular and therefore inferior raw materials. In some of the competing countries greater precautions are being taken to supply cotton growers with good seed than in the United States. Not only the varieties and the quality of the seed, but the planting dates, the handling of the crop, and the clearing of the fields to destroy insect pests are matters that in some of the foreign countries are being prescribed and enforced by Government regulations. For example, the State domains in Egypt are utilized for the production of select seed which is distributed to the growers. In the silk industry of Japan all of the producers are supplied every year with hybrid silkworm-eggs of standard quality from Government laboratories.

Several of the obstacles that stand in the way of a general improvement of quality in the American cotton crop have been summarized in a recent publication (93).

PRECAUTIONS COMMONLY OVERLOOKED

In the absence of a scientific understanding of the principles of selection and of the precautions that are necessary, most of the cotton growers are without any basis of practical judgment regarding the values of seed stocks and are frequently misled by newspaper reports.
or statements of advertisers. In order to maintain good stocks of seed, continued selection, roguing, and testing of progenies and increased stocks are necessary, as well as complete isolation from other varieties. These operations must take account not only of numerous characters or differences among the plants but also of many facts of other kinds which may determine success or failure in this field of work. The objects to be attained, the material to be employed, the conditions required, the methods to be followed, and the ways of utilizing the results all need to be considered carefully.

Some of the difficulties in maintaining varieties of cotton undoubtedly are due to the failure to distinguish between different methods or systems of selection that have been applied. Distinctions are drawn by many writers between mass selection and individual selection, but the analysis of the problem must be carried further in order to reach a clear understanding of the facts, as developed in the breeding of cotton. Other forms or systems of selection may be recognized, which will facilitate the study of the breeding problems. A wide range of selective treatments is possible, from weeding out only the worst plants to saving only the best. Also, it is possible by way of error to discard the best type from a variety and to turn the course of selection to a defective or mediocre stock.

The name "type selection" has been used for a breeding method which is being applied to varieties of cotton, and especially to Acala, a variety grown extensively in organized communities of California and the Southwestern States. In some of the irrigated valleys where communities or districts have adopted the plan of growing only one variety of cotton, so that the usual mixing and mongrelizing of seed stocks are avoided and an extensive production of pure seed is made possible.

In an organized community all the farmers can be supplied with seed of the same quality. This is a radical change from the condition that exists in unorganized communities, where each farmer feels at liberty to exercise his own preference or fancy in trying new kinds of cotton or in continuing to plant the local "gin-run" seed. Under the usual conditions of production the local stocks of seed are mixed by the machinery of the public gins, and plants of the different varieties are cross-pollinated in the fields.

The practical conclusion reached through the study of breeding problems is that seed improvement in the cotton industry should be essentially a community undertaking. Without the cooperation of his neighbors, the individual farmer seldom is able to keep up pure stock seed, even for a few seasons. The biological problems of maintaining varieties attain a new importance when it is recognized that a system of adequate utilization of superior types can be developed through community production (8, 16, 24, 30).

**SELECTION TO MAINTAIN ADAPTATION**

The assumption has been in the past that only a narrow range of adaptation was possible with varieties of cotton, so that a large number of varieties was supposed to be needed to meet the great diversity of soils and climatic conditions represented in the American Cotton Belt. It now appears that less confidence should be placed in this idea of close adaptation. Many test plantings have been made of the
same series of varieties in different regions, which leave no doubt that it is possible for the same variety to thrive and fructify under a wide range of conditions. Such tests have included several new varieties of upland cotton that were introduced from Mexico and Central America during the period of the boll-weevil invasion and tested in different parts of the country to determine their behavior. A notable extent of adaptation to different conditions has been shown in the Durango and Acala varieties in most of the cotton-growing regions of the United States. Not only were they found to be distinctly better adapted to the conditions of the irrigated valleys of the Southwest than eastern or Texas varieties, but also they gave excellent results under eastern conditions. The wider adaptation is significant as indicating that the present multiplicity of varieties is unnecessary.

If the same biological type can be retained with the same complex of characters, the adaptative qualifications of the stock should remain unimpaired and be capable of extensive utilization. By virtue of its adaptative qualifications the same biological type, if grown under different conditions, will show different characters, so that the same formal standards of recognition are not properly to be applied under all conditions. The conception of a biological type is to be distinguished from that of a formal complex of characters. If attempts are made to apply the same formal standards under all conditions, it is probable that mistakes will be made in selection and will result in a loss of the original biological type through shifting to a variant form. The danger of such unconscious shifting and substitution of types is indicated not only by the nature of the facts but by actual experience in cotton breeding.

Writers on heredity often refer to "merely fluctuating differences" as of no significance, but characters that are readily adjustable to conditions are not, for that reason, to be considered as less hereditary than characters that are not adjustable. The different degrees of adjustability of such characters may be very important from the standpoint of production, and the breeding experiments obviously must take practical account of the adjustment of the characters and range of adjustment to environmental conditions. Selection is not made most effectively unless the conditions are such as to test the environmental relation and allow the deficiencies of less vigorous plants or lines of descent to be recognized. Choice of the conditions of selection and of the places where the work of selection can be done to the best advantage should be recognized as a part of the practical breeding problem.

The requirement to be faced more definitely in breeding operations is to retain the adaptability of a variety. Not only uniformity but also productiveness is necessary and this includes the ability to behave normally under varied conditions. Even in cultivation in a single locality, a variety is exposed to a wide range of conditions during the growing season. Changes of moisture, temperature, and day-length conditions are generally to be met. In the southwestern irrigated valleys the soil and weather conditions are especially varied, so that a variety which proves to be generally adapted to the irrigated districts may also be of use in other parts of the Cotton Belt.
A wider use of the best varieties and a reduction of the number of varieties in use would be of general advantage in the production of cotton, as tending to increase the available quantities of uniform fiber. Also the use of the same variety in different regions of production makes possible replacement of seed stocks. The possibilities of such replacement need to be considered, not because the varieties are supposed to "run out," but because in some districts a nearly complete destruction of local seed stocks may occur in bad seasons, either as a result of adverse weather conditions or through heavy infestation of boll weevils or other insect pests. Floods, droughts, and untimely frosts may affect wide areas, and all of the good stocks of planting seed may be lost or badly depleted. Unless other supplies of good seed are then available, resoil may be made to inferior stocks for replanting, so that the effects of such disasters are carried into other seasons.

Though most of the data given in this publication are drawn from the study of Acala cotton, the methods and precautions indicated by experience with this variety undoubtedly are applicable to other varieties and are equally necessary for maintaining the productiveness and uniformity of the seed stocks. The more extensively a variety is used, the more important is the problem of preserving the essential characters. The Acala stock undoubtedly could be split into many local varieties, as other stocks of upland cotton have been, but this seems less desirable than the preservation of such a stock in a condition of general adaptation, so that it can be utilized over a wider range of conditions.

The Acala variety was discovered in southern Mexico and acclimatized in Texas, where it soon became popular, but the usual mixing with other varieties took place, and the seed stocks were allowed to deteriorate, so that in a few years the buyers refused to pay premiums and the growers were disappointed. At that stage the variety might have been discarded completely if it had not been adopted in some of the irrigated districts of the Southwestern States. One-variety communities for Acala cotton were established, which made it possible for the seed to be kept pure. With supplies of pure seed available, the use of the variety extended later to all of the irrigated valleys. Nearly 900,000 acres of cotton were planted in the irrigated valleys in 1929, and a large proportion of this was Acala.

Though not confined to the irrigated districts, the Acala cotton in several respects is better adapted to southwestern conditions than any of the upland varieties that have been brought from the eastern Cotton Belt. In many formal tests it has been more productive than the Texas big-boll varieties, such as Melane and Lone Star. Also the fiber is superior and has sold at a premium over ordinary short-staple cotton. The characters and history of the variety were given in a recent publication, which also contains a brief reference to the plan of type selection (22).

The larger series of experiments in different regions undoubtedly will be necessary to determine the extent of the practical applications that may be expected from the use of the type-selection method here indicated. It is believed that the features already observed in breeding Acala and other varieties of cotton afford sufficient reason for making such experiments, as well as for calling the attention of
breeders to some of the new aspects of the breeding problems. From
the nature of the work, effective cooperation of investigators and
practical breeders will be needed in the further development and
use of the type method.

NATURE AND EFFECTS OF SELECTION

The functions of selection are commonly misunderstood and pre­
sent critical questions in the field of breeding. The arguments and
controversies regarding natural selection and evolution undoubtedly
have tended to obscure thought in practical breeding work, where
clearness is essential. Many writers refer to selection as though it
were “an agency, capable of producing continuous and progressive
facial changes”; but this general idea of an active power of changing
characters, though forming the background of many discussions of
selection, often proves misleading. The biological facts of selection
need to be separated from the philosophical inferences.

Darwin’s theory of selection as an agency for changing the charac­
ters of species was based on the assumption of blended inheritance,
which has largely given place to the recognition of alternative in­
heritance, as shown by Mendelism. Even under the Darwinian
theory, the effect as credited to selection was to preserve new vari­
ations from extinction, rather than to change the characters. The
idea that selection created the characters and caused evolution to take
place was not a necessary inference from the biological facts, though
many of the earlier statements by Darwin, Huxley, and Wallace were
misleading to philosophers and religious writers. It seemed a logical
inference from Darwinism that evolution was merely an effect of
environmental conditions, working through natural selection, and
from such a generalization it was easily inferred that artificial selec­
tion could produce any desired changes in domestic breeds and
varieties. Such misunderstandings not only have led to controversy
but have interfered seriously with the extension of popular know­
ledge, regarding heredity and breeding (5).

Selection is a sifting process, not a mending or a making. By
being rid of the poor plants we have more good ones. If all the
plants are good the object of selection is fully attained. The breeder
works entirely by elimination, his only direct action being upon the
plants that are rejected and destroyed. The plants that are retained
are not altered but merely allowed to reproduce.

A group effect of selection can be claimed, but not an individual effect
as involved in changing a character. The species is changed, or the
crop is improved in the sense that averages of certain qualities are
raised. The group improvement is accomplished not by altering any
of the characters but by substituting a different population through
control of parentage. The expression “improvement by selection”
may be used as a figure of speech, but “improvement through
selection” accords better with the facts.

Selection readily becomes an agency of deterioration if wrongly
applied. Grave injury may be done to a stock of plants by adverse
selection. Though the breeder always looks for the best individuals,
the course of selection must be chosen with caution, since even in
careful breeding work there is always the possibility of selecting and
propagating from individuals that appear to be good because they
have features that are specially desired, but that later may be found lacking in other essentials. Not only good characters but full combinations of good characters must be sought and maintained. The favorable effects of breeding from better individuals are reversed, and the group is impaired rapidly by breeding from mediocre or inferior individuals.

Selection may be applied in the hope of continually improving a variety, without being considered as a means of maintaining the variety. The idea of continued improvement no doubt is responsible to a considerable extent for the failure to preserve varieties. A continual succession of improvements is expected by believers in selection, while selection may be disregarded by those who believe in the stability of "pure lines." In either case the value of a superior type is not fully appreciated, and the attention necessary to preserve a superior type may be neglected.

A clear separation of the different purposes or functions of selection may not have appeared necessary in the past but now is in order, because in recent years many biologists have accepted the idea of Johannsen that selection as an agency of improvement ceases to have any effect as soon as the condition of a uniform pure line is attained. Some writers have believed that there are unit characters which are incapable of variation, while others have admitted slight changes of characters which might be preserved and increased in successive generations. In recent years many instances of gene mutation have been reported.

Selecting to maintain a variety is a different operation from what may be expected if the breeder is holding to the idea of continued improvement of a variety. As long as improvement is considered the primary object, the search is more likely to lead to the selection of off-type plants, so that the type is changed instead of being preserved. It is certain that most of the deviations from a type are not in the nature of improvements, though a few may present desirable characters. All the deviations need to be rejected, or at least separated and tested, instead of being substituted casually for the normal type of the variety.

For purposes of practical breeding it probably is desirable to discard, or at least to suspend, the idea of continued improvement of varieties in order to avoid the misleading implication that changes of characters are to be expected as a result of selection. There is no way to exclude or to set a limit to the possibility that desirable variations may occur which will further enhance the value of a select type. The search for such variations may be continued, but they need not be thought of as products of selection, in the sense of supposing that selection causes the variations to appear. From the nature of selection, the differences must arise in advance in order to be recognized and preserved by the breeder. The type may not be improved by continued selection, but selection must be maintained to keep the stock from deteriorating. Such selection may be considered as an intensive roguing process to prevent deterioration of the type. The object of ordinary roguing is to eliminate degenerate mutations before they can contaminate a seed stock, while the object of type selection is to avoid even those forms of weakness or degeneracy which are not readily perceptible, and which may be detected only by careful comparison and discrimination.
Breeders are attracted by novelties and often overlook the need of uniformity or other essential features; they also frequently change their basis of selection from season to season. Some varieties have been altered completely within a few years because the breeder slipped from one type to another, sometimes intentionally but often unconsciously. Though the dealer may continue to furnish seed under the same varietal name, the plants of the two stocks may appear entirely different when raised in adjoining rows. For practical purposes it is obviously more important to maintain a superior variety which may continue in use for a period of years than to develop a succession of short-lived varieties or strains, as the custom has been in the cotton industry. Many varieties are current for only a few years and pass out of use too rapidly for their true values to be determined, as this requires several seasons and many tests in different regions.

Lint percentages and individual plant yields are features to which attention often is directed almost exclusively, to the neglect of other characters of equal or greater importance from the standpoint of production. Many intelligent farmers believe that seed should be saved only from 5-lock bolls, while others are willing to pay fancy prices for seed from a high-yielding field with little regard to quality or mixture with other varieties.

Many varieties have been developed from plants with defective fruiting branches, defective bolls, or even defective fiber characters. The cluster varieties have the fruiting branches abnormally shortened and give an impression of fruitfulness, as the bolls are crowded together and show large masses of white cotton at harvest time; but cluster plants are often sterile, and no consistently productive cluster varieties have been developed. The clustered bolls are more difficult to pick, and the points of the divisions of the bolls are not well separated, so that the fingers of the pickers are more likely to suffer. Also more trash is likely to be picked with the cotton and the commercial grade lowered.

The breeder's psychology usually is very susceptible to the attraction of any feature that he may happen to notice on a plant that is larger or more productive than its neighbors, though the difference in size or yield may be only accidental. For instance, it may strike a breeder's fancy to select a plant that shows the first open boll, even without considering any other characters. New varieties in many cases are selected, advertised, and placed on the market solely on account of some slight peculiarity that serves as a "talking point," to furnish the breeder with a reason, or at least an argument, for introducing this new stock. Thus an abnormal form of boll with open sutures at the tip was selected a few years ago by a private breeder to develop an "improved" Acala cotton.

The nature of the abnormalities often favored by breeders may be understood by referring to the plates. Normal forms of bolls in Acala and Durango cotton are shown in Plates 1 to 14 and boll abnormalities of Acala cotton in Plates 15 to 19. The selection used by the private breeder is shown in Plate 18.
Careful comparison with a good stock of the original variety is seldom considered necessary by breeders of novelties, which often are placed on the market within a few seasons after the "discovery" is made of a productive plant with a peculiar character. Seed growers choose a good field in order to increase a new stock as rapidly as possible, without waiting to determine whether it really is better than the parent variety. Many such novelties are compared with older varieties at the State experiment stations, and in the great majority of cases no indications of superiority are found.

Errors by cotton breeders may be very costly to the producers, and every means of avoiding them should be applied, both in relation to the characters selected and to the methods of conducting the breeding operations. The precautions that really are necessary to maintain good stocks of seed are generally overlooked in the effort to supply the popular demand, which such advertising indirectly creates, for wonderful new kinds of cotton. Although it is far from the mind of the breeder to develop an inferior variety, yet this undoubtedly has been done very often in the field of cotton breeding.

The assumption, usually is made that a selection from Acala or any superior stock will have the good characters of the parent variety, plus any special feature that the breeder may have fancied in a plant that has varied from the stock. In other words it is assumed that variations in single characters occur frequently and can be picked out and increased for production without needing to be compared and tested anew in order to determine their adaptations to different conditions.

It is seen from experience given in this bulletin that such confidence in the value of new selections, even when made from the best varieties, is not warranted. Careful tests are required in each case where an individual selection is separated from an established pure-bred stock. Not only have all of the recognized departures from the type to be tested, but unrecognized departures from the type must be carefully avoided.

LIMITATIONS OF THE PURE-LINE THEORY

The functions of selection in maintaining varieties have not been appreciated, because many writers on plant breeding have assumed that seed stocks may be brought to a pure-line condition of complete uniformity and that such a condition, once attained, will continue indefinitely if no mixing of seed or crossing with other varieties takes place. All that seems necessary, from that viewpoint, is to isolate a pure stock, which then is expected to remain uniform without further attention. The problems of cotton breeding thus appear greatly simplified, as is shown in the following paragraph from a current textbook (2, p. 393-394):

Breeding cotton.—The most valuable parts of the cotton plant are long silky hairs attached to the seeds inside the cotton "boll" or seed pod. These hairs vary in number, length, and strength. It is desirable for most purposes (e.g., automobile tire casings) to have them as long, strong, and flexible as possible. Cotton in nature readily crosses, so that pure seed can be produced only by guarding against cross-pollination. The method of accomplishing this is both unique and effective. In certain isolated valleys of the arid southwestern United States cotton can be grown by irrigation and can easily be kept pure provided only one variety is grown in each valley. Growers in a valley agree
ACALA TYPE BOLLS

Typical forms of bolls and involucral bracts at Indio, Calif., October, 1921. (Natural size.)
ACALA TYPE VARIATIONS

Illustrations of individual hull forms on plants of normal Acala type at Indio, Calif., November 28, 1925. The three upper hulls are from one plant, the lower hull from another plant. (Natural size.)
ACALA TYPE BOLLS FROM NEW MEXICO

Shape of normal bolls in Indio selection of Acaba, grown at the New Mexico College of Agriculture, Greenber, N.M. The outline is more sloping above and less rounded at the base than in the bolls grown at Indio. See Plates 1 and 2. (Natural size.)
ACALA LATE-SEASON BOLLS

Broader forms of bolls, more flattened underneath, are produced late in the season. Compare with Plate 5, showing bolls of the same plants developed earlier in the season and showing more oval forms. Also compare with Plate 6, showing Durrango bolls produced in the same locality. (New Mexico College of Agriculture, State College, N. Mex.) (Nearly natural size.)
DURANO COTTON BOLLS

Grown at the New Mexico College of Agriculture. These show close similarity to the Acena bolls grown in the same locality, Plate 2. Also to the variations of the Acena bolls grown in California, Plate 2. (Nearly natural size.)
ACALA TYPE BOLLS FROM NORTH CAROLINA

ACAla bolls grown near Fayetteville, N. C., in 1928. The two upper bolls are of the oval normal type and the three lower ones of local ACAla selection with blunt tip and flat base. (Nearly natural size.)
FORMS OF BOLLS OF ACA LA COTTON

Bolls from several plants of Indio (Chile) selection, grown at Fayetteville, N. C., showing the much larger forms of bolls, in comparison with the same stock grown at Jamaica Island, S. C., shown in Plate 9. (Photographed August 13, 1895. Nearly natural size.)
ACALA TYPE BOLLS FROM SOUTH CAROLINA

Bolls, involuted bracts, and calyx of Acala cotton, photographed at James Island, S. C., in August, 1926. Compare with Plate 10, showing the narrow Acala bolls produced at James Island in 1925. (Nearly natural size.)
FORMS OF ACALA BOILS

Bolls from three plants of Indio (Colia) selection, grown at James Island, S. C., showing the narrow form of bolls. Compare with the same stock grown near Fayetteville, N. C., and at the New Mexico College of Agriculture, Plates 8 and 1. (Photographed August 25, 1925. Nearly natural size)
FORMS OF ACALA BOLLS

Bolls' from three plants of Shafter (Calif.) selection, grown at James Island, S. C., showing narrow form of bolls in comparison with Plate II, which shows the same stock grown at Shafter, Calif., in the same season. (Photographed August 4, 1937. Nearly natural size.)
ACALA TYPE BOLLS FROM ARIZONA

Acala bolls grown in the Gila Valley of Arizona in 1921 from Indio (Chili) seed. The upper two are
13 mm.; the lower three are from a different plant and are slightly broader and flatter at the base;
also the surface is more remotely pitted. (Nearly natural size)
DIVERGENT BOLL FORM FROM ARIZONA

Bolls of an off-type cotton plant grown in the Gila Valley of Arizona in 1921. Compare with the typical boll forms shown in Plates 1 and II, also to show the range of boll forms and surface sculpture on the same plant. (Nearly natural size.)
DIVERGENT BOLL FORMS FROM ARIZONA

Bolls from off-type plants in the Gila Valley of Arizona, 1921. Compare with typical boll shown in Plate 11. The upper five bolls are from the same plant. The sole boll below are from a different plant, seriously beyond the range of the type. The smaller boll at the bottom is from a normal plant. (Nearly natural size)
VARIATION IN AGALA BOLLS

Different forms of Agala in the Shafter (Calif.) selection, grown at Shafter in 1927. There are many bolls of this stock with more triangular outlines than in the selection with typical bolls developed at Jullio, Calif. Compare Plate 2. (Photographed December 19, 1927. Nearly natural size.)
ACALA OFF-TYPE BOILS

Definite departures from the normal Acala boll type in the Sanjito (Calif.) selection in 1928. Each pair of bolls is from the same plant, showing the range of individual boll variation. (Natural size.)
OfT-1-1PE BOll FORMS

Range of boll forms in a selection of Acala cotton at Shafter, Calif., in 1928. Note the general tendency to pyramidal form with sloping shoulders and flat base, in contrast with a few bolls of normal form with rounded shoulders and base. (About one-third natural size.)
BOLLS OF AN ACAIA ROGUE

A plant with small, blunted-tipped cotton bolls found in a field of normal Acala cotton near Las Cruces, N. Mex., October, 1926. Compare with normal bolls of Acala, Plate 4, from the same district in the same season. (Nearly natural size.)
SELECTION OF ABNORMAL ACAŁA COTTON BOLLS

A variation of Acala bolls with the carpels not united at the ends, as shown by the deep grooves. This variation was used by a private breeder to form a new variety. (Las Cruces, N. Mex., 1926. Nearly natural size.)
ABNORMAL BOLLS WITH SUTURAL GROOVES

Variations in hull characters in a degenerate hybrid plant, showing pronounced examples of sutural grooves, in some cases extending the entire length of the hulls. Compare with Plate 18. (Nearly natural size.)
on a certain strain and then prevent by law the planting of any other kind. Selection for improved seed is then made in isolated breeding places until a suitable variety has been secured, and then only pure seed is sown in the valley. It remains pure merely because it has no chance to cross.

Many writers assume that species in nature are composed of uniform individuals and that diversity is due to hybridism or crossing with other species. Hence the inference is drawn that uniformity is a natural state of heredity and that the reproduction of uniform individuals will continue after a stock is purified from the results of crossing and then kept isolated. The mixing of different types undoubtedly is one of the causes of diversity and abnormality, while uniformity and stability of characters are sought at the opposite extreme by analysis of select groups into pure lines. The study of definitely contrasted characters in Mendelian hybrids no doubt has tended to establish a belief in pure lines as a stable condition of heredity.

Following this course of reasoning, an advantage may be expected from the repeated separation of a stock into individual lines of descent, as a continued approach to the ideal conditions of a pure and stable heredity. The tendency of the theory is to individualize the lines of descent as far as possible, on the assumption that this is desirable and assures a more stable condition. But in reality no advantage has been gained merely from the separation of the lines of descent in a group of plants, except as this facilitates selection. Pedigrees are records of descent, but other evidences of superiority are required to give such records a practical meaning. To go on making separations of individual lines, after a state of apparent uniformity has been reached, and without means of determining what differences may exist, is open to serious risk, especially if the work is done under favorable conditions for the growth of the plants. The choice of the best progeny becomes arbitrary, so that the more resistant lines of descent may be discarded, and others may be preserved which have less resistance to unfavorable conditions, with a consequent loss of adaptation.

The facts do not indicate that an absolute type can be maintained or will maintain itself simply by pure-line breeding, with selection relaxed or discontinued. The cotton plant affords unusual opportunities for putting the question of uniformity or diversity to a definite test. The plant is not too small to see readily nor too large to compare readily in most of its parts. Study is facilitated because flowering and fruiting of cotton are continued over periods of several weeks or months, in contrast with the many plants and trees where flowering and fruit setting are limited to a few days and in many cases to only a few hours. The general habits of the plants, the modes of branching, and the large number of differences that may be recognized in the leaves, flowers, and bolls are readily accessible to observation, and even the lint and seed characters are easily compared. In all of the characters that have received detailed study, tendencies to diversity have been found, even in stocks that have been selected carefully for many generations.

It need not be assumed that variations occurring in uniform purebred stocks necessarily represent new characters, since there are many of the so-called recessive characters which are inherited with-
out being brought into expression. Also, many of the differences that appear in hybrids and in mutations may be considered as reversions to older characters. Selective breeding tends to establish uniform expression of characters, but uniformity is never absolute. Even with vegetative propagation, variation is not entirely excluded. Many cases of bud mutation are known, and in some groups of plants such changes are not infrequent. The crazy top and other diversity diseases also show that the normal expression of the characters may be deranged in many ways during the development of the plant.

Among the equivalent structural members of the same plant body, differences are found which also seem to indicate that heredity is not stabilized. Not only is there a normal diversity of internode individuals to form the different organs, as required in the development of the plant, but the internodes of the same class often show slight individual differences (15).

Diversity instead of uniformity seems to be the condition of all natural species, as seen when sufficient study is given for one to become familiar with their characters. At least in the species and varieties of cotton notable diversities are always to be found, and it has not been possible by any refinement of the breeders' art to establish and maintain a condition of complete uniformity. Even in strains that have been self-fertilized for periods of years and have appeared very uniform, definite mutative changes of characters have occurred. It may be considered as a general rule or law of heredity that diversity tends to recur through mutations or by reappearance of recessive characters. As soon as selection is relaxed, the return to diversity becomes apparent.

**EFFECTS OF CONTINUED LINE BREEDING**

It is conceivable that a stock propagated for many generations on separate individual lines may become weak or unstable. The instability may be increased as the series of generations is extended. Selection may continue to remove all of the lines of descent in which a decline from standards of the type has been shown, either in external characters or in ability to produce, but other lines may then show weakness. The evidence of decline may be sought in plus and minus differences among members of the same types, as well as in characters that distinguish types or varieties from one another. Even with no appreciable changes in the external, visible characters, some members of a type may be stronger and more productive, while others lack vigor or bear little fruit.

A pedigree is not to be taken as a test or a proof of continued performance, but only as a promise or indication that good performance is possible. The highest parental standards are not likely to be maintained in all of the descendants. Even if selection is confined to the best individuals, some of the offspring are found to be inferior. Selection has to be continued in order to keep the stock from being diluted by the progenies of inferior individuals that would reduce the yield or impair the quality of the product.

The greatest and most obvious effect of selection is exerted at the first operation when a good type is separated from a diverse, degenerating stock. The more miscellaneous the stock, the greater the improvement by selection appears to be, when progenies of good
individuals are contrasted with a diversified general population. Notable improvements of yield, often to the extent of 20 or 30 per cent, may be made by suitable selections, as many unproductive individuals are usually to be found in mixed gin-run stocks. Such increases from selection are not to be expected in good stocks that are nearer to a state of uniformity. The theory of pure lines may be useful in helping to avoid unreasonable expectations if the assumption of natural uniformity and stability can be avoided.

No doubt the same extent of uniformity will not be attained with different plants when the phenomena are studied with sufficient care. As some writers have suggested, the pure-line theory may be more applicable to self-fertilized plants than to others. Essential differences may be found in the modes of inheritance in the various groups.

In upland varieties of cotton the stigma is much shorter than in the Egyptian and sea-island cottons, and on that account the upland varieties appear to be less exposed to crossing. On the other hand, greater susceptibility of upland cotton to fertilization by pollen of Egyptian cotton appears to be indicated by experiments conducted at Sacaton, Ariz., in 1920 by Kearney (38, p. 9), who makes the following statement:

Plants of Pima were grown isolated in a plot of Acata and vice versa, and were left to natural pollination. The seeds from both sets of plants were planted the year following, and the Acata seeds yielded 28 per cent of hybrids while the Pima plants yielded only 12 per cent.

The extent of crossing between the two species no doubt is influenced by other features than the exserted stigma. On account of the longer style of the Egyptian cotton the pollen tubes must grow farther to reach the ovules. The pollen grains of the Egyptian cotton are much larger, and pollen tubes may grow faster, or some other factor may give an advantage in the competition with the pollen tubes of the upland cotton. This problem, however, is distinct from that of crossing among the plants of the same variety.

SYSTEMS OF SELECTION DEFINED AND ILLUSTRATED

FOUR SYSTEMS OF SELECTION

The following definitions and comparisons may serve in discriminating between type selection and other systems:

Mass selection is a process of reproducing from the better individuals of a stock. A separation may be made by discarding inferior individuals or by assembling good individuals, but the selected individuals have different characters, their progenies are not kept apart, and the resulting population continues to be diverse, even after many generations of mass selection.

Individual selection is a process of separating superior individuals and raising separate progenies from such individuals to start new populations. The effect is sometimes to produce uniform stocks and sometimes diverse stocks, depending on the characters and heredity of the individuals selected.

Progeny selection is a process of choice among progenies raised from superior individuals, progeny plantings being used as the basis of comparison and selection, instead of depending upon the
choice of the best individual plants. Progeny selection is more effective than individual selection, but may not result in uniform stocks. Progenies of different types may be included, or the type may be changed from year to year in an annual plant like cotton.

Type selection is a process in which the choice of individuals to furnish seed for progeny plantings is limited to a single type of plant, so that the progeny blocks are made as uniform as possible, to the limit of the breeder's ability to avoid deviations from the type. Also any variant individuals that can be detected are removed from progeny blocks and increase fields as a means of maintaining the uniformity of the stock.

**COMPARISON OF SYSTEMS**

Mass selection is the simple and gradual method of improvement that no doubt was followed, consciously or unconsciously, with all of the domesticated species before the more specialized methods were devised. Even among very primitive people, plants that attract favorable attention by special vigor, productiveness, or quality are likely to be saved for seed or propagated in other ways, though usually without being separated from each other or even from the general stock. As in natural selection, the poor forms are handicapped and the good are favored, but the selections are not of the same type. Continued mass selection raises the average of a population by lessening the representation of inferior lines of descent, but may not reduce to any great extent the diversity of the stock. Plants with inferior characters continue to appear, and crossing keeps the inferior characters current in the stock, even though seed be saved only from good individuals.

Individual selection is based on the recognition of single superior plants. The breeder trusts to his ability to pick out the best plant in a field or a breeding block, saves the seed of this individual, and makes a separate small planting for increase as a seed stock. A uniform progeny may be obtained in this way, and the next year a field planting may be made. The system of individual selection was used effectively for many years with sea-island cotton on the coast islands of South Carolina and Georgia.

In progeny selection the breeder does not rely upon his ability to choose the best plant, but selects many good plants and the following year compares their progenies, planted in adjacent rows. The precaution of comparing the progenies of the selected individuals affords a better means of determining the characters or differences that may exist in a series of selections and also of comparing and determining the uniformity of the selections, to the end of choosing the best progeny for increase as a seed stock. Undoubtedly progeny selection is a step in advance of individual selection, but it has practical limitations from the standpoint of establishing and maintaining the uniformity of a seed stock.

Type selection follows the methods of individual and progeny selection, but with further precautions of adhering to a single type in the selection and progeny work and of roguing the progeny blocks and increase fields. Roguing is applied to remove the off-type plants that continue to appear, even in the stocks that are bred with greatest care, or in progenies produced by self-fertilization.
Progeny blocks that are not restricted to the same type of plants do not produce uniform seed stocks unless artificial self-pollination is applied. Making a collection of good individuals, but of different types, and raising their progenies together, is not essentially different from mass selection. Much crossing may take place between the adjacent rows of cotton, so that with different types represented in the progeny blocks the crossing and mongrelizing of the stocks is continued as in ordinary fields. Good progenies may be adjacent to selections with divergent characters and may be thoroughly contaminated by cross-pollination if many bees or other insects are at work in the fields. Such diversity is excluded from the progeny blocks under the type system.

If plants that diverge from the type are selected intentionally for further study or testing, they should not be designated or numbered as progenies, but only as selections, and these are not to be grown in the progeny blocks or in adjacent rows, but in isolated plantings. The two projects of preserving an existing type and of breeding novelties need to be handled separately.

It is much more important to maintain a desirable type from year to year than it is to try to find a novelty that will be so definitely better than the type as to justify a substitution. The possibility of finding a valuable new type of plant is not to be excluded from the breeder's hopes, but the responsible breeder should moderate his zeal for novelties. At least he should appreciate the necessity for testing thoroughly each new form and for testing it in many localities before exploiting it as a commercial seed stock, and the need for maintaining by continued and careful selection any form which is to be used for practical production purposes.

**TYPE SELECTION AND PROGENY SELECTION**

Adherence to a type simplifies breeding operations, as a more definite object is presented. The object is not to discover new characters or to establish new combinations of characters, but only to preserve the combination of characters already existing in the type—not incompatible or doubtful combinations, as in many hybrids, but combinations already well balanced and adjusted to each other. So many characters are involved in a type that selection for each one of them would not be feasible, but the entire combination is selected by keeping within the type. The special advantage of the type system is to maintain the selection of many characters at once.

The selection of the best individuals of the type serves to keep up the full expression of the desirable characters, though it is not to be expected that all of the desirable characters will be brought to full expression in any one place or in any one set of conditions. Characters of special value from the standpoint of adaptation to particular conditions need to be specially guarded, and selecting must be done under conditions where differences in these characters can be shown. Otherwise there is danger that exclusive consideration of one character or of a few characters may result in loss or impairment of other characters and restrict the range of adaptation.

The highest-yielding plants in one season may excel by reason of some particular character, while a different season requires excellence in another character. The breeder may suppose that he is selecting
consistently for the same character (yield), but different characters may be responsible for good yields in different seasons or in different soils. The type may be guarded the better by being selected for different characters, but special precautions are necessary to avoid departure from the type, as explained later. The selection of the same type under the varied conditions is a way of assuring the continued possession of all of the desirable characters. In this respect type selection is analogous to natural selection.

Type selection, especially if applied under different conditions, may be considered as an extension of natural selection, since it is not merely analytical and exclusive, in the sense of isolating particular characters, but is a system for maintaining the full series of type characters by checking against possible losses of desirable characters in some of the lines of descent. The problem is not to be solved by applying an artificial standard, but by learning to recognize the actual forms of the plants. In practice, the type is not established nor standardized by assuming that the plants ought to show certain characters under all conditions, but by observation and familiarity with plants of the same stock grown in different places. The ability to recognize the same type of plant, even under widely different conditions of growth, is essential to useful breeding work by the method of type selection.

The advantage to be expected from comparisons of type progenies is the assurance of maintaining a more uniform stock, but there is no reason to expect that yields will continue to be increased, or even that high yields will be maintained, unless special precautions are taken. The usual comparison of progenies or of small increase blocks affords little basis for judgment regarding the various characters that are expressed in the yields. The effects of slight differences of soil or moisture conditions are such as greatly to complicate the task of progeny selection. Usually there is little ground for choosing a particular progeny as the best, in a series raised from plants that were carefully selected for adherence to the same type. A field of such progenies appears uniform, and the yield differences between the rows may be only accidental. Progenies with low yields may be rejected as a precaution, without attempting to determine whether the apparent deficiencies are real; but even that ground of choice is lacking among the progenies that yield well.

As often shown in field plantings, row variations as large as 30 or 50 per cent may occur, which have no genetic significance.

Maintaining a seed stock on the basis of a series of progenies is a different system in several respects from taking a single progeny for increase and rejecting the others. Taking only one progeny for increase involves the risk of definitely impairing the true type of the variety by losing some of its essential characters. Selection for uniformity alone may result in a loss of productiveness. Even if the external features of the type appear to have been retained, the range of adaptation may be narrowed, to the detriment of production. Apparently there is no practical way of assuring the preservation of all of the desirable characters of a type where selection in each generation is limited to a single progeny or to a single locality. At least it can be seen that such an undertaking is essentially more
difficult and precarious than maintaining a superior type as a group of progenies that can be tested in different places.

The danger involved in the restriction of seed stock to a single progeny is greater where the progeny plantings are made under the very favorable conditions that are commonly preferred for breeding work. The best conditions usually are considered necessary for breeding experiments, in order to raise the most thrifty and productive plants and show to full advantage the desirable characters of the variety, as well as to increase the seed stocks as rapidly as possible. But with breeding confined to the most favorable places, the differences that affect the resistance of the plants to adverse conditions are not brought into expression, and the weakness of a select stock may not become apparent.

SIMPLIFIED TYPE SELECTION

Type selection may be practiced without the precautions of progeny selection. If the breeder has sufficient skill, accuracy, and regularity of perception always to recognize his type, it is possible to maintain a high-quality seed stock, even though the selected plants are not picked separately or the seed planted in progeny rows. A method of type selection, very simple and yet very effective, was used for many years by the late Alexander Mebane in the breeding of the Triumph variety of Texas big-boll cotton, at Lockhart, Tex. The practical feasibility of the method was demonstrated by maintaining a very uniform variety of cotton through the long period in which the work was continued by Mr. Mebane. The same stock was selected on the same farm for about 30 years.

The method followed was to select the planting seed for the next season from the best and most productive plants. Enough seed was selected each year to plant the entire farm, with an adequate reserve for replanting. The selections were made carefully, only the plants that were notably more productive than their neighbors being considered. Each of these productive individuals was observed closely to detect any deviation from the variety in plant characters. Then the lint and seeds were examined, to make sure that the fiber was of normal length, strength, and abundance and that the fuzz of the seeds was not colored, abnormal, nor deficient. The accepted plants were marked by drawing a furrow with the foot, and the cotton was harvested at once by a careful picker.

Such an operation might be mistaken for mass selection if it were not known to be directed to a single type of plant, but this is a vital difference. The usual practice among cotton breeders has been to carry a miscellaneous collection of types in their breeding blocks. Obviously, the value of the field work depends upon the ability of the breeder to apply the necessary discrimination of the type. Such skill was evidenced in Mr. Mebane's case by the great uniformity of his increase stock. The fields of Triumph cotton at Lockhart were carefully inspected on two occasions in 1906 and 1907. The entire acreage was grown over consecutively, and very few rogues or aberrant plants were detected.

The system applied by Mr. Mebane did not include the precaution of separating and comparing the progenies of the select individuals.
Nevertheless it included another selective feature which the usual progeny methods do not provide. The operation of choosing from the more productive plants of his type was repeated each year and had the effect of a continued selection for normal behavior and productiveness under the varied seasonal conditions. On account of the wide range of climatic variations in Texas, different adaptive characters are brought into expression, as shown by the contrasting behavior of plants of the same stock when grown for successive seasons in the same field. Hence it can be understood that an annual reselection of the best plants of the type may be very important in maintaining the vigor, fruitfulness, and uniformity of seed stock.

The principal advantage of growing the progenies in adjacent rows is that the breeder can test and check his judgment regarding the type and eliminate the progenies that give any indication of weakness or divergence. Hence the use of progenies seems advisable, as an additional precaution in type selection and to facilitate the comparison and recognition of the uniformity in seed stocks. It is important to have the assurance that the work of breeding is well done. Practically uniform fields of cotton will result when the type that is being selected is carried correctly and accurately by the breeder and the progenies are planted together, though slight differences are still to be found when well-selected progenies are closely and carefully compared. The progeny-row comparisons are needed especially for the study of the lint and seed characters, where slight differences may be important and yet are difficult to establish. The separate ginning and planting of the progenies are the only additional operations required in handling type selections as progenies.

RECOGNIZING AND MAINTAINING A SUPERIOR TYPE

It is obviously important to know how to choose the type of plant that is to serve as the standard of selection in a variety of cotton, since this largely determines the value of the subsequent breeding operations. The recognition and preservation of a superior type already in existence are the practical alternatives to the theory of forming synthetic types of plants by hybrid combinations of characters.

In view of the number of characters to be considered, it is seen that the choice of a new type is not a simple or arbitrary act. Efforts have been made with cotton, as with other plants, to establish varieties on a basis of artificial standards expressed numerically on score cards. Such schemes have not produced practical results, probably because many of the score-card features were of little importance and made the problems of selection too complicated to be followed. From the nature of the facts, explicit directions are hardly to be given for recognizing a superior type of cotton.

The recognition of a type as potentially valuable is merely provisional and preliminary to the careful comparing and testing that are necessary before a definite assurance can be reached that the new type has a practical value. In the case of the Acala cotton, it happened that only a single plant was seen at the locality in southern Mexico, where the existence of the new cotton was first recognized as having characters that might render it useful in the United States. Before this provisional judgment could be verified, it was necessary
to send another expedition to the cotton-growing districts of southern Mexico for stocks of seed and afterwards to determine the adaptability of the new cotton to conditions in Texas by several seasons of acclimatization and selection (4, 23).

A stock of seed that came from the town of Acala, in the State of Chiapas, behaved best under Texas conditions and furnished the progenies that later were increased to the scale of commercial planting. It was not until adequate stocks of acclimatized select seed were available that it was possible to make thorough and conclusive comparisons with other varieties under regular field conditions. Such tests left no doubt of the ability of the new stocks to yield well and to produce fiber of excellent quality under boll-weevil conditions in Texas.

The choice of a superior type in the Acala cotton followed a similar experience with Durango cotton, which had been introduced and acclimatized from Mexico a few years in advance of the Acala. A superior type was recognized in the Durango cotton at Del Rio, Tex., in 1907, and developed to the scale of commercial production in California. The first field of Durango cotton in California was planted in 1911 in the Imperial Valley near El Centro.

The possibility of finding other good types in the Durango stock was also considered when the superior type was first recognized. The plantings of the original stock of seed in Texas were continued in the following seasons to see if any other types of plant could be found of as great value as that which had been chosen, or of greater value. In the course of two or three years several recurrences of the superior type were obtained, but no other type was found which appeared to be more promising or even to be equal to the type that had been selected. Thousands of plants were inspected carefully in the search for a better type, and progenies were grown from all individuals that appeared notable in any desirable respect.

The same precautions were observed in the breeding of the Acala cotton from the original seed stock obtained in Mexico. The first plantings in Texas, in 1907, were at Victoria, Kerrville, and Del Rio. A superior type of Acala was recognized at San Antonio in 1909, and a field planting of this stock was made at Waco in 1911. After the good type had been distinguished, other types with characters of equal quality and promise were sought but were not found. During the years that the variety has been cultivated, great numbers of off-type plants have been observed and studied, without any being found that were better than the normal type in productiveness or quality of lint. Only a few were found that were even approximately equal to the normal type.

Some of the off-type plants were very productive and attracted favorable attention, especially those of the cluster habit with bolls crowded together on the short branches. As in other varieties, the cluster plants often appear very prolific and may yield well under favorable conditions. But under stress conditions the cluster plants suffer more, and cluster variations of Acala have appeared to be more susceptible to shedding. Hence it has seemed necessary to avoid cluster variations in the Acala stock. Reasons for considering the cluster character as abnormal were given in earlier publications (19, 38).
The type recognized as superior in the seed stock from Acala had early and prolific plants of an erect, pyramidal form with large oval bolls. Lint of good length and abundance was found more regularly on plants of this type than on other forms of plants. A remarkable combination of desirable characters was obtained.

The essential features of the Acala cotton are the upright habit of growth and the ability to set promptly a good crop of large, well-shaped bolls. The fruiting branches have joints of moderate length, not of the short cluster form. The bolls open well and have the storm-proof character of holding the seed cotton in place for a long period. The fiber is abundant and of even length, attaining 1½ to 1¾ inches when raised under favorable conditions. The staple has a firm body and a good "drag," and excellent spinning qualities have been reported from the mills.

The behavior of Acala cotton in Oklahoma in 1919 was described in an article by Clarence Roberts (40) in the Oklahoma Farmer-Stockman for December 10, 1919. The storm-proof character, good yields, early maturity, high turnout at the gin, and length and strength of staple were the features specially noted. In that season premiums from $15 to $40 per bale were reported.

Reports for the season of 1920, published in the Marketing Bulletin of the Oklahoma State Market Commission (35), January, 1921, showed larger yields from Acala cotton than from other varieties, production of the crop in shorter periods, and higher premiums for the fiber. Maturity of the crop in 90 days was reported in two cases, below 100 days in four cases, and in 110 days or less in five other cases. The turnouts varied from 81 to 88 per cent of lint, 15 of the 23 reports being 35 per cent or above. Premiums of from 100 to 300 points are shown in 15 reports, 12 reports showing 300 points or more, or an average premium of 382 points in the cases given.

Comparisons of Acala with many other varieties were reported in 1928 in a bulletin of the Texas Agricultural Experiment Station (36). Acala ranked first in yield of lint from 1922 to 1927. Only one variety, Lightning Express, was reported as earlier than Acala in this series of tests.

After the good qualities of the Acala type of cotton had been definitely determined the seed was distributed, and in a few seasons the new variety was widely appreciated. Indeed, its popularity soon became so great as to invite disaster, since the stocks of good seed were entirely insufficient to meet the demand. Large quantities of mixed seed were planted, or mixtures of other varieties sold as Acala. Some of the fields showed small proportions of genuine Acala plants, while in other fields no such plants could be detected. The better stocks or seed rapidly disappeared as a result of mixing at public gins, as at that time there were no communities where separate ginning of different varieties was practiced. A few private breeders or seed firms undertook to develop stocks of Acala cotton, but much of the seed obtainable from such sources was badly mixed.

Though 25 reports are indicated, 1 is missing from the list, and several are not complete. A list of 28 addresses where planting seed of Acala cotton was offered for sale in Oklahoma in 1921 is included.
Selection was attempted by several volunteer breeders, but often the true type of the variety was not recognized. Hybrids or divergent forms lacking some of the characters of the genuine Acala type were substituted. Crossing with other varieties took place extensively, and many hybrid plants could be found in the mixed stocks. It was natural that breeders who had been engaged with the Texas big-boll varieties should select from the mixed Acala stocks the forms of plants that were considered desirable in Melbane and Lone Star or in other Texas varieties.

Thus the variety was mongrelized by some of the local breeders, instead of being improved, and it might have followed the usual course of being discarded in a few years if the breeding work had not been maintained elsewhere. The only opportunities for maintaining the selection of the Acala type under the condition of complete separation from other varieties have been in California, where pure-seed districts have been established for growing this variety exclusively. The subsequent development of Acala production in California has been described in other publications (3, 30).

Supplies of pure Acala seed have been available in California since 1920, and the use of the variety has extended gradually until in the irrigated valleys of California, Arizona, New Mexico, and western Texas most of the cotton raised is Acala. Better stocks of seed are being developed in Texas, Oklahoma, and Arkansas, so that the use of the variety is again increasing, and the favorable results of the earlier years are being repeated. It is plain from the past experience that the extent of utilization of the variety may depend entirely upon suitable stocks of seed being developed and maintained in the different cotton-growing regions.

The danger now is that a wider use and appreciation of the variety may lead again to a general mixing and deterioration of the seed stocks unless a system of selection can be applied on a sufficient scale, so that entire communities in different regions of the Cotton Belt can be supplied with pure seed and establish new centers of continued production. Without such precautions no large volume of good Acala cotton is likely to be produced in the eastern Cotton Belt to an extent that will show the full value of the variety.

Unless selection can be directed to the true type of the variety, there is the same danger as before, that off-type plants may be selected and local stocks of seed developed with divergent characters. Selections may be made from Acala cotton with differences as great as between other varieties. Such departures from the type could only lead back toward the general condition of diversity and mongrelizing of seed stocks, though all might be derived from Acala. Even in California, where the principle of 1-variety production of cotton has been most definitely adopted, the need of holding the selection of seed stocks to a single type of plant is not appreciated fully, nor is the danger realized sufficiently of replacing one type with another before adequate tests have been made to determine whether any advantage will be gained.

**SELECTION FOR PRESERVING A TYPE**

After a superior form has been found and separated from a miscellaneous stock, selection has another function to perform in order
to maintain the true characters and qualities of the recognized type during the period of use. The development and the preservation of varieties are different functions, though both are accomplished by selection.

The need of holding to a single type in the selection of a variety of cotton, in order to maintain its good qualities, was recognized in a publication issued in 1910 (7). Attention was called to the use of the external characters of the plants to facilitate the recognition and removal of off-type individuals from progeny rows and increase fields. Later experience has tended strongly to confirm the need of such precautions and of bringing the principles and methods of type selection more definitely to the attention of plant breeders and seed growers.

Unless a type is recognized, there is no assurance that the operations of breeding and selection will produce a uniform stock or maintain a condition of uniformity after it is once established. Taking account of the many characters of a type and of the many modifications of such characters that are possible under different conditions, also of the endless departures from the type that may be found as contrasting individual variations, it is plain that experience and careful observation of even a single type of cotton will afford material for extensive study.

The type to be selected necessarily remains indefinite in the sense of its characters being subject to the influences of local conditions. Caution, therefore, is always required in order that the breeder may adjust and accommodate his ideas to the facts before him. Any fixed idea of a particular character that must be expressed in a definite way, as a certain size and shape of bolls, is to be avoided. A scorecard standard brought from another place might not result in holding to a type but in slipping away from it.

Outstanding departures from the type are easily recognized and discarded, even by the beginner. Many off-type plants are obvious freaks, even to the extent of complete sterility in some cases. (Pl. 24.) Hardly less striking are plants with defective or misshapen bolls, bolls of very small size, as those in Plate 17, or larger bolls of markedly divergent forms, as those in Plate 18, as compared with normal forms, as those in Plates 1 to 3. Variations in habits of branching and in characters of the seeds and lint have been described in a separate publication (3f), to which reference may be made by those particularly interested in cotton breeding. The inheritance of several of the off-type characters was tested by comparisons of numerous off-type progenies at Sacaton, Ariz., in the season of 1924. Several of these variations showed the cluster or semicluster variations, with short-jointed fruiting branches, while others were rank, unproductive plants, and some were of nearly normal form. (Pls. 25 and 26.) Some of the off-type plants gave notably uniform progenies, while others were remarkably diverse, like the perjugate (second and later) generations of hybrids between widely distinct species.

Though all characters of the plants are subject to variation, differences in the form of the bolls are among the more tangible features and serve best to illustrate the nature of the variations that need to be recognized in selection for maintaining the type. The breeder's
LINT FROM A "BUTTERFLY" COTTON HYBRID AND ITS PARENTS

A hybrid between Triumph or Melane and Durango cotton, showing uneven "butterfly" lint, shorter at the base of the seed. Melane cotton at left, Durango at right, the hybrid between. Note even lint of parent varieties, in contrast with hybrid. (Nearly natural size.)
FIBER VARIATIONS OF ACA LA COTTON

Combed seeds from a normal Acala variety (A) and from a rogue progeny (B), the latter notably irregular, with some of the plants reverting to short "butterfly" lint, which does not appear in the normal Acala type. (Nearly natural size.)
COTTON BOLLS INJURED BY STRESS CONDITIONS

Upland cotton bolls seriously dwarfed by checking of growth under stress conditions. The fibers of such bolls are much shorter and weaker than that of well-developed, normally opened bolls, such as are shown in Plate 21. The three bolls at the top are Arica, the three middle bolls are Llano Star, and the three at the bottom are Melanie. (Nearly natural size.)
OPEN BOLLS OF ACAIAG COTTON

Upper A) and lower B) surfaces, showing small boll hearts and compact stormproof lobes. Held firmly between the divisions of the boll wall. Compare with the dwarfed, stress-induced bolls in Plate 22. Natural size.
A BARREN OFF-TYPE PLANT

An extreme variation of Xella cotton in a field of productive plants at Las Cruces, N. Mex., October, 1926, resulting in complete sterility through abortion of all the flower buds, as shown by the scars of the fruiting branches. (Nearly natural size.)
BRANCH VARIATIONS IN OFF-TYPE PLANTS

Normal plant (at left), three forms of cluster and semi-cluster plants, and one large sterile plant (second from right).
OFF-TYPE ACALA PROGENIES

Plants representing two off-type progenies, one rank and unproductive, the other of nearly normal form. (Sahona, Ariz., 1921.)
endeavor must be to establish a correct judgment that will make the proper allowance for local influences or adaptations of boll forms in the true type of the variety and at the same time will not fail to recognize any departures from the type. For each undertaking in selection the breeder must be ready to give himself a few hours of special education, through careful study in the field, in order to have proper ground for confidence in his ability to recognize the type readily and accurately under the local conditions. If the plant forms and boll forms are normal and familiar, selection may proceed without delay, but if it is necessary to take new bearings, this should be done carefully. The need of these precautions and of avoiding fixed ideas of a type will be appreciated by considering the range of boll forms shown in the illustrations of bolls of the Acala type in different places. (Pls. 1 to 4 and 6 to 14.)

Comparison of the boll forms from different localities makes it plain that the local phases of boll forms may cover a range of differences much greater than those that may separate two strains or even two varieties growing in the same place. The Durango boll forms, as shown in Plate 5, are hardly more different from some of the Acala boll forms than some of the latter are from the others. The Acala boll form at James Island, S. C., in 1927 offers as great a contrast to those of Acala from several other places as to bolls of other varieties. Compare Plates 9 and 10 with Plates 1 to 4 and 6 to 8.

Even in the same locality it is necessary to make proper allowances in the recognition of a type. Not only do the plants grow to different sizes and show different habits of branching, which are dependent upon the seasons, but also the forms of the bolls may be notably different. Thus the bolls of Acala cotton produced in 1927 on James Island, near Charleston, S. C., were notably smaller and of a narrower and more pointed shape than those produced in 1926. Compare Plate 8 with Plates 9 and 10.

In curious contrast to the narrowing of the bolls on James Island in 1927, a marked tendency to shortening and blunting of the bolls was observed at Fayetteville, N. C., in the same season. (Pl. 7.) Also these shortened bolls were in contrast to those produced at Fayetteville in the previous year, which were nearly normal. (Pl. 6.) But when these bolls of 1926 at Fayetteville are compared in turn with bolls of 1926 at James Island, they are seen to be somewhat narrower. Thus the season of 1927 showed unusual forms of bolls in both places, narrower at James Island and broader at Fayetteville, and in both cases it happened that the local tendencies shown in the previous year were reversed. It was noted in 1926 that much of the cotton in the vicinity of Fayetteville showed a buckling of the leaves, due to a slight contraction and yellowing of the margins, which suggested that the plants might be suffering from a mild mosaic disease.

Even in the same place and on the same plants appreciable changes of boll forms may occur with the advance of the season. The late-season bolls often are larger and generally are distinctly broader and more abruptly narrowed at the base than the bolls of the same plants formed earlier in the season. A rather striking example of seasonal
variation in boll form was noted at the New Mexico College of Agriculture in 1926. The late-season top-growth bolls were notably shorter and broader than bolls that had developed earlier in the season. (Pls. 3 and 4.) The leaf characters and habits of growth may also show changes late in the season, especially on plants that start into new growth after a period of dormancy resulting from stress conditions.

Reference is made elsewhere to fluctuations in the shapes of individual bolls of the same plant, which are a further indication of the need of familiarity with the plants and of cautious judgment in selection, disregarding the differences that are not significant, but not overlooking any tangible indications of plants that are not representative of the type. When the facts are considered it is plain that mistakes may occur readily under any casual procedure that bases its decisions on inspections of individual plants without the precaution of establishing the local type. Though the external boll characters are of little importance in themselves, they are important to the breeder as the readiest means of recognizing departures from the type which are not signified in the form of foliage of the plant. Many departures from the type can be detected in this way without waiting or taking the time that is necessary to examine the lint characters.

A simple and practical test of ability to recognize the true type of a variety can be made by any breeder for himself, or by others who may witness his work, in the correctness of judgment of the plant in relation to the lint characters. A beginner in selection should do his first practical work when green bolls are still available, but after some of the bolls have opened, so that the relations of the plant characters to the boll and lint characters can be compared, tested, and verified repeatedly to any extent that is necessary to establish a full acquaintance with the type. A regular agreement in lint characters will be found if the true type is being recognized, while poor and irregular lint, which occurs in many off-type plants, will show that the course of selection has departed from the true type.

A relatively slight variation in lint characters may be found among the plants that adhere to a type, but plants of the good type are not found with notably poor or short lint unless cultural conditions are very unfavorable. Serious departures in lint characters seldom or never occur without departures in plant characters, though some of these are more striking than others. The assumptions of some writers that plants may be uniform in other respects but diversified in their lint characters, or may be uniform in lint while diverse in other features, apparently do not accord with the facts.

The biological principle that facilitates type selection is that variations in different characters are symphonic, or generally occur in conjunction, instead of single characters being changed separately. If the variations were not symphonic it would be much more difficult to detect the changes of individual characters, as required in selection and roguing of seed stocks. Considering the off-type characters as reversions may help to explain the general tendency to shorter or less abundant lint among the off-type plants. Such departures from the type might be expected to inherit their lint characters also from more primitive ancestors.
Experience has shown that many differences that are not apparent at once, and that may not be recognized even in careful inspection of a breeding block, may still come through to the breeder's consciousness after days or weeks of continuous contacts with the plants. A block of well-selected progenies may appear to be very uniform, with no outstanding or readily appreciable differences between the rows, but slight distinctions become perceptible with sufficient study and are gradually extended by comparisons among the rows.

In every case where familiarity with blocks of progenies has afforded a basis of judgment, the same conclusions have been reached, that slight but consistent differences exist among the progeny rows. Adjacent rows have not been found that were exactly alike, nor could rows that were not adjacent be matched exactly, as should have been possible if self-fertilization had established a condition of complete uniformity. A large proportion of the seed of upland cotton is self-fertilized. Some of the breeding stocks have had the same parentage for many generations and in many cases have been artificially self-pollinated.

More pronounced or definite differences among the rows or among the plants in the rows would be interpreted as results of different combinations of alternative characters, as in Mendelism, but the usual contrasts and distinctive classes of Mendelian hybrids are not indicated. The slight and indefinite nature of the variations suggests an individual origin, as though an incipient tendency of variation had affected each parent plant and had been carried over to the progeny. Progeny-row differences observed among type selections of Acala cotton may be indicated briefly, to show the general nature of the progeny-drift, or genocline, variations, as they may be called.

The habit of the plants in some rows is seen to be slightly more compact, in some more open and spreading, and in some more vigorous or a little taller. The height of the plants is affected not only by the vigor of growth but also by slight variations in the length of the internodes. Differences may be recognized in the number and development of the vegetative branches, especially in the plants with the tendency to taller growth. The fruiting branches vary somewhat in the length of the joints, tending by degrees to the cluster or semi-cluster conditions which appear frequently in off-type plants. Some rows may be distinguished by having slightly larger or smaller leaves than their neighbors. The involucral bracts in some progenies tend to be larger and more leafy, in others somewhat smaller or more deeply dissected. The bract differences among progenies are superposed on the larger environmental differences in the development of the bracts, as shown in Plates 1, 4, 5, 6, and 8.

Also in the boll characters slight but consistent differences may be detected among the progenies. The oval shape of the bolls is more pronounced in some of the progenies, while others tend to longer and narrower forms of bolls, to shorter and broader forms, or to other slight modifications. The tips of the bolls, though subject to much variation on the same plant, offer slight differences which appear more definite when series are compared. The difference shown in
Plate 2 between bolls from two plants at Indio, Calif., may illustrate this form of variation. The two lower bolls are more definitely tipped than the three upper bolls.

The greatest diameter of the bolls may be near the middle in some progenies, in others nearer the base. The surfaces of the bolls differ slightly in texture and in the abundance and depth of the oil glands. The black glands may show distinctly on a rather smooth surface, or the surface may be somewhat pitted with small depressions around the glands, and the dark color may be less pronounced on account of the glands being set more deeply below the surface. Though the pitting of the surfaces of the bolls is more frequent and more pronounced in some localities than in others, slight but consistent differences may be found in progenies or individual plants of the normal type. Although the distinction may not be clearly seen in the illustrations, the bolls shown in Plate 11 have distinctly pitted surfaces, while those shown in Plates 12, 13, and 14 are slightly pitted.

The abundance, length, and character of the lint show slight but perceptible differences between adjacent progenies. Also, different degrees of the "butterfly" tendency may appear, with the lint fibers shorter at the base of the seed than at the tip. After the lint is removed from the seeds other slight differences may be perceptible in the coating of fuzz that is left on the surface of the seeds. The length, color, abundance, and distribution of the short fuzz fibers are subject to slight but consistent changes as between the progeny rows. The seed of some progenies may appear to germinate more promptly or more regularly than others, or the seedlings may grow more rapidly, but such differences may be determined by planting depths or by the relation of the rows to the plow furrows.

Similar indications of progeny drift have been observed in select stocks of other varieties of cotton, such as Lone Star, Durango, Kakchi, and Mende, as well as in Egyptian and sea-island cotton. Though progeny drift is hardly to be claimed as a new fact, it apparently has not been studied or viewed as an evidence of the nature of heredity.

In view of the uniformity of the rows and of the slight and consistent nature of the progeny-drift differences between the rows, this class of variations apparently should not be interpreted as a residual of diversity from previous crossing, but rather as arising in the parent plants, though in most cases it may be too slight to be detected in a single individual. The differences are usually so slight that they become perceptible only when they are projected into progenies, so that collective impressions can be formed and compared.²

SIGNIFICANCE OF PROGENY DRIFT

The progeny drift indicates that the breeder is not dealing with heredity as a system which is constant or capable of being definitely fixed in a uniform set of characters, but rather with a system which is essentially versatile, having an inherent and constitutional propensity to change. Though the changes as shown among the

² As a formal name for progeny drift, such a term as "genorhep" may be useful. The Greek word rhaphe means to bend one way or another, also to wave, shift, or show a tendency. The word genorhep might be defined as a very slight progeny variation, a barely perceptible difference between progenies which have been selected to represent the same type of a variety, as observed in upland cotton.
progenies may seem to be restricted to rather slight differences, a condition of complete and absolute uniformity is not attained.

The slight differences that are found among progenies, even in stocks that are carefully selected, may be of interest from another viewpoint. It is possible that the crossing of lines of descent, even inside the slight progeny-drift diversity of a type population, may retain something of vigor and stability in the stock without inducing the greater diversities which are involved in the crossing of different types of plants. A practical uniformity of fiber characters may be obtained even from plants that are appreciably different, and crossing among these slightly different plants does not produce such a diversity of fiber characters as appears when widely distinct forms are hybridized, such as Egyptian and upland, or upland and sea-island cotton. As absolute uniformity of characters may not be expected, it is in order to consider the range of the minor differences that may exist within the practical uniformity of a carefully selected type, as already enumerated.

The formation of composite stocks by bringing together a collection of desirable types and allowing them to cross, in order to build up superior combinations of characters, was suggested by Allard (1910) in the following paragraphs:

In fields of carefully bred and selected cotton, on the other hand, intercrossing is probably a beneficial process. As a result of a more or less complete blending of parental characters in the complicated processes of inheritance, a start made with a number of pure, superior, and uniform types followed by intercrossing must tend to bind very closely within the heredity mechanism of the future plants the original parental characteristics. Promiscuous natural crossing is undoubtedly one of the most potent factors producing variability in a cotton field. A vast amount of the so-called inexplicable fortuitous variation is without doubt traceable to this cause. A number of very promising distinct long staple types which have been grown several years in the experimental fields in Georgia surrounded by varieties and hybrids of all sorts have finally become, through natural crossing, almost hopelessly swamped with hybrid types of every conceivable sort.

A plant that appears to be a mutant may have resulted from some new complexity of parentage induced by intercrossing. Why should not endless readjustments of the hereditary forces tend to produce exceptional plants far more surely than by any process of pure mutation? This writer feels that this very phase of natural crossing is a most important basis for further improvement in cotton. What led to the origination of the striking Columbia variety? Was it the result of what we term mutation forces, or was it due to some interchange of the hereditary units? One of the most promising upland long-staple strains the writer has ever seen gives strong evidence of a cross in the past.

That interesting results might be obtained from such an experiment, carefully conducted through a sufficient period of years, may not be denied, though a uniform product would not be expected unless selection to single separate types were subsequently applied. The present proposal is different to the extent that only a single type is included, although the state of theoretical purity is not attained, in that the individual lines of descent are not absolute duplicates.

Allard's suggestion that mass selection be used as a means of building up a superior type would not be inconsistent with a subsequent use of type selection to maintain such a type after it had been developed. On the other hand, the mixture of widely diverse types brings in the element of degeneration from crossing, a fact that Allard recognizes. This danger is avoided by adapting a type al-
It remains to be determined whether the crossing that still may take place among the very slightly different type progenies has any appreciable effect, beneficial or otherwise.

De Vries (42, p. 100) has observed that selection has a double meaning, first, "the distinction and isolation of constant races from mixtures," and second, "the choice of the best representatives of a race during all the years of its existence." The recognition and segregation of a desirable type, and its subsequent preservation by selection, would seem to be implied. It is plain from the context that the reference to constant races is not to be taken in the sense of a fixed or uniform condition of heredity.

Selection applied to cotton with the idea of continued improvement may take a different line from that for maintaining the type. The development of a high-producing strain might be attempted without recognizing the need of holding to a particular type of plant in the interest of uniformity and stability of the characters. The apparent effect of selection would be most pronounced under such a system, since a rapid regression would be taking place as a reaction from the crossing of diverse types.

That it may be possible to eliminate some or all of the perceptible progeny-drift differences by continued selection and self-fertilization in separate lines of descent is doubtless to be expected, but an early attainment of complete uniformity is not indicated by experience with self-fertilized strains of Acala and other upland varieties. Acala progenies from self-fertilized strains have not appeared to be more uniform than those produced in the usual progeny blocks. For practical purposes, an effort to establish a condition of absolute uniformity in the type would be justified only under the belief that a condition may be reached in which continued selection would become unnecessary, which apparently is not indicated.

**COTTON VARIATIONS UNDERLYING THE APPLICATION OF SELECTION**

**INDIVIDUAL BOLL FLUCTUATIONS**

Progeny comparisons have shown that some of the individual plants display a greater tendency than others to produce the variant forms of bolls, so that slight differences in these respects among the progenies of such plants are indicated in advance. This is not to say that all of the individual boll fluctuations are of significance in heredity, but when a consistency of departure in boll forms is found, so that a consistency of departure in boll forms is found, so that the aberrant bolls of one progeny or of one plant are different from those of another, a tendency to variation may be indicated.

In the case of plants that give no other suggestion of genetic differences. A single boll of the broad, the narrow, or the rounded forms shown at the middle and the right of Plate 4 might be passed as of no significance in plants with the more normal boll forms shown at the left of that plate, but not an occurrence of several bolls of the same divergent form. The three upper bolls of Plate 4 were from one plant, the two lower bolls from another, and the variant bolls of the two plants were more different than the normal bolls. This peculiarity might be expected to show in the progeny of a plant having several of the variant bolls, though in other respects divergence
from the type might not be detected in advance. Of course, allowance must be made in comparisons of boll forms for differences in the number of locks. Thus, the narrow boll at the middle of Plate 4 had only four locks, while the other bolls had five.

**ABNORMAL VARIATIONS OF BOLLS**

Caution has also been advised against the selection of cluster plants and of plants that show deformities of the bolls, which often are associated with the cluster habit. A statement regarding these features is as follows (23, p. 25):

> The bolls of the cluster variations of Acala commonly are shorter and broader than those of adjacent normal individuals, and often the broader bolls show distinct grooves or folds at the tips, along the sutures between the carpels. These “split-nose” bolls with partly open sutures are to be recognized as a deformity, comparable to the barrel defect in animals. The tendency to open sutures, as well as the cluster tendency, should be carefully avoided in the selection of superior plants to maintain the seed stocks of Acala or of other varieties.

> The open sutures render such bolls more accessible to fungi and bacteria, and in some localities serious losses may result from mildew or rotting that begins at the tip of the boll. Such deformities of the bolls are not confined to Acala cotton, but are even more common in Lone Star and other varieties. Plantings of Lone Star and Acala at Manchester, N. C., near Fayetteville, have shown large numbers of bolls with open sutures, and these are often accompanied by rounded protuberances at the base of the bolls, alternating with the carpels.

> Other examples of the extra grooves at the apex of the bolls are shown in Plates 18 and 19. This variation is considered morphologically as a partial reversion to a primitive condition of open sutures between the carpels, which in normal bolls are completely obliterated. This interpretation apparently is confirmed by cases of greater abnormality that sometimes occur, as shown in Plate 19. Some of the open sutures extend the entire length of the boll, intermediate between the smaller grooves that mark the fissures where the opening of normal bolls takes place.

> The basal protuberances of the bolls also occur frequently in the Texas big-boll cottons, and possibly are to be associated with the intracalicary organs described in an earlier paper on the general anatomy of the cotton plant (25).

> The intracalicary organs, as was noted in the original description, are small flaps or protuberances standing inside the calyx and placed alternately with the calyx lobes. Another series of rudimentary organs is often to be found inside the boll as supernumerary carpels. Thus there are three kinds of floral abnormalities which may be of the same general nature, that is, they may be considered as rudiments of supernumerary organs. It has been noted in many cases that more of these abnormalities appeared in the late-season bolls than in bolls that had developed on the same plants earlier in the season. But even in the late-season bolls more tendencies to abnormalities were shown on some of the plants than on neighboring individuals, so that in these features also slightly different tendencies of individual variation may be detected.

> A slight departure from the type, which may be difficult to detect and of no practical importance in itself, may serve to indicate tendencies of variation toward abnormality, as stated in the discussion of progeny drift. The forms of bolls in a selection of Acala cotton
at Shafter, Calif., as shown in Plate 16, are only slightly broader and more triangular in outline than the normal Acala type, but the differences are consistent. Under widely different conditions, at James Island, S. C., in 1927, the Shafter selection showed a much narrower boll form, as did other strains of Acala, but the distinctive features of more sloping tips and more abruptly narrowed bases were retained, with the greatest width of the boll nearer the base. The forms of bolls at James Island are shown in Plates 9 and 10; they should be compared with Plates 14, 15, and 16, illustrating bolls of the same stock at Shafter. These in turn are to be compared with the examples of normal boll forms shown in Plates 1 to 4.

The departure from the normal Acala type in the Shafter selection appears much more definite when bolls of the form shown in Plate 15 are found to be common, though a few bolls of the more oval normal form continue to appear, as may be seen in the larger series of bolls of this selection in Plate 16. Many of these bolls show the apical grooves and basal tuberosities which were associated with the cluster tendency in the statement quoted above from the publication of 1927. Not only a general cluster tendency is apparent in the plants of the Shafter selection, but pronounced cluster variations occur rather frequently. The association of the cluster habit and aberrant boll forms as indications of abnormal tendencies therefore seems warranted.

**UNIFORMITY AN ESSENTIAL IN COTTON BREEDING**

The problems of selection may be better understood by taking account of the different forms or factors of diversity that need to be removed or held in check in order to produce heavy yields of good fiber. Though any features of diversity are of interest from the breeding standpoint, the fiber and yield characters are of primary importance and afford a useful background for a more practical consideration of the problems of selection as actually encountered in choosing and maintaining a superior type.

The fiber characters and the yield characters are alike in one respect, in that they are not definitely known till the end of the growing season, so that preliminary selection must be made on the basis of other features. Also both groups include several characters which are essentially distinct, though they are easily confused in a common result. As yet there has been no adequate analysis of either group of characters, but the subject may be opened to further study by a preliminary sketch. Much fiber is classed as irregular without any effort being made to determine the cause or to distinguish the different kinds of irregularity that may be represented in commercial samples. Yield differences also have remained very obscure and inconsistent, for lack of knowledge of the ways in which the behavior of the varieties may be affected in different places or in different seasons.

Differences in plant characters might seem to be of small significance in cotton, since only the seed characters are of direct economic importance, the cotton fiber being an outgrowth from the seed. Yet the seed characters are reflected in many ways in the plant characters, and these relations of plant and seed characters are the keys to the application of selection.
COTTON IMPROVEMENT THROUGH TYPE SELECTION

EFFECTS OF MIXING AND CROSSING

As already indicated, the general diversity of fiber in commercial cotton is contributed largely by the fact that the plants in the fields are different from one another and for this essential reason produce different lengths and qualities of fiber. This factor of diversity is due to the neglect of selection, the mixing of seed of different varieties at the public gins, and the crossing of different kinds of plants in the fields. Much of the cotton crop, therefore, is produced from badly mongrelized seed which can yield only irregular fiber, even under favorable conditions of growth.

Without an examination of the fiber, or even in advance of the opening of any of the bolls, the diversity of plant characters in a field of cotton may show very definitely that the stock is mixed or inferior and that a crop of uniform fiber is not to be expected. The diversity of plant characters is a practical index of diversity of fiber characters, and it is only by careful selection and guarding of seed stocks that this general factor of diversity is to be removed.

A mistaken idea is often encountered, that the yields can be increased or the staple improved by mixing seed of different varieties, which is sometimes done deliberately. The value of hybrid varieties in other crop plants is taken to indicate that similar advantages may be obtained in cotton, and the seed is mixed so that crossing can take place. Also mixing is suggested to some farmers by noticing hybrid plants in the fields, which often are larger and more productive than either of the parent varieties, especially where grown under adverse conditions.

The immediate effect of crossing, as shown by the superior hybrids which appear in the first generation of crosses between upland and Egyptian cotton, or between upland and sea-island cotton, is very misleading. In such crosses between the widely different species, only the first generation of the hybrids is productive, with the plants and the fiber uniform. In the second and later generations great diversity appears, with many of the plants abnormal, the fiber very irregular, and many individuals partly or completely sterile.

It might be supposed that good types could be established by selection among the hybrids, but this has not proved feasible, as the breaking-up process continues for many generations. A series of hybrids between upland and sea-island cotton was carried for 12 generations with no indication of finding uniform progenies. Also many such experiments have been made with the upland and Egyptian cottons, but no uniform hybrid stocks have been obtained. Such hybrids are in a different category from crosses of closely related varieties or strains of the same species of cotton. The effect of crossing between related varieties is to induce somewhat greater variation rather than to cause serious abnormality.

The first generation of a cross between different varieties often shows a notably greater resistance to unfavorable conditions and greater productiveness than adjacent rows of plants grown from pure stocks of seed, so that some of the reports of higher yields from gin-run seed than from well-selected stocks may be explained as results of crossing. In districts where many farmers have good stocks of seed it is possible for large numbers of true first-generation
crosses to be formed as a consequence of mixing. With varieties that are similar, like those of the Texas big-boll series, mixtures are more difficult to detect, since the crosses are not distinguished readily from the parent varieties. The advantage to be obtained from such crosses would depend on the nature of the parent stocks. If the parent stocks have been selected for uniformity alone, or without adequate testing of progenies, they may be low in productivity in comparison with first-generation crosses.

The effects of crossing different varieties of upland cotton have been investigated only to a slight extent, either from the standpoint of determining how far the vigor and fertility are increased in the first generations of such crosses or by following the effects of crossing into the second and later generations, to see whether diversity and degeneracy appeared. Lint from a first-generation hybrid between the Triumph or Mebane cotton and Durango, photographed in 1910, is shown in Plate 20, in comparison with lint from the parent varieties. The lint was somewhat longer than in the Durango parent, but was unlike either of the parent varieties in being "butterfly"; that is, with the fibers shorter at the base of the seed than at the tip. The "butterfly" character in this case may be considered as a reversion or reappearance of an ancestral feature, like the blue hybrid pigeons produced by crossing two white varieties.

In corn culture it is possible to make use of the increased vigor of the first-generation hybrids, since hybrid seed can be produced in practical quantities by the simple operation of planting two varieties in alternate rows and cutting off the tassels of one variety. This method of quantity production of hybrid seed is not applicable to the cotton plant, in the absence of a specialized male inflorescence like the corn tassel. The only possibility thus far indicated of producing cotton fiber of uniform quality from hybrids is by propagation from cuttings, which under some conditions are readily rooted. In districts where the plants live through the winter, several crops may be obtained without replanting. Apart from such expedients, which as yet have not been tested, no prospect can be seen of hybrids being utilized in the production of cotton, because the mixed stocks produce irregular fiber in the second and later generations. Not only must mixing and deterioration of seed stocks be avoided, but careful selection and roguing applied, but other causes of uneven fiber must be recognized and eliminated as far as possible. The danger of mistaking hybrid plants for desirable variations is avoided under the method of type selection.

DIVERSITY IN FIBER CHARACTERS

The analysis of commercial samples has now been carried to the point that machines have been invented for sorting and laying out the fibers according to length, so that the length composition of the samples can be more accurately determined. But such analysis affords little indication of the causes of the differences in the lengths of the fibers. The different elements of irregularity must be distinguished, if the problem of uniformity is to be solved effectively. The facts must be interpreted by tracing the differences back to the seed stocks or to the conditions of production in the field.
Three general factors or forms of diversity that contribute to the differences found in commercial cotton fiber may be recognized in the field. Some of the fiber difference can be traced to differences among the plants, some to differences among the fibers that grow on the same seed, and some to differences in conditions of production. For breeding purposes the three kinds of differences should be especially considered, because different characters of the plants are involved and different methods of selection are required to eliminate or reduce the different forms. The several factors contributing to the different forms of diversity should be recognized and appreciated in order to make proper distinctions in textile quality and value between different lots of cotton. The careful analysis that is now being applied by investigators of the textile characters of cotton fibers will have further meaning when the differences that are established are traced back to the fields and are understood in their natural relation to the production features.

A fourth class of differences are those introduced by carelessness or defective machinery in handling or ginning the cotton. Cotton may be picked carelessly or left too long in the fields. Cotton that is ginned when it is wet often is badly damaged. But such differences should not be confused with those that can be recognized while the plants are growing or before the cotton is picked.

**Fiber Differences on the Same Seed**

All of the fiber differences are not removed by having the plants alike and of one kind in the field, because differences are also to be found among the fibers produced on the same plant and even on the same seed. Each fiber grows out as a separate cell from the surface of the seed and may be said to have an individuality of its own. The conditions of growth may affect the length and strength of the fibers and make them irregular, but even under good conditions different kinds of fibers are found together on the same seeds. Usually there are two kinds of fibers that are easily distinguished—the long lint fibers that are taken off in ginning and the short fuzz fibers that remain on the seed. In most of the varieties of upland cotton the fuzz fibers are abundant and form a complete covering of the seed, so that even after ginning the seeds still appear white. Some varieties have less fuzz, and the black seed coat shows through, giving the seeds a grayish color. A few varieties are distinguished by greenish or brownish fuzz.

The specialization of two forms of hairs, the lint fibers and the fuzz fibers, is more definite in some kinds of cotton than in others, and variations sometimes occur with fibers intermediate in character between fuzz and lint. The so-called “Texas wool” cotton with soft greenish lint may be considered as such an intermediate expression of the characters, having the length of normal lint fibers combined with the bluish-green color and soft texture of the fuzz fibers. In many upland varieties the fuzz fibers often show a greenish or brownish color although the lint fibers are pure white. In some of the tropical cottons the lint as well as the fuzz has a brownish color, even a deep rusty brown in some cases, though most of the so-called brown cottons are only slightly tinged with a very light brownish or tan color.
Varieties with white fuzz are preferred because greenish or brownish fuzz may give a tinge to the cotton, especially when excess linters are run into the bales by ginning too close. Varieties with colored fuzz would have a natural protection against overginnen, as an excess of colored linters could readily be seen, while the presence of white linters is seldom recognized, even as a cause of neps and waste. The intermediate stages between lint fibers and fuzz fibers are not desirable, as they add to the quantity of substaple which contributes to the waste in spinning or remains on the seed after ginning and passes into the linters. If the fuzz fibers are long enough to be tangled into neps, the cotton is rendered less valuable for spinning purposes. Seeds with too much fuzz or short fibers should be avoided in selection and the normal separation maintained between the fuzz and the lint fibers. In a study of such relations in the Columbian cotton, the longest and most uniform lint was found in connection with uniform short fuzz on the seeds rather than with the seeds that had the longest and most abundant fuzz.

"Butterfly" cotton

Inequalities of the lint fibers also are easily seen. With the lint combed straight on the seed, the fibers at the base of the seed, around the point of attachment, often are found to be much shorter than the fibers at the other end of the seed. In some cases the lint at the base of the seed is only half as long as that at the tip, or the basal fibers may be nearly equal to the others. When the inequality of the fibers is apparent the cotton is said to be "butterfly," since the combed samples with the longer fibers at the top suggest the form of a butterfly. The long fibers may be lacking only at the base of the seed or may be restricted to a small area at the top. Examples of unequal butterfly fibers are given in Plates 20 and 21. The first instance is that of a hybrid between the Mebane and Durango varieties, while the second shows reversions to butterfly fiber in a progeny from an off-type Acala plant.

From the form of the combed samples it is plain that butterfly cotton is undesirable on account of the irregular staple length, and variations showing this tendency are always to be rejected. This precaution is continually needed, as the tendency to butterfly variations is very general, though much more pronounced in some varieties and lines of descent than in others. Most of the eastern small-boll varieties of upland cotton show strong butterfly tendencies. A historical example of butterfly cotton was the variety called Floradora, which, on account of this defect, gained an undesirable prominence at the beginning of the present century. The Floradora was recommended as an earlier and more productive variety of upland long-staple cotton and at first was well received, but when the stage of commercial production was reached the reaction among the manufacturers was very unfavorable, as the fiber was found to be very irregular. The reason was not known to the buyers, though obvious enough in the field, as Floradora showed the butterfly character to an extreme degree. The variation in length of fiber on parts of the same seed sometimes was nearly an inch. The fibers at the top of the seed attained nearly an inch and a half in length, while those at the base of the seed sometimes were only half an inch long. That
such a cotton was selected and placed in cultivation is a striking example of disregard of an essential character.

ESTIMATION OF SUSTAPLE

In addition to the shorter fibers at the base of the seed, as seen especially in butterfly cotton, short lint fibers are always to be found among the long fibers on other parts of the seed in all kinds of cotton. Although such fiber inequalities are universal, in the sense that they occur in all varieties, varying proportions of the short sub-staple fibers are to be expected, not only as between different varieties, but also in the same variety under different conditions of growth. Even under the most favorable conditions the fibers are not of the same length, even within an eighth or a quarter of an inch. Many fibers much below the commercial staple length of the cotton are always to be found.

That cottons of all varieties have substaple or under fiber can readily be seen by pulling out the long fibers from combed samples and leaving the short fibers attached to the seed. An approximate separation of fibers of different lengths can be made in this way, which can be used for discrimination of varieties or strains of cotton as one of the precautions in selection, or for showing the effects of adverse conditions. The operation of pulling out the longer fibers should be performed somewhat gradually, to avoid loosening the short fibers and also to make a more careful separation into the different lengths of staple.

FIBER AFFECTED BY STRESS CONDITIONS

Where stress conditions are severe and the growth of the plants is checked suddenly, as often occurs in the irrigated districts of the Southwest, the size of the bolls and the development of the seeds and fiber in the bolls are also affected. One of the first effects of severe stress conditions is that all of the floral buds and young bolls may be shed. Other bolls are checked in their growth and fail to develop the normal number or weight of seeds. Abortion of seeds may occur at any stage of growth, from the small ovules that form the motes to seeds that reach nearly the full size but have shriveled kernels and weakened or “perished” lint. Even on the seeds that do not abort, the lint fibers do not grow to full length, and the walls of the fibers remain thin and weak. The shortening of fiber by stress conditions often is readily perceptible, and bolls of the same plant frequently may show such differences, which sometimes are taken to indicate that the seed has been mixed. An example of shortening of fiber by stress conditions may be found in the department Yearbook of Agriculture, 1928 (21, p. 239).

With the varying degrees of stress and of impaired growth of the fibers in bolls of different sizes, every stage of irregularity of fiber and of variation in the proportions of substaple may be expected in commercial samples from the irrigated districts. The damage to the fiber from stress conditions is readily perceptible in the fields, not only by examining the fiber from the injured bolls but even by noting the general development of the bolls and the behavior of the plants. The small, stunted, “pinched” bolls fail to
open properly and are found not to contain normal, well-developed fiber.

High turnouts at the gin may be obtained from fields that have suffered from stress conditions, but should not be taken as evidence that the crop is good, that the fiber is of normal quality, or that the seed is of special value. A very high turnout often results from the seed being light, since in periods of drought the kernel may be aborted even after the fiber has developed.

Later pickings may be inferior to earlier pickings of the same fields. Stress conditions may act more severely on plants that have set a full crop than on those that are developing only a few bolls, so that the fiber of the low-yielding plants may be appreciably better. Picking may be delayed for long periods, especially in the irrigated districts, and the exposure of the cotton in the open bolls may affect the quality of the fiber.

In order to have comparative tests of the strength or other spinning qualities of fiber of different varieties or strains of cotton it is necessary that the test material be grown under the same conditions, preferably in alternating blocks as required for definite yield comparisons. Such material was obtained from a series of experimental plantings of several well-known varieties in Texas in the seasons of 1923, 1924, and 1925. The spinning tests by the Bureau of Agricultural Economics were concluded in 1928 and showed a notable advantage for the Acala variety in the breaking strength of the yarn. The other varieties, in the order of breaking strength of the yarn, were Kekchi, Lone Star, Rowden, and Kasch.

Studies of the occurrence of abortive seeds, or motes, in upland cotton have been reported by Ren (37, 38, 39). Many upland varieties, including Acala, were examined, and motes were found in all, the proportion varying with the varieties and with the seasonal conditions and increasing in dry seasons. Abortive ovules are found more frequently at the base of the lock, and in that position may be considered as normal for some varieties, in view of their general occurrence. Another reason for considering the basal motes separately is that they do not break the locks and render clean picking more difficult, as results from the occurrence of motes in intermediate positions. Where the abortion of seeds is induced by stress conditions, larger proportions of the seeds may be expected to abort in prolific varieties like Acala than in those that set fewer bolls.

**VISIBLE AND INVISIBLE CHARACTERS**

The need for maintaining the adaptive characters of varieties adds new elements of complexity to the breeding problems, since some of the most important characters are not of a nature to be directly visible or are perceptible only under certain conditions. The visible changes can be recognized at once as departures from the type and are readily removed; but other changes may occur which, although not visible at the time or while the same conditions continue, may become apparent in later generations, after the stock is placed under other conditions.

The visible changes do not cause serious difficulties in the breeding of cotton when the method of type selection is applied. The plants that adhere to the type in their external, visible characters also are
found to have the seed and lint characters of the type. This is a matter of observation, which any breeder or student of genetics should be able to verify for himself by becoming familiar with the plants. A close association exists between the external characters of the plants and the seed and lint characters, not in the sense that particular characters of the plants have been found to be linked with particular characters of the seed, but in the more general sense that departures from the type in plant characters generally are accompanied by differences in lint and seed characters, so that retention of the plant type is a practical protection of the uniformity of the lint.

It is possible that particular departures from the type in plant characters may be correlated with particular departures in lint characters or in adaptations to conditions, but this has not been determined.

Though a single difference may distinguish an off-type plant, so that it may be rogued out at once, definite variation in a single character seldom if ever occurs. Such cases have been unsuccessfully sought for many years. If one feature of a plant appears definitely different from the type, other off-type features usually are not difficult to find. The new complex of characters often comes true from seed, and may be maintained through many generations of offspring without returning to the characters of the normal type. A narrow-leaf variation of the Acala cotton has been selected carefully for numerous generations, but has not shown the characters of boll or lint of the normal Acala type. It is known that many of these complex variations behave as unit characters when hybrids are made.

Some of the differences between the Lone Star and the Triumph or Mebane varieties will serve as illustrations of invisible characters. The external, visible differences between these varieties are relatively slight and much less important than the internal, physiological differences. The bolls of Lone Star are slightly larger, the fiber usually about one-sixteenth of an inch longer, and the seed also slightly larger, but differences in these characters may be so small as to escape detection, even by breeding experts. The most important difference, and one that might be termed an invisible character difference, is that the Lone Star is somewhat more vigorous and productive, often continuing to set more fruit after growth and fruiting have stopped in the Mebane. Checking of growth in the Mebane cotton may open the bolls in advance of the Lone Star, though the first picking from Lone Star may be larger; also the later pickings of Lone Star are often larger, on account of continued growth of the plants in the latter part of the season.

Lodging of the stalks is another difference between these varieties that in many plantings may not be perceptible, but it sometimes appears very important. Lodging occurs only where the plants grow large and are heavily loaded with fruit. All varieties may lodge where the growth is too rank for the stalks to support the weight of the plant, but marked differences in lodging may appear. The Lone Star may remain erect while the Mebane under the same conditions becomes entirely prostrate. At the next stage of luxuriance, Lone Star also becomes lodged, but the stalks of the Acala are still stronger, so that in several tests the Acala plants have stood
erect where both of the Texas varieties lay flat on the ground. Not only is picking more difficult where the cotton is lodged, but many of the bolls may be rotted by lying on the ground. Half of the crop may be lost in this way.

Differences in susceptibility to adverse conditions, though not perceptible in good fields, become obvious enough where stress conditions occur. In one place the plants may appear closely alike, while in another place notable differences are shown, even to an extent that may seriously affect the production of a crop. It may be reflected in such cases that the constitution of the plants rather than their external characters determines the success of production. Such a distinction may be useful in general discussions of the breeding problems, but should be applied with caution, since the nature of the constitutional differences remains to be determined. Some of them may be connected with definite unit differences in the plants, as observed among the visible characters, while others may arise from varying degrees of stability or coordination of the characters as balancing or reacting upon each other in the course of development.

The hereditary constitutions of the plants may vary in different lines of descent with respect to the control or adjustment of the characters, in addition to other differences. The location of the hereditary elements in the chromatin material of the germ cells and the specialized behavior of this material during reproduction and development are great advances of knowledge, but as yet there is no conception of how the characters are represented in transmission or how they are brought to expression in the development of the individual.

Many of the external characters or differences of varieties apparently have no use, at least in the sense that they have no direct or obvious relation to production. Some of the differences serve as marks of recognition for the types that have been separated as desirable; but this separation by visible characters, though it may be very important from the standpoint of establishing and maintaining the uniformity of seed stocks, does not afford a complete and adequate discrimination of all of the differences that may be found, even in the best and most carefully selected strains.

Physiological mutations may be expected to occur, as well as changes in visible characters, and may result in a decline of vigor or fertility or a greater susceptibility to adverse conditions. Undoubtedly there are internal characters which are not of any direct use or value under some conditions, but may be very important in other places. Care should be taken not to lose any of the useful characters of a variety, though their expression may be limited to particular conditions.

With uniformity in the visible characters maintained by type selection, it becomes possible to conduct more effective selection of the invisible characters, such as earliness and resistance to stress conditions. Such differences will explain why seed of the same stock may produce uniform plants under some conditions, while under other conditions the plants appear more irregular. The differences in the reactions to the conditions could not be detected if other forms of diversity were included in the experiments. The larger differences, as in habits of growth and branching of the plants or in
other structural features, would mask the smaller differences and complicate the questions of determining the strength or weakness of particular lines of descent in the presence of adverse conditions.

**EARLINESS CHARACTERS**

Earliness may be reckoned among the adaptive or physiological characters that are expressed in the behavior of the plant rather than in its morphological features, though certain of the visible differences are not without significance in relation to earliness. Since the arrival of the boll weevil, earliness has been considered as one of the principal characters in determining the yield, and has received special study. The problem of earliness in cotton is much more complicated than breeders have recognized in the past.

As might have been inferred from the inconsistent behavior of varieties in tests of earliness, several distinct characters are involved, which need to be distinguished before a clear understanding can be reached of the earliness problem as a whole. Each character that contributes to earliness needs to be considered separately, since different earliness characters may be significant in different experiments or at different stages of development of the crop in the same experiment. The relative importance of the characters varies widely with the seasons. Experience has shown that some of the earliest varieties are practically worthless for purposes of production, but claims of special earliness are still used to advertise inferior sorts.

Earliness has been emphasized greatly in recent years, because the usual effect of boll-weevil injury is to shorten the period of setting the crop. With the spread of the weevils through the Cotton Belt late varieties were discarded because they were found to suffer more injury than the early ones. Attention turned generally to the breeding of extra-early varieties, and any character that could be connected with earliness was supposed to be valuable. Many tests were made to determine which varieties produced the first flowers, or the first open bolls, or gave the largest yields at the first picking, in the belief that these characters were very important. Also increased earliness was sought in such characters as the placing of fruiting branches lower down on the main stalk, or the shortening of the joints of the fruiting branches as in the cluster cottons.

In some of these projects the essential feature of earliness was overlooked. The practical object in earliness is not to advance the initial date of fruiting or flowering, but to produce the crop as rapidly as possible after fruiting begins. The earliest varieties are those that can produce the largest crops under short-season conditions, and this is the standard of earliness applied to the Acala cotton. The earliness characters, the methods of breeding for earliness, and the cultural methods of inducing earliness should be considered from the standpoint of total production of the crop without placing an exclusive emphasis on any feature.

**EARLINESS IN HABITS OF GROWTH**

Some earliness characters are connected with the habits of growth. The production of fruiting branches at the lower nodes of the main stalk, nearer to the seed leaves, enables some varieties to produce
flowers and bolls a few days earlier than others, but this character is
of doubtful value for practical purposes. Bolls too near the ground
are in greater danger of being soiled or rotted.

Another limitation of earliness is that if bolls are set when the
plants are too small less growth may be made and fewer bolls pro-
duced. Plants that have set only one or two bolls may stop growing
in periods of dry weather, while neighboring individuals or rows
that were planted somewhat later and have not begun to fruit will
continue to grow and are able to set larger crops when more favor-
able weather comes. Thus it is possible for varieties to be very early
and yet make so little growth that only a small crop is produced.
Examples of this behavior were noted especially in the Foster variety,
which sometimes showed the earliest flowers and the first open bolls,
but yielded only a small crop.

A determinate habit, with a definite cessation of growth of plants
after a crop has been set, has been reckoned as a desirable character,
tending to earlier maturity of the crop under short-season conditions.
In practice it may be difficult to distinguish between a determinate
habit and a greater susceptibility to checking by adverse conditions.
The difficulty in making practical use of a determinate habit is that
if the plants stop growing they may lose time and produce smaller
crops than varieties that continue to grow and are able to set fruit
as long as conditions are favorable. A variety that stops growing
in midsaison, though it may open all of its bolls, is not to be valued
on that account as an early variety, unless it is found by adequate
tests to produce larger or better crops.

Earliness has practical value only in districts that can produce
paying crops with reasonable regularity. In localities where the
seasons frequently are too short for the bolls to open, so that practical
yields of cotton are not produced, the climatic barrier should be
recognized instead of placing hopes in obtaining the much-earlier
varieties that would be required to avoid the cool weather conditions
in the fall. The tests have shown that Acala is a very early variety,
with as good a prospect as any other of maturing a good crop under
short-season conditions. Many of the tests have been made in Cali-
\[\Rightarrow\]fornia and leave no doubt that Acala is more productive than Mebane
or Lone Star, as well as producing a longer staple.

Efforts are made to grow cotton in districts where the seasons are
too short, as in the northern part of the San Joaquin Valley in
\[\Rightarrow\]alifornia and in the Sacramento Valley. The periods between
frosts may be as long as in some of the recognized cotton-growing
districts, and good crops of bolls may develop, but cool weather often
comes too early for the bolls to open. Favorable seasons may show
encouraging results, but in other years little or none of the cotton
can be harvested. Many comparisons of other varieties with Acala
have been made to determine their behavior under marginal condi-
tions. Plantings at the United States Plant Introduction Garden
at Chico, Calif., have continued since 1917.

The Delfos variety occasionally has outyielded the Acala in the tests
conducted in the northern districts, though yields often have been so
small that practical cotton growing is not indicated. Earlier opening
of the bolls is the advantage to be expected in Delfos, since the bolls are
smaller than those of Acala; but the lint percentage or gin turnout is
lower, so that definite advantages in other features would need to be shown. The higher yields of Delfos may be explained by the fact that the seeds are smaller, so that heavier seeding occurs unless the planters are adjusted. The records of the experiments at Chico show that the plants generally were more numerous in the Delfos row sections than in the Acala. Thus a spacing effect is indicated, rather than a larger yield from earlier opening of the bolls in the Delfos variety.

EARLINESS WITH SMALL BOLLS

One variety of upland cotton may be earlier than another because it has smaller bolls that require less time to reach full size or that open more promptly than large bolls. In many comparisons it is found that some of the small-boll varieties of upland cotton begin to open a few days in advance of any of the large-boll varieties. Nevertheless, varieties with small bolls are not preferred, as the expected advantage from greater earliness does not prove to be very important and is counteracted by other less desirable features.

Larger numbers of bolls, of course, must be picked in gathering the same amount of lint from a small-boll variety, and this requires more labor. Fifty or 60 large bolls may yield a pound of seed cotton, while 100 or more small bolls may have to be gathered. Pickers avoid the small-boll cotton and often refuse to gather it at the same price.

Another drawback of the very early small-boll varieties is the short fiber that allows the seed cotton to fall out readily from the open bolls, so that more frequent pickings are required. Otherwise much of the cotton may be lost, especially in stormy weather.

EARLINESS FROM CHECKING OF GROWTH

Apart from the production of early flowers or bolls, some varieties are more susceptible to checking of growth by unfavorable conditions, which often results in earlier opening of the bolls. Plants that have stopped growing may open their bolls with no obvious sign of distress, or the bolls may be dwarfed or "pinched" and opened prematurely. The more persistent fruiting habits of the Acala variety may be said to conflict with that form of earliness which results from checking the growth of the plants by adverse conditions. Varieties that are checked more readily than Acala may begin to open their bolls a few days in advance, but this usually does not mean that larger yields are obtained.

The mistake is frequently made, even among cotton breeders and experiment-station workers, of reporting a variety as late because it continues fruiting after other varieties have ceased, so that green bolls may be found on the plants at the end of the season. Such misunderstandings have occurred in relation to the Lone Star cotton, as well as with the Acala, since either of these varieties may continue growing and fruiting after other varieties have stopped. The Mebane variety often is reckoned as earlier, on account of showing no green bolls at the end of the season, although Acala or Lone Star usually yield more than Mebane, and even the first picking may be larger, as shown in carefully conducted tests. It is only by direct comparisons that such facts can be determined. If any late bolls
are caught by the frost the farmer naturally feels that he has lost a part of his crop, and he may not be aware of advantages already obtained from earlier or more persistent fruiting. The production of late bolls is not inconsistent with earliness, but is a separate character and often of practical advantage.

Early opening of bolls as a result of checking would not be considered as a desirable character, but rather as a weakness to be avoided by selection, especially if it were found that the fiber was not matured properly, which usually is the case with bolls that are opened prematurely in periods of drought. Even apart from injury to the fiber, premature opening of some of the bolls in advance of the main crop is not desirable, as the cotton may be lost by falling to the ground or may be stained or mildewed before the regular picking season arrives.

Cotton that has its growth checked early and matures a small crop of bolls may later put on top growth and set another crop of bolls, but usually too late for them to open before frost. A variety that escapes checking in the summer may open more bolls in the fall than one that began to show open bolls in the summer, as a result of checking. Some varieties stop growing, while others continue under the same conditions. Once the growth is checked, time is lost before it can be started again, so that the earliness and yield relations of varieties often appear to be reversed in different seasons. The varieties have different reactions to the weather conditions, depending partly upon the stages reached in the growth and fruiting of the plants and partly upon the vigor of growth or susceptibility to checking and shedding.

The extra-early varieties, if placed under very favorable conditions where they are not checked in their growth but are able to fruit continuously, may yield well. On the other hand, varieties that make somewhat more growth before fruiting is begun are on a safer rooting for setting good crops of bolls in short periods of favorable conditions, as in weevil-infested regions. Shedding of the early buds or young bolls may even appear as an advantage under severe stress conditions, as enabling a variety to put on a larger crop in a subsequent period of favorable weather than if the early bolls are held. If conditions become definitely unfavorable, as in periods of water shortage or very hot weather in the southeastern valleys, the varieties that have set early bolls are checked more than the others and lose more time before growth is resumed.

EARLINESS INDUCED BY CLOSE SPACING

In the cooler districts, where the growing seasons are shorter, the precaution of closer spacing of the plants in the rows should not be overlooked. No advantage in yield has been shown from leaving the plants more than 6 inches apart. Two plants in a hill 12 inches apart, or a hoe width, is the spacing now generally advised, though wider spacings are still used by many farmers. With moderately open stands, where the plants average 2 to 4 inches apart, cotton that is not thinned often yields more than adjacent rows where wider spacing is given.

Restricting the size of the plants tends to an earlier opening of the bolls. Where close spacings are used under short-season conditions
the advantage may be strikingly shown. In rows where there are no breaks the plants are regularly restricted in size, and all of the bolls may open. At the ends of the rows or where breaks occur plants of larger size may develop, and these may continue their growth too late in the season for the bolls to open before frost.

Cool weather in the fall is a limiting factor of the crop in the more northern districts of California. The plants may stand uninjured, apparently with no change of condition, during several weeks before they are killed by frost. Reference has been made already to experiments at Chico, Calif., where the rows of Delfos cotton had closer stands than the Acala rows and gave higher yields, although in other experiments Acala outyielded Delfos.

Under long-season conditions different spacings of the plants at 6 inches, 1 foot, or even 2 feet may show little difference in the yields; but the yield differences become much more pronounced under short-season conditions and may amount to 50 or even to 100 per cent or more, as demonstrated with Acala cotton at San Antonio, Tex., in 1914. Under the conditions of that experiment the period of setting the crop was restricted to about three weeks, on account of weevil infestation (9, 10, 11, 13, 34).

An effect of close spacing in some cases is to induce an abortion of early flower buds at very small sizes, before they reach the stage of being infested by the boll weevil. This is a notable and frequent effect with the sea-island cotton, but also may occur with upland varieties, especially if checked by dry weather. In such cases it appears that the losses of the first flower buds in early stages of development are more than made good by setting larger numbers of bolls a little later, since the plants make more growth than if the early buds developed, and the breeding of early boll weevils is avoided.

The Acala cotton is somewhat better adapted for close spacing than Mebane or Lone Star, because the Acala plants usually are narrower and more upright. A further advantage of the stronger growth of the main stalk is seen in the rapidity with which new fruiting branches are added, which in turn makes possible a rapid succession of flowers and bolls. The period between the first flowers of successive fruiting branches in upland varieties is two or three days, while the period between successive flowers on the same branches usually is five or six days (31, 33).

EARINESS WITH NARROW LEAVES

Soon after the Acala stock was introduced from Mexico, a narrowleafed variation was found and carried for several years in Texas as a separate selection. Later the narrowleaf stock was transferred to southern California. It seemed that a cotton with more open foliage might be of value from the standpoint of earliness or from that of protection against the boll weevil, either by allowing more of the weevil-infested squares to be dried by the sun or by giving render access to poison.

In several experiments the narrowleaf Acala has matured in advance of any other variety, and in some instances has given the highest yields, especially in places where the seasons are too short for the other cottons to open their bolls. However, in most of the tests the narrowleaf Acala was found less productive, so that a substitu-
tion of this form for the normal broadleaf type could not be advised. Without waiting for such tests to be made, the seed no doubt could have been sold extensively, as the prospective advantages of the narrowleaf feature could be used as effective arguments.

RESISTANCE TO ADVERSE CONDITIONS

The Acala cotton, like other varieties, suffers severely when the extreme conditions of heavy soils and high temperatures are encountered in some of the irrigated valleys of the Southwestern States, but the damage is not greater than in other upland varieties, and often is appreciably less, as shown in many side-by-side comparisons between Acala and other varieties. Where comparisons are not made and serious damage occurs to the Acala fields it is natural to suppose that the variety must be very susceptible, and this view is often taken by farmers who are disappointed with their crops and do not know that careful comparisons of Acala with other varieties have been made.

Since Acala cotton is more prolific than other kinds, it may have more buds or young bolls to shed when periods of sudden and severe stress are encountered. Allowance must be made in such cases for differences in the fruiting state of the plant when the stress periods occur. The practical indication of better adaptation is that the Acala cotton generally is able to yield more than the other upland varieties and to produce better fiber, even under extreme conditions. Only in the Egyptian type of cotton, represented by the Pima variety, has a greater resistance to stress conditions been shown than in the Acala. The upland and Egyptian cottons belong to distinct species with many differences of structure and behavior that affect their environmental reactions. A recent investigation disclosed that the leaf temperatures of the Pima cotton are different from those of the upland varieties (26), and this fact throws new light on the apparent ability of the Pima cotton to endure high temperatures with less injury. From the readier wilting of the leaves it seemed that the Egyptian cottons were injured more by hot weather than the upland varieties, but now it appears that the wilting of the leaves is a protection against the excessive transpiration required by the upland cottons to keep the leaves in a turgid, fresh condition.

Many of the cotton farmers in the irrigated valleys of the Southwest are new settlers from Texas or Oklahoma or other States farther east and are not familiar with the effects of the extreme conditions upon the crop. The different behavior of the cotton naturally is ascribed to the variety, and many efforts are made to get seed from their home States, though such importations are forbidden by the plant-quarantine regulations, in order to keep out the boll weevil and the pink bollworm.

In the early days of the cotton industry in the Imperial Valley it was found that the Durango cotton was more productive than the Triumph or Mebane cotton, and later that the Acala variety was slightly more resistant to adverse conditions than the Durango. Even under very adverse conditions the Acala outyielded the Mebane and Lone Star in a careful test that was made near Calipatria, Calif., in 1925. Conditions have changed in recent years in this valley, and other crops have been substituted for cotton on most of the
better lands. The effects of extreme conditions on the development of the bolls are shown in Plate 22. The extent of the reduction may be seen by comparison with Plate 23, showing full-size open bolls of Acala.

Extremes of heat and dryness are also encountered in the Coachella Valley, but the plants are not so badly injured because the soils and subsoils are much lighter and more open. Most of the flower buds fall off during the stress periods in the summer months, but the plants continue to grow and are able to set heavy crops in August and September. Large yields are obtained, often more than 2 bales to the acre, though in other ways the full possibilities of the variety are not shown. Even in the best fields the bolls are slightly smaller than those produced from the same seed in districts where the extreme conditions do not occur. Also the fiber in the Coachella Valley does not attain the full length or quality of some of the Acala cotton that other districts can produce from the Coachella seed.

Conditions of production in the irrigated valleys are extremely varied. Not only is a wider range of conditions presented than in the eastern Cotton Belt, but also very abrupt changes of conditions. The soils in many localities are uneven, as could be well imagined, often passing in a few yards, or sometimes within a few feet, from gravel or coarse sand too open to hold water to heavy adobe deposits very impervious to water. Even the loamy or silty lands that appear uniform and fertile may be difficult to irrigate, and the behavior of the plants may be very irregular, even in parts of the same field. Land not properly leveled also grows very irregular cotton; the plants in high places are burned and in low places flooded out.

The proportion of damaged cotton varies, of course, with the locality and the season, but is greater in the districts that have the heavy tight soils. Some of the heavy soils produce excellent cotton if the weather conditions are not extreme, but in several of the irrigated valleys periods of very hot weather are likely to occur, and then the cotton on the heavy land suffers severely, even with the best care that can be given.

The effects of the soil irregularities are more definitely understood in districts where only one variety is grown. In other places it is possible to suppose that the particular variety or seed stock is at fault. The farmer who is not satisfied with his crop decides to change his variety, instead of recognizing his errors and learning to be more careful, either in his methods or in his choice of land.

It is a mistake to plant cotton on land that is not adapted and well prepared for it. The cotton that is grown under adverse conditions is of inferior quality and should not be sold in the same lots with good cotton. The production of large quantities of damaged fiber is becoming a serious handicap in the marketing of the cotton from the irrigated valleys. Many of the American manufacturers have condemned all of the irrigated cotton after receiving shipments of irregular, wasty fiber. The usual commercial classing of the fiber often fails to distinguish the stress-damaged cotton.

The only way that has been suggested for avoiding the marketing difficulties is to keep the cotton from the good and bad fields separate. It is not impossible to do this, as the condition of the cotton in the fields is easily recognized by inspection. Even in the same field, good
and bad areas could be separated if the need of such precautions were recognized. As long as the separation is not made, the farmers must not expect to get more for their good cotton than for the damaged and irregular fiber, which determines the basis price. The more discriminating buyers have separated much of the good cotton and shipped it to Europe, leaving the less desirable remainder to be placed in American markets. A single commercial agency is reported to have handled about 73,000 bales of the southwestern cotton for export and less than 500 bales for the American market. The buyers naturally desire to protect themselves as far as possible from paying the farmers higher prices than necessary, but greater discrimination of quality in the primary markets undoubtedly would result in better cotton being grown.

GROWTH IN COOL WEATHER

One of the special characters of the Acala cotton is an ability to grow in cool weather, which appears also in the Kekchi cotton from Guatemala, but not to the same extent in any of the upland varieties previously known in the United States. In several of the experimental plantings notable differences in early development of plants could be seen, with the Acala cotton outgrowing the other varieties with which it was compared, unless the Kekchi also was included. The differences are not shown in all cases, since periods of cool weather are required for the additional growth to become apparent.

Late in the season the tendency to continue growth in cool weather may again be observed in the Acala cotton, after other varieties have become dormant. A striking example of this difference of behavior was seen at Sacaton, Ariz., in November, 1924, in comparisons of Acala with other varieties. After a slight frost had occurred the Lone Star and Mebane varieties, though not appearing to be badly injured, showed no signs of further activity, while the Acala plants in the adjacent rows continued to function and opened many bolls in the normal manner before another frost occurred. The differences were obvious in the field and were amply confirmed by the harvesting of more cotton from the Acala block.

An additional picking was made November 21, in which the Acala block yielded much more than the others. The totals were 51.5 pounds for the Acala block, 18 pounds for the Lone Star, and 29 pounds for the Mebane. The rows of the Acala block varied from 6.3 to 9 pounds, the Lone Star rows from 2 to 3 pounds, and the Mebane rows from 3 to 5.5 pounds.

The Lone Star plot, as noted under date of November 15, 1924, still had a large number of bolls unopened, while the Acala plot had relatively few bolls that were not open. The Lone Star block, on account of the plants being smaller, had somewhat more exposure, which might be expected to assist in drying the soil and opening the bolls. On the other hand, many of the Lone Star plants leaned over or lodged, while the Acala plants stood erect. In general, it appeared that the late bolls of Acala were held at least a foot higher from the ground than those of Lone Star, and this might make a difference in frost injury. The frost had not been sufficient to freeze the bolls through, though many were blackened on one side. Such
injuries may have been less in the Acala block, judging from the bolls that were not yet opened. A neighboring Durango block also had less cotton open than Acala, while in a block of Harveryville it was noted that the cotton in many of the late-opened bolls had not fluffed, so that the locks remained separate and often fell out. The lanes between the Harveryville rows were well strewn with cotton, which did not occur with the other upland varieties, though some of the Pima cotton also fell out.

Tolerance of cold in the Acala cotton may be connected with the fact that this variety was obtained from a table-land district of southern Mexico at an altitude of about 3,000 feet. The summer climate of the plateau regions in Central America is cool and cloudy, and most of the rain falls in that season.

In the native district of the Kekchi cotton, in eastern Guatemala, the summers are so cloudy and wet that cotton is grown in the winter. The only weather that is dry enough to pick the cotton and avoid rotting the seeds is a short period in the spring months. The Kekchi Indians have the custom of planting their cotton in October, so that it can ripen and be gathered in March or April. It is easy to see that selection under such conditions would favor the development of an ability to grow in cool weather.

In view of the natural qualifications for earliness and tolerance of cool weather, the possibility of utilizing the Kekchi cotton in the northern districts of California has been considered, and comparisons have been made with Acala, including several years of experimental plantings at Chico, but the yields have not equaled those of Acala. The Kekchi cotton at Chico appeared in some seasons to be more susceptible to injury by thrips, as the foliage turned brownish in advance of the other varieties. However, this might indicate a greater maturity of the plants, as the Kekchi cotton, when it behaves normally, is an early-maturing, short-season variety.

The ability to grow in cooler weather may explain why the Kekchi cotton has appeared as the highest yielding variety in several experiments in Texas, both at San Antonio and at Clarksville. Also a fact has been observed in Texas which may explain, at least in part, the ability of the Kekchi cotton to make more growth during the cool weather in the spring. The cotyledons or seed leaves grow larger in the Kekchi cotton than in other upland varieties and no doubt function to a greater extent and for a longer period as true leaves. Large cotyledons have not been observed in the Acala cotton, and it is certain that the ability to make more growth in cool weather is not confined to the seedling stage of the plants in either variety. In several of the experimental plantings, in both Texas and California, the Acala and Kekchi cottons have shown late-season flowers and bolls after the other varieties became dormant from the cold. A curious persistence of the flowers of Acala cotton after a night of severe frost was noted at Peoria, Ariz., November 7, 1924. The frost was severe enough to injure exposed surfaces of bolls, as well as to kill all the leaves, but flowers on the same plants survived. In some cases even the bracts were killed, but the petals were uninjured and opened normally.

That the same variety of cotton should be able to outyield other good and hardy varieties both in the hottest and in the coolest dis-
stricts would not be expected and might be considered improbable. Nevertheless, these seemingly contradictory facts may be capable of simple explanations. The hot-weather and cold-weather adaptations no doubt are separate characters, though working in conjunction. Less checking of growth in hot weather allows more advantage to be obtained from the ability to grow in cool weather. The extent of the advantage would differ greatly with localities and also with the seasons. In a warm spring or an open fall other varieties might be on an equal footing with Acala, but in a cool spring or fall the ability of the plants to continue their growth at lower temperatures might have a definite effect upon the crop. The late bolls are caught by the frost in short seasons, which may be very disappointing to the farmer, but the advantage obtained in other seasons should not be forgotten or confused so as to mistake the production of late bolls for a lack of earliness in the variety.

To insure the retention of this important character of the Acala cotton, it is plain that some of the selection work should be done in places and in seasons that would serve to test and distinguish the plants or the progenies with reference to their ability to grow in cool weather.

STRESS EFFECTS AND GROWTH DISORDERS

From the standpoint of heredity, the differences that are shown among plants under adverse conditions may be considered as of two general kinds. Some of the differences are merely responses or accommodations of the plants to irregular conditions, while other differences appear to be inherent in the plants, although they may become perceptible only under extreme conditions. The second class of differences may be said to show that the limits of adjustment to the adverse conditions are not entirely the same, even among the members of carefully selected groups. Also in some cases it appears that stress effects may induce heritable changes of the characters, though this has not been established conclusively.

That the crazy-top abnormalities are not inherited should not be taken to mean that no impairment may occur in the characters of a select type from exposure to severe stress conditions or to growth disorders. Even a slight disturbance of the normal processes of heredity, perhaps only to be distinguished by means of careful experiments, might cause serious injury if a select breeding stock should thereby lose uniformity.

Differences of susceptibility to adverse conditions commonly are supposed to be due to the state of health or vigor of the individuals most affected. Physiological causes are assumed without admitting genetic differences. Allowance, of course, must be made for many differences that may be merely accidental and without significance in breeding or heredity, but there is no warrant for denying that genetic differences also are involved in the reactions to conditions. The stability and adjustment of the characters may be subject to variation, in addition to differences that usually are admitted to exist among the characters themselves. The effects of subjecting a seed stock or a group of progenies to adverse conditions and of making selections under such conditions need to be studied with greater care.
Stress conditions may be so severe as to render all the plants of a variety abnormal, or great differences may be shown in the nature and extent of abnormality. At the extremes of the series of stress effects are the growth disorders or mosaiclike diseases of cotton which have been described in other papers. The crazy-top disorder of cotton in Arizona shows the greatest range of stress effects, and many of the plants are reduced to complete sterility. Some of the affected plants produce seed, and the disorder has not reappeared in the seedlings, but the tests have not been carried to the point of determining whether the quality of a seed stock may not be affected by crazy top or other extreme conditions (19).

The relation of the growth disorders of cotton to mosaic diseases is still undetermined. Some of the disorders do not show the mottling of the leaves which has characterized the typical mosaic diseases, though they are like the mosaic diseases in being manifested only in the new growth of the plants, while the parts that are formed before the onset of the disease remain normal.

Occurrences of the Arizona crazy-top disease in limited spots, often with diseased and normal plants standing indiscriminately in the rows, are favorable to the idea of an insect-borne virus. In Texas the cotton-flea leaf hopper has been suspected of causing the cotton plants to show an abnormal type of growth and become sterile by shedding all their flower buds. Abnormal diversities have been observed in late-season top growth of cotton in Texas, in districts where leaf-hopper injuries have been reported earlier in the season, though no definite relation has been shown (14, 17, 18, 19, 27, 29).

In view of these extreme effects of local conditions, it is in order to determine the possible relations of such conditions to the quality of seed stocks. Though for some reasons it may be desirable to make selections in districts where exposure to adverse conditions is expected, yet it is conceivable that conditions might be too extreme, so that regular breeding and increase of seed stocks in such districts would not be advantageous. It might be found that seed stocks could be damaged, at least in the sense of being rendered more variable. Such impairments of the quality of seed stocks by adverse conditions have not been demonstrated, but are commonly believed to occur. Few farmers would plant seed from a low yield for fear that the variety had run out. The general tendency has been to restrict all efforts at selection to places where the largest yields were obtained. It now appears that this may be a mistaken policy, but difficulties may also be encountered at the other extreme.

A remarkable feature in some of the growth disorders is that the individual plants as they stand in the rows show great diversity in many features of their abnormal growth, not only in habits of branching and foliage characters but also in the ability of the affected individuals to produce flowers and bolls under adverse conditions. Although the apparent intensity of the disease is seen to depend very greatly upon the conditions of growth, yet the nature of the individual diversities apparently has no relation to the intensity of the disease as affected by the conditions. The growth of the crazy-top plants becomes more normal as the conditions become less ex-
treme, but the individual diversities continue to appear wherever the disease can be recognized.

The range of diversity in the growth disorders undoubtedly is abnormal, as well as the other disease symptoms, but similar reactions of less extent may be expected in the expression of characters among members of normal strains under severe stress conditions. Every possibility that adverse conditions can affect the quality of the seed is worthy of investigation, in view of the popular belief in the superior quality of seed that is grown under favorable conditions. Also it remains to be determined whether the more exaggerated abnormalities and diversities that appear in mosaic or crazy-top affections are not intensifications of differences that may exist among normal plants, and hence of a nature to render some plants more susceptible to changes of characters when grown under stress conditions.

FIELD CONDITIONS AND PRECAUTIONS IN SELECTION

CHOICE OF CONDITIONS FOR SELECTION

Conditions that bring forth the greatest expression of differences in a seed stock afford the best opportunity for selection. Cotton plants appear more uniform and the individual differences among the plants are harder to detect at the extremes of growth conditions. With the same stock of cotton planted in different regions, the diversities that can be seen among the plants are much more apparent in some places than in others. The most striking examples of such differences in the extent of diversity have been observed in acclimatization experiments with foreign cottons planted in different districts or in different seasons in the same district. Also similar differences in the extent of diversity have been noted when inspections have been made of the same varieties grown in different localities from the same stocks of seed.

The greatest expression of diversity occurs where the conditions are balanced between good and bad. Soil conditions may be favorable, but periods of hot or dry weather may occur, sufficient to check the growth of the plants and allow the individual differences in vigor and productiveness to become apparent. Differences among the plants under one set of conditions may be so slight as to be very difficult or impossible to detect, but in other places readily perceptible differences may be found.

Notable contrasts were observed between the behavior of the same selections of Durango cotton grown at the different places in Texas in 1907. Under relatively dry conditions at Del Rio obvious differences were shown between two selections that were compared in detail, while under more humid conditions at Victoria only slight differences could be detected, which in all probability would not have been recognized except for the previous study of the characters at Del Rio. The plants at Victoria not only grew much larger and became more crowded in the rows, so that differences in habits of growth and branching were rendered less apparent, but even with careful checking of points noted at Del Rio, fewer and less definite differences could be found at Victoria. Nevertheless, full expressions of the characters that had been recognized at Del Rio as marking a superior type of Durango cotton were shown later in many other districts of the Cotton Belt.
Field selection is complicated unavoidably by the fact that under irregular conditions many of the differences of the plants in size, vigor, or productiveness are merely accidental. At the same time real differences may exist, though these are difficult to determine. Many selections may be made of plants whose progenies do not appear to have any special value, but if some of the progenies have the desired characters of greater resistance or adaptation to the conditions, and such progenies are retained in the stock, the purpose of the selection is accomplished.

The difficulties of obtaining definite evidence of the value of particular progenies should not be taken as proof that differences do not exist or that the precautions of continued selection are not required. Progenies from poor or mediocre plants, if grown under very favorable conditions, may appear to be as good as progenies from the best plants, but such comparisons, even if made carefully in one place, are not conclusive evidence that differences do not exist that may be shown when the same stocks are compared under other conditions. As the effects of such reactions upon the growth of the plants are cumulative through the season, only slight differences of vigor or fertility are needed to produce notable results in stature or yield when the conditions are such that the differential reactions can occur.

More careful choice of conditions for applying selection becomes feasible in districts where all of the cotton is of the same variety and of the same stock of seed, as in some of the irrigated valleys of the Southwest where the Acala variety is grown exclusively. In such districts observations and comparisons of the differences of growth, behavior, and diversities of the plants in different fields can be made which are beyond the range of study as long as such differences of behavior are obscured and confused by the planting of many different varieties and mixed stocks, as in the eastern Cotton Belt. The choice of unfavorable or moderate conditions of growth, as affording the best opportunities of selection, has not been customary, but more attention needs to be given to the study of such relations of conditions to the expression of desirable or undesirable characters.

**CONDITIONS FOR ROGUEING**

Roguing is easier and more effective where individual differences of the plants are more definitely shown. In order to be most effective, roguing needs to be repeated at least three or four times during the season. Some of the aberrant characters are shown by the seedlings, as in the color of the cotyledons or in the lobing of the first true leaves. Other off-type characters of foliage, growth, or branching habits become more prominent before flowering, and roguing at that time has the advantage of preventing the crossing of the normal plants with aberrant individuals.

With plants grown under favorable conditions all that lose their terminal buds should be removed, as these generally do not show normal forms or habits of branching, and render the genuine rogues more difficult to detect. This precaution is not applicable where the young plants are badly injured by the tomosis or leaf-cut disorder, so that most of the plants may lose their terminal buds.
In such cases the early growth may be so irregular that roguing is hardly practicable until the flower and boll stages are reached.

Plants that show off-type characters in the petals, stamens, or bracts can be recognized and removed to the best advantage in the early flowering stage. Another roguing may be done to advantage at the stage when the early bolls have attained their full size, so the aberrant boll forms or failures to set bolls early in the season can be detected. Finally, a late roguing is needed to reject individuals that are off type in lint or seed characters (7).

More effective roguing can be done in progeny blocks and smaller increase plots than on a more extensive scale. Close roguing of large fields of cotton is scarcely feasible, as the effort of attention required for the best work can be sustained for only short periods. The removal of outstanding rogues can be continued, but when such work is checked later other aberrant plants are found, showing that the previous operation was not complete. Even a partial roguing undoubtedly is worth while with any stocks that are to be used for planting.

PRECAUTIONS WITH SELECT STRAINS

Examples of concealed adaptive characters have appeared in strains of Acala cotton when tested in different places. In comparisons of two stocks under stress conditions at Sacaton, Ariz., the behavior and yields differed notably from other comparisons of the same stocks in California. One stock bore its crop early at Sacaton and afterward produced only a few bolls, late in the season, while another stock continued growing and fruiting for a much longer period. In this test the longer-fruiting stock produced a notably larger crop, with differences of 20 per cent or more in many of the comparisons, but the results at Sacaton were in striking contrast with those obtained in comparisons of the same stocks in other places. At Indio, in southern California, the stock that matured early at Sacaton was more uniform than the other and produced more cotton, as the checking of growth did not take place under the Indio conditions. The greater uniformity of one of the stocks would give an advantage in places where the stress conditions were not sufficiently severe to check the growth and fruiting of the plants. On the other hand, the less uniform stock was more productive at Sacaton, by virtue of more persistent growth and fruiting under the adverse conditions.

The comparison of the two strains at Sacaton was repeated in six borders of seven rows each, with the strains represented by 3-row and 4-row blocks in alternation, or 21 rows of each strain. Sixteen of the rows of the longer-fruiting strain produced from 15 to 20 pounds of seed cotton, while only three rows of the other strain produced as much as 15 pounds. The variation in row yields in the longer-fruiting strain was from 12.5 to 20 pounds, the average being 16.8 pounds, while the yield in rows of the other strain ranged from 9.9 to 19.6 pounds, and averaged 13 pounds. On the basis of row averages by blocks, only one of the blocks of the longer-fruiting strain was outyielded by an adjoining block of the other strain.

It is plain from these facts that such a character as susceptibility to checking may exist in a progeny or strain without being recog-
nized. As long as the stock is kept where the plants are not exposed to sufficient stress to bring about a cessation of growth, the difference is not shown, but definite differences may appear when the stock is transferred elsewhere. Precautions against such impairments of seed stocks obviously will need to be taken, in order to maintain the adaptation of any variety of cotton to a wide range of conditions. In reality, very little cotton is grown under conditions so ideal that no periods of stress are encountered during the crop season.

With cotton, as well as other plants, it has been customary to recognize differences of adaptation between the species and varieties. But now it is seen that pronounced differences of adaptation may also exist between lines of descent or closely related strains of the same stock derived within a few generations from the same individual plant. That carefully selected strains of good varieties of cotton are more susceptible to adverse conditions is a belief that often finds expression among practical breeders. Such differences are being shown in comparison between strains of Lone Star cotton in Texas and also between strains of sea-island cotton which are being tested in South Carolina. Some of the sea-island stocks are much more susceptible to shedding of the young buds and bolls under adverse conditions, showing that the full possibilities of production have not been maintained by the system of individual selection used in the past.

METHODS OF TESTING PROGENIES

The planting of progenies from type individuals in adjacent rows is useful for observing their uniformity and comparing their habits of growth and other plant characters which show their adherence to the type. Differences that would not be detected among plants scattered in a field are easily recognized by means of the progeny comparisons, but the usual progeny plantings afford little evidence regarding productiveness or resistance to adverse conditions. Progeny blocks are subject to row variation, even in places where the most regular and favorable conditions for showing yield differences might be expected.

On account of the great variations of row yields, adequate tests of productiveness are not easily made. The methods formerly used in making such tests were found to be of little value. Row differences that may be only accidental are made to appear significant by being multiplied into acre yields. The only way that has been found for obtaining effective comparisons of varieties, seed stocks, or progenies is to limit each test to only two components. The stocks to be compared are planted in alternate blocks, usually of four rows each, with three or four repetitions. This simplifies the tests and makes the results as definite as possible. Blocks of at least four rows are desirable, as outside and inside rows often yield differently.

At the time of picking, the blocks of rows are divided crosswise into three sections, and each section of each row is picked, weighed, and recorded separately. The data obtained in this way afford numerous direct comparisons between the two stocks included in the test.
Comparisons of the yields of the small sections of rows show the regularity or irregularity of the conditions of production in the field and afford a basis of judgment regarding the value of the tests. If the conditions are not too irregular, and consistent differences are shown between the two varieties, the test is considered significant. An alternate block test of two varieties requires at least three of the 4-row strips of one variety and four of the other, with one or two guard rows added to the outside blocks, making 30 or 32 rows in all. With four blocks of each variety, 34 or 36 rows are required. With the plot cut across at picking time into three sections there are 90 or 102 row sections to be picked and recorded, and usually twopickings are made. The guard rows should be picked and recorded like the others, and they often afford data of interest in interpreting the experiments. A diagram of a 4-block test of two varieties or progenies may be found in a recent publication (22).

The data obtained from such tests can be combined in several ways. Totals or averages may be very misleading and often have less significance than comparisons that can be made in other ways. The outside rows of the block sections may be compared, or the inside rows, or the four rows of each block section can be treated as a unit. The nine 4-row block sections of one variety can be compared with the sections of the other variety on either side, giving a total of 18 comparisons of side-by-side block sections. Notwithstanding such precautions, it usually is not feasible to determine differences of less than 10 per cent, on account of the wide variations of yields, even among the row sections of the same variety.

The need for such precautions is appreciated when account is taken of notable differences that occur in the yields of individual rows, even in the same stock of cotton. Acsha progenies and increase stocks have been grown for several seasons in the same field at Indio, Calif., by H. G. McKeever, and the row yields have been recorded separately. In the season of 1927, for example, the progeny rows showed a range in yields from 51 to 76 pounds, while the yields of adjacent rows of increase stock, all planted from the same seed, ranged from 44 to 88 pounds, and even reached 91 pounds in an outside row. Also in 1925 and 1928 the increase rows showed greater ranges in yields than the progeny rows. In 1926 two outstanding progeny rows yielded 98 and 110 pounds, respectively, the next highest progeny row 79 pounds, and the highest increase row 89 pounds. The productive progeny was separated and a regular test made in alternating 4-row blocks, where it yielded no more than the regular seed stock. Usually the increase rows have been somewhat more numerous, and this may explain their wider variations, though not reducing the interest of the data as illustrating the phenomenon of row differences. Also, it was noted that high-yielding and low-yielding rows were not consistently in the same places, but varied with respect to positions in the field in the several seasons.

A reason for greater row variation in cotton than in other crop plants may be found in the fact that growth and fruiting are continued through a longer season. Cotton is a plant of tropical origin and makes only slow growth in the spring, or until the weather and the soil are warm. Soil differences no doubt are responsible directly
for much of the row variation, though not for all. Slight differences in depth of planting may influence germination, or the seedlings may stand in better or worse relation to furrows made by plows or cultivators. Such accidents may affect the growth of the roots or the supply of irrigation water. Rows that have a better start in the spring and occupy more soil are able to maintain the advantage through the season, so that a cumulative effect is obtained. The stands also affect the row yields, but to a variable extent. Rows with close stands may have distinct advantages in some places, while in other places rows with more open stands may be equally productive.

COMPARING TYPE PROGENIES IN GROUPS

Adequate testing of large numbers of progenies by repeated comparisons in several places to determine their reactions to different conditions would hardly be feasible as a breeding method. Much more seed would be needed for making such tests than usually is available from single plants, and the increase of numerous stocks of seed in separate isolated plantings is a difficult undertaking. Less complicated tests probably would prove more serviceable in practice. Groups of progenies from different places could be brought together and compared, or seed stocks developed by type selection in different places could be compared to see if differences of adaptation could be found. Or progenies from different places might be planted in blocks and these alternated with the best available seed stock to see whether any indications of greater value for selections made in the different places could be detected.

The provision of adequate quantities of seed as the basis of practical tests is often overlooked. For a single comparison in alternating 4-row blocks not less than a half bushel of seed (15 to 20 pounds) of each kind should be available. Usually such comparisons need to be made in successive seasons or in several places, if results of practicable value are to be obtained. Such undertakings commonly misfire for lack of an adequate supply of seed. From 10 to 50 bushels of seed should be reserved from stocks sufficiently promising to warrant thorough testing, in order to have seed available for a prompt increase of any stock as soon as a special value is indicated.

Under the system of type selection here projected these tests of progenies or seed stocks in alternate-block comparisons would be made when definite determinations of the values of different seed stocks were necessary or desirable. The testing of all the progenies would not be attempted, but only of those that were to be separated as the basis of new stocks.

The effects of self-fertilization also might be determined more definitely in the same manner by comparing series of progenies that had been self-fertilized for several generations with others raised from seed of the same lots and grown under the same conditions, but not protected from crossing with other progenies. Such comparisons would need to be made in different places, in order to determine whether differences of adaptation could be detected or variations in the extent of diversity were shown among the progenies or lines of descent. All the experiments that are carried to
the stage of yield comparisons must be on a rather large scale and are rather difficult and costly.

If progenies are carried in sufficient numbers, provisional comparisons of their behavior under different conditions may be made, even with small quantities of seed, and any that give signs of being weak or defective may be rejected. Such comparisons and rejections would be used merely as a precaution, without waiting for the more careful tests that would be necessary to prove that an actual deficiency existed. If progeny parents are selected under favorable conditions, enough seed may be obtained for small plantings in two or three places, or tests in several places could be made with seed that had been increased in a progeny block. Self-fertilized seed of each progeny could be obtained in limited quantities for tests of the inheritance of recessive characters or of reactions under different conditions. The production of larger quantities of self-pollinated seed in screened inoculums apparently is feasible to save the labor of artificial pollination.

Another procedure that may be advisable in some districts is to divide progeny seed for planting in successive seasons, reserving at least half of the supply of seed for the second year. Progenies that give any signs of inferiority in the first season may be thrown out, to the advantage of a progeny block in the next year grown from the reserved seed. Also, by bringing the more promising progenies more closely together in the second season they may be compared to better advantage and with less danger of good progenies being injured by crossing with inferior pollen.

Using a group of progenies instead of a single progeny as the basis of a stock would not mean that a single definitely superior progeny could not be separated and put into use, after its special value had been determined by adequate tests. The same method of selection would be continued after such a substitution had been made, since the same need would exist for maintaining the new stock, and there would be the same danger of departing from the type by selecting unintentionally a progeny or line of descent lacking an essential character. The choice of a single plant with an unrecognized defect may impair the entire stock of seed, if dependence is placed on the increase of a single progeny to furnish the breeding stock.

In the selection of Acala cotton the precaution was taken, in the interest of safety, of saving the two best progenies, those that seemed to have the most uniform expression of the recognized Acala characters. One of these progenies was planted and the other held in reserve.

Progenies that showed any deficiency or appreciable departure from the type were rejected, while the others went with the increase stock raised from the progeny that was considered best in the previous year, to provide for a more rapid increase to the volume required to supply the community. Under this procedure about seven-eighths of the increase stock was derived from a single best plant, with the other progenies contributing only a small proportion. Most of the progenies were from plants of the best row of the preceding year, and nearly all of the stock from one plant of two years before, or in all cases not more than four seasons from a common ancestor.
PROGENY COMPARISONS IN DIFFERENT PLACES

For three seasons, beginning in 1926, a series of about 20 Acala progenies has been planted for comparison in three places—Shafter and Bard, Calif., and State College, N. Mex., near Las Cruces. The same series was included in the main progeny planting at Indio, Calif., where most of the progeny selection work with Acala cotton in recent years has been done by H. G. McKeever. Studies of these progenies have been made, but without finding pronounced differences of adaptation among those included in the series. Slight differences of local reactions were perceptible, to the extent that progenies noted as being most alike in some of the plantings did not show the same similarity in other places, but no such contrasts were found as between the Acala seed stocks that were compared at Sacramento, Ariz., in 1927 and 1928, as already described. This may indicate that such divergencies are not of frequent occurrence. Differences between the progenies are more apparent at Shafter and at State College, especially in the boll characters, on account of a better development of the bolls at these localities than at Indio or at Bard. Higher temperatures prevail at Indio and Bard during the growing season than at the other places.

An example of possible effects of local environments on the quality of seed stocks was observed at Kerrville, Tex., in 1907, of which a brief account was published in 1909 (6). Numerous off-type plants were found in a field of Triumph cotton grown from seed obtained from the breeder of the variety, Alexander Mebane, at Lockhart, Tex. As the Mebane seed stock at Lockhart had been inspected the previous year and found to be very uniform, the off-type plants that appeared at Kerrville were especially noted and seed saved for planting the following season. Their characters did not indicate that the off-type plants were a result of crossing or accidental mixture of other varieties. The range of diversity was very wide among the off-type individuals, but several plants were alike in having very small bolls which did not open before frost, so that no seed was obtained. Progenies of the other off-type plants were raised the following season, and in several of these a definite inheritance of the off-type characters was shown. It may be assumed that the environmental conditions at Kerrville permitted certain characters to come into expression which had been suppressed or restricted at Lockhart, except that too many differences appeared for the effect to be considered as a simple effect of environment. Hence there could be little doubt that definite variations had occurred in the planting of Triumph cotton at Kerrville.

Adequate comparisons should be made between progenies and seed stocks selected under stress conditions and those produced under more favorable conditions. Blocks of progenies from stress-condition localities could be compared under favorable conditions with standard seed stocks or with other blocks of progenies selected from superior stocks grown under favorable conditions. Such plantings would serve the double purpose of determining whether any differences in the qualities of different lots of progenies could be detected, and of increasing the stocks of carefully selected seed. Any progenies that proved inferior or off-type should be rejected, and in regenerating the progeny blocks account should be taken of the numbers and
characters of the off-type plants in the stocks from the different places, to determine whether any consistent differences can be found in the nature and extent of such variations from the type. To check these results, similar comparisons should be made in the stress-condition localities to see whether the local selections show any differences of behavior or differences from good seed stock produced elsewhere.

Another test of possibilities of local variation might be had by making a series of progeny selections in the same stock in several different places and then comparing these series of progenies in the several places. Such comparisons would show whether special characters or values appeared in particular progenies or whether the series of progenies from some places were better than those from other places. Consistent differences among such groups of progenies would indicate that different characters were involved in the productiveness of the parent plants at the different places.

**SUMMARY AND CONCLUSIONS**

How selection is to be applied most effectively in maintaining superior varieties is the general breeding problem of the cotton industry. The theories and methods of selection, in order to serve this purpose, require careful revision in the light of new facts. The factors of heredity involved in the preservation of the varieties need to be studied with as much care as the factors that are involved in the development of new varieties. The production of novelties has engaged the attention of plant breeders almost exclusively. A different technic has become necessary, and a closer approach to methods of continued selection employed in animal breeding. The contrast between animal breeders and plant breeders in the theory and practice of selection is taken to indicate that the state of knowledge among plant breeders is relatively backward, especially in the features relating to the preservation of varieties.

The history of Acala cotton affords practical illustrations of numerous breeding problems, showing limitations of the methods that have been relied upon in the past, indicating the reasons for these limitations, and leading to the recognition of a more effective method of preserving the true characters of the variety, as well as of maintaining the purity and uniformity of the stocks of seed.

The new method is called type selection, in order to direct attention to the essential requirement of recognizing a single type of plant as the basis of selection and thus maintaining the uniformity of the stock. To appreciate and apply the new method to the best advantage, it is necessary to analyze and discriminate carefully between type selection and several other methods that have been used in the past, including mass selection, individual selection, and progeny selection.

The two principal theories of selection, as accepted in many scientific treatises and textbooks, prove to be misleading when applied to cotton breeding, since both have tended to obscure the need for continued selection as a means of preserving superior varieties. The theory of continued improvement by selection encourages frequent changes of varieties and contributes to the unfortunate custom of seed dealers of bringing out a succession of untried new sorts which
are advertised and sold for a few years and then discarded. On the other hand, the pure-line theory has led many to suppose that pure stocks would remain uniform without further selection.

Comparisons of large numbers of progenies of different species and varieties of cotton show the general occurrence of off-type plants and also of slight but consistent differences among progeny rows of the same purebred stock. The recognition of these progeny-drift variations affords a better understanding of the need of continued selection, in order to preserve the characters of superior varieties of cotton, and to maintain a uniform expression of the characters through periods of years. The need of selection is seen to be apart from the question whether a further improvement of the variety is possible, and the arguments that have been used in the discussion of this question need not complicate the work of the practical breeder.

A new requirement of selection is recognized in the need for maintaining the adaptation of varieties to a wide range of conditions. Many comparisons have been made of the behavior of the same series of varieties under different conditions and have shown that a wide range of adaptation is practicable. Selection and testing of progenies under different conditions is recognized as a means of preserving the adaptive characters of varieties, which otherwise may be lost even without being recognized. To maintain the selection of a type it is necessary to be aware of as many of the characters as possible, both visible and invisible, so that all of the essential characters of the type may be carefully guarded.

The usual methods of comparing progenies in single-row plantings in breeding blocks do not afford a basis of selection for maintaining the productiveness of a seed stock. The progeny plantings are subject to the usual row variations, which commonly are great enough to mask any differences to be expected between progenies of the same type. With selection confined to a single locality or to favorable conditions of growth, there is danger that characters of adaptation and resistance to unfavorable conditions may be lost. Difference in vigor or fertility may arise like changes in other characters among the lines of descent, even in a carefully guarded seed stock. In order to be assured of maintaining the productiveness and uniformity of superior types of cotton, it is necessary that selection, comparing of progenies, and testing of seed stocks be done in different regions covering the range of conditions of production. Groups of progenies, instead of single progenies, are maintained as the basis of seed stocks, which are continuously reselected from productive individuals.

Choice of conditions for selection is a precaution to be recognized in practical breeding work for maintaining good seed stocks of superior varieties. Conditions most favorable for selection are those that permit the plants to show differences in reaction to adverse conditions as well as ability to produce large crops under favorable conditions. Differences in stability of characters are to be recognized, as well as differences of actual expression of characters, which may vary greatly with the conditions. The effects of stress conditions on different varieties and seed stocks need to be determined as a part of the breeding operation.
Several of the characters of Acala cotton contribute to earliness of the crop, one of the most important being the ability of the plants to make more growth in cool weather and to open bolls normally after other varieties have become dormant. The Acala plants flower abundantly, so that large numbers of young bolls may be set in a short period. Closer spacing of plants in the rows is a means of inducing earlier opening of the bolls by restricting the size of the individual plants.

Study of several factors of earliness show that some of them are less important than breeders supposed and need to be avoided in selection instead of being considered desirable. How to get the largest crop matured before frost is the practical question of earliness, rather than obtaining a few open bolls at a very early date, or even an early opening of all of the bolls, since the application of these standards of selection may render a variety less productive.

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