We now turn to the results of handing the ginned lint from the dated flowers to an expert grader, in order to assess their "strength." The manner in which this was done has been described in the Appendix, and it may be taken for granted that the grader had no guide whatever as to the relation between the various samples, nor any opportunity of revising his judgments. His results can also be arranged in a curve, and smoothed to five-day means, and compared directly with the other curves.

Grading and Hair Strength.

When treated in this way it at once becomes apparent that *grader's "strength" and "breaking strain" are utterly disconnected,* and have nothing whatever to do with one another. This is a practical result of the first importance.

The most striking example of this is at the end of the curve (Fig. 21), where the breaking strain is falling rapidly to zero, but the grading remains up at SS on the scale. Comparing this with the notes given in the previous section as to the behaviour of 77 G. and 310 N., it becomes possible to see what Strength, as determined by hand-pulling, really means. The grader takes a tuft of lint to test, keeping to a uniform size of tuft; if the hairs are but slightly thickened, and consequently of low breaking strain, he takes more of them; while if they are heavily thickened, coarse, and of considerable strength individually in consequence, he includes fewer to obtain a tuft of the same size.

It is pointed out in the Appendix on p. 191 that "impact testing" of a bunch of fibres gives a result which is proportional to the number of fibres tested, and the testing which the grader applies is nearer to "impact" than to "straining." Consequently, what the grader does is to test the resistance to impact of equal weights of lint each time.

Uniformity and Strength.

But this being the case, he might be expected always to obtain the same result, and if all the fibres in a sample were alike he would do so. All the fibres are not alike, however, and so the determination of strength by the grader resolves itself very largely into a test for regularity of strength.

We can corroborate this deduction by comparing the breaking strain variability from fibre to fibre in large samples with the grader's judgment upon them. There may be a high proportion of strong fibres present, but if they are mixed with weak ones the sample is graded as "weak." This comes down finally to whether the tuft of fibres breaks under the grader's hands with a "snap" —*i.e.*, all simultaneously—or raggedly.

Having discussed the evidence obtained mainly from the abnormal conditions of a wide-sown, water-shortened, experimental plot, we will now consider the results obtained in actual field crop, since it might well be the case that the variations we induced experimentally were far greater than would ever arise in normal cultivation.

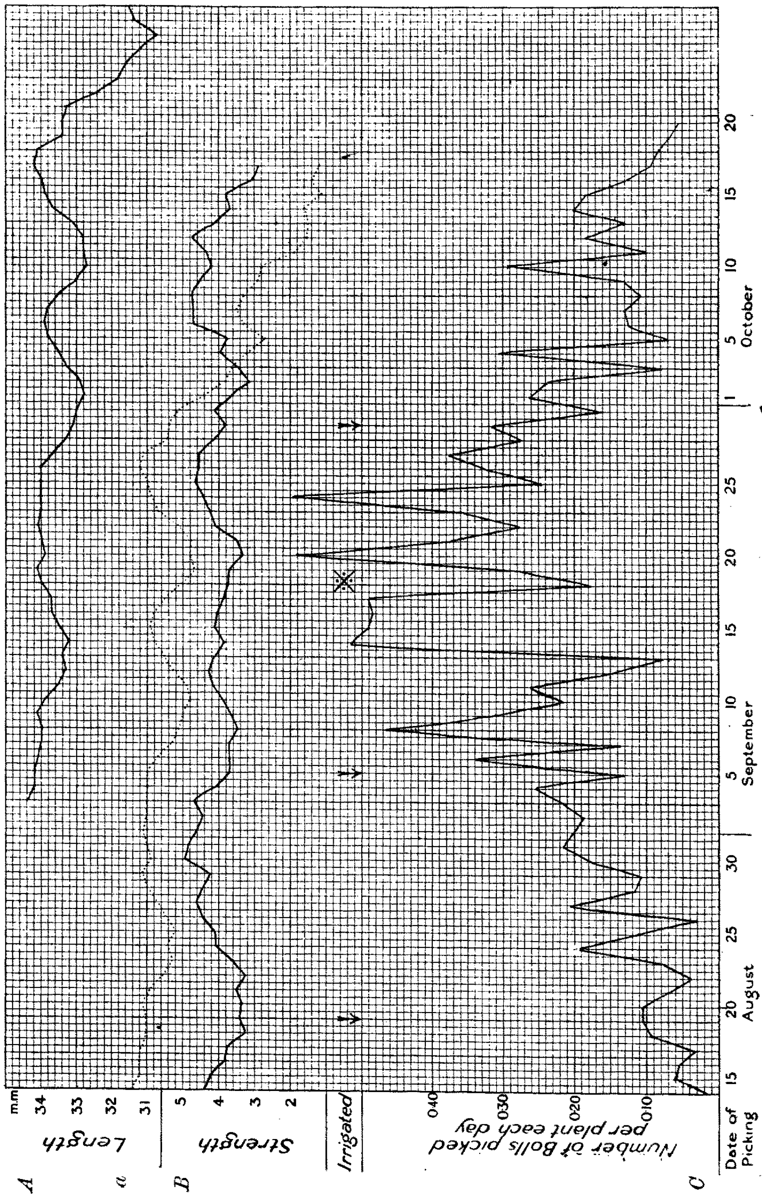
A
Length
a
m.m
34
33
32
31
B
Strength
5
4
3
2
Irrigated
C
Number of Bolls picked per plant each day
040
030
020
010
Date of Picking
15
20
25
30
5
10
15
20
25
1
5
10
15
20
August
September
October

Fig. 15.

FIG. 15.—DAILY PICKINGS, 1913.

Similar to Fig. 14, p. 90, but showing the properties of the lint from *bolls picked every day* for seventy-five days off a group of plants in field crop.

From above downwards:

*A*, Curve showing daily change in lint-length.
*a*, The same curve shifted back twenty-three days, to synchronize the action of the environment upon length, with its action upon:
*B*, Strength of the lint hairs, which is determined when the boll is twenty-three days older.
*C*, Zigzag curve, showing the number of bolls ripening daily on the 130 plants employed. Note the effect of the recovery from shedding, shown on September 14, due to a watering given forty-eight days previously; also slightly shown on October 6 from the irrigation shown (arrow) on August 19.
Asterisk denotes the *beginning* of the rise of the water-table, which has the same initial effect as an irrigation.

Note how the curves of strength and shifted length begin to rise four days after each watering, and reach their maximum after eight days more. Thus, this diagram indicates the possibility of obtaining more uniform cotton by shortening the picking period, and relating it to the dates of irrigation.

Note also that length and hair strength *in any one boll* are entirely independent of one another.

### DAILY PICKINGS OF 1913 (FIG. 15).

The series of data accumulated under this title were derived from an "observation row" of about 130 plants growing under field crop conditions at Giza, on rich deep soil, severely attacked by both ordinary boll-worm and pink boll-worm, but otherwise typical of excellent cultivation, and setting a crop of bolls which in the absence of this exceptionally bad attack of boll-worm would have weighed out at 700 pounds of lint to the acre.

The part of the field containing this group was carefully watched every day of the season, and the general health of the plants was kept as uniform as it could be, under the limitations of field cultivation. Any fluctuation shown in the cotton ripened in this experiment will, therefore, be less, if anything, than an ordinary field would show when cultivated with the same pure strain.

The strain employed was the same as in the previous series, and comparison between the two results brings out some points of interest, especially with regard to the senescence or self-poisoning induced in the previous experiment by withholding water early in the season.

The data thus obtained are directly "practical." The successive days are dated by the opening of the boll, or picking, and not by marking the flowers, while the strength was determined by "impact testing" of bunches of lint, and not by breaking single fibres.

Although the series embraces ninety consecutive days, the measurement of length on 500 seeds, and the counting of about 4,000 fibres one by one, the results can be summarized in a very few lines:—

The strength and length of each sample are again utterly disconnected. If the curve showing the length is moved backwards over 23 days it fits exactly to the curve of strength (Fig. 15).

---

Hastening Maturity.

In the water-short plot of 1912, the best fit was obtained with a 21-day shift, as against 23 days in this experiment, indicating that the senescent condition of the 1912 plot shortened the maturation period by checking growth. It is common knowledge that water shortage "ripens off the crop"; we can now see the price which is paid for it; namely, weakening and shortening of the lint, and reduction in actual yield. The crop which is thus being hustled into maturity will look better than one which is being allowed to take three or four days longer over its duties, because the withering and falling of the leaves exposes the open bolls to view, but a count of the actual numbers will show that there are not so many.

Length of Lint.

Comparing the lint length in this new series with that in the old one, we find that, whereas the plot which had been starved of its due water allowance only once exceeded 31 millimetres on the five-day means, this properly-cultivated field-crop series only drops below 33 millimetres five times before October 22, and does not touch even the maximum of 1912 till it has finished cropping. The maximum reached in this series was 34·4 millimetres instead of 31·1 (*cf.* Figs. 14 and 15).

The next point of interest in regard to lint length is the fluctuation it shows, even under conditions which were almost ideal for a field crop. Obvious senescence appears to have been excluded entirely, but in spite of this the length swings steadily over a range of 1·4 millimetres on the five-day means, which in actual daily data of the same precision would be nearly 2·5 millimetres, or $\frac{1}{10}$ inch. The length of the lint as shown in these experiments is determined by combing on the seed; if expressed as the length of a "pulled tuft," in the usual way, this fluctuation would be stated as a change from about $1\frac{5}{8}$ to $1\frac{3}{4}$ inches, which, though not great, is still appreciable in the manufacture of combed yarns.

Fluctuating Length.

Lastly, it will be seen that after the lint length curve has been shifted 23 days to fit the strength curve, each irrigation shows an effect upon it. On the third or fourth day after watering the two superposed curves begin to rise, continue to rise until about the tenth day after watering, and then die away again, to be revived by the next irrigation.

Effect of Irrigation.

Adding on the 23 days of the shift, this means that the length shows the first signs of having been affected by watering in those bolls which open 27 or 28 days afterwards, and that the maximum effect of watering upon the length is shown in those bolls which open about 32 days afterwards.

To obtain the age of the boll at which the effects of watering are produced, we must subtract these intervals from the maturation period; this period was determined for this series by an indirect method as being 48 days.

Therefore the maximum effect on lint length is obtained when the boll is 15 or 16 days ($48-32=16$) old at the time of watering, while if the boll is more than 21 days old ($48-27=21$) it is unaffected.

This result is different in degree from that which we obtained in the previous series after the long water starvation, and it indicates that in this case we are dealing with a simple and straightforward limiting factor effect, instead of the complicated poisoning effect. In this case the effect of watering is simply to allow the lint hairs to grow more during the last few days than they would otherwise have done. The general principle, that the maximum effect is produced round about the fifteenth day of boll development, is the same as before.

Strength of Lint.

Turning now to the strength curve, we may first note that it is immaterial for general purposes whether the strength is determined by breaking single hairs, or whether bunches are tested by impact. The impact figures obtained in this series cannot be converted directly into breaking strains for direct comparison with the previous series, but some determinations of the breaking strain made tediously by hand—in the absence of the author's automatic tester (Pl. XVI.)—indicate that the maximum strength attained in this series was rather higher than the maximum attained in the former series, just as in the case of lint length. Moreover, whereas the former maximum was rather spasmodic, the strength in this series under good field conditions is maintained steadily for several days at a time.

If we next consider the extent of the change which the strength undergoes between the effects of one watering and that of the next, we find that it is very much greater than in the case of the length. The change which we found between 32·7 and 34·4 millimetres in the five-day means of lint Length stands in the ratio of 95 : 100. In the case of lint Strength the extreme values recorded stand as 65 : 100. This greater capability for fluctuating is not due to accidents of method, for the fact that our impact test determinations are less precise than those of length should help to obliterate such distinctions. We may safely assert that in this series the strength of the lint rose from 60 to 100 in a single week (August 22 to 29).

Greater Fluctuation in Strength.

This phenomenon introduces a proposition of very practical interest to the spinners of fine cotton. Would it not be worth while to encourage the practice of picking at shorter intervals? If we regard these curves as an analysis of the three "pickings" in which the cotton crop is usually harvested, it becomes clear that the composition of the lint at any one picking cannot be uniform, except by accident against long odds. In conventional practice the bolls which we have studied here would have been gathered in three groups or pickings, on or about September 10, September 30, and October 20. By reference to the curves it will be seen that pickings taken on any of these three dates would have been irregular in length and in strength, since they would consist of all the bolls ripened before that date. In general experience the first

Short-Period Pickings.

picking is the best, and the third the worst. The differences are partly due to increased frequency of insect attack, and partly to the fact that the third picking, if delayed too long, will include senescent lint, especially if cultivation has aimed at hastening maturity by deprivation of water, or if the water-table has risen in the meanwhile.

Quality of Pickings.

As in the case of other common experiences which we have discussed, this difference between the pickings is a matter of accident—excluding boll-worm—and not of direct and necessary causation. The temperature in Egypt during all the period from July to mid-October is rarely a limiting factor directly, so that it is not till late October that the cultivation of cotton in middle Egypt becomes dependent on the temperature; if the cultivator will abstain from trying to save a day or two in maturity by cramping the water-supply (and it should be noticed that the Fellah himself never does so unless he is obliged), and is lucky with the boll-worm attack, there is no reason why he might not obtain cotton of the same value in his third picking as in his first picking, excepting that the autumn fogs may cause the lint to mildew if left too long on the plant after the boll opens. The whole thing is a question of accidents; there are more chances of unfavourable accidents late in the season than in the beginning of the season, but most of them can be avoided. The worst of all these accidents in Egypt is the rise of the water-table, which takes place in permeable soils when the flood comes down.

Water-Table and Lint Quality.

In the year 1913 the Nile flood was later than it had been for over a century, and lower also. There is therefore very little effect visible in these curves, as compared with what a normal year would have shown, excepting a beneficial one due to capillary damping of the supernatant soil on and after September 15 (star in Fig. 15), when the effect of the previous watering was dying away; since the water-table in this particular plot of the Daily Pickings did not rise nearer to the surface than 1·30 metres, no very striking effect could be expected so late in the year. The 1912 results from daily flowers were also unsuitable for demonstration of the water-table effect, since wide-sown cotton does not suffer nearly so much from this cause as do the closely crowded plants of field crop. Nevertheless we can draw our own deductions from existing evidence about the effects of the water-table on other growth-processes in a field crop of cotton, and from what we have already learned about the development of the lint, with the following conclusions:

When the water-table rises so as to immerse the lower half of the root system of a field crop of cotton in Egypt, the effects will show up in the following order: Bolls opening ten days later will have weak but long lint, those opening five weeks later will have lint both weak and short, with a high ginning out-turn, and those opening seven weeks later will be worthless in all respects.

Returning now to our original statements as to the possibility of growing equally good lint at any time during the season until the falling autumn temperature

Differences between Pickings.

becomes a limiting factor, and barring accidents such as boll-worms and water-tables, let us see where the longest and strongest lint was produced in this Daily Picking Series. The lengths of the earliest bolls have not been determined, but their weakness puts most of them out of the running; those of September 3 were good in both respects, but only slightly superior to those of September 26, and on October 9 we have another period which is much the same. An important conclusion follows from this search for good samples: it should have been possible so to adjust the irrigation intervals that the length and strength of the samples, although determined at 23-day intervals, should move together. The obvious way of doing this is to keep the intervals between irrigations constantly related to 23 days for this strain, and to 20-26 days for other strains and sites.

Canal Rotations.

It may not be entirely coincidence or convenience, as is commonly assumed, that the rotation of water in the Egyptian canals is commonly arranged nearly at this interval; the usual explanation is that the cotton cannot stand longer intervals without water, but this is not strictly correct. Personally the author considers that lighter waterings at 11 and 12 day intervals alternately would be better still, and would of course produce the same result.

Leaving this point, and assuming that the irrigation intervals had been so adjusted as to change length and strength simultaneously, this would not abolish the net change of both. Thus the commercial pickings would still be composed of samples showing various properties. If, on the other hand, the intervals between the pickings were shortened, and the pickings kept separate, much greater uniformity could be attained—it might even be permissible to mix certain pickings together; thus, in the series here discussed, a much more level sample is produced by mixing September 1, 2, 3, 25, 26, 27, and October 9, than by picking all the bolls which ripened between August 22 and 29. Such mixing would not be permissible for the unskilled cultivator, but there are some clues upon which he might guide his conduct.

Classification of Pickings.

For example, if strain No. 77 were being cultivated at Giza, and if short-period picking were practicable, and if the irrigation intervals had been adjusted to bring strength and length fluctuations into step, then the grower would keep all the bolls which opened between the sixth and twelfth days after each watering separately, and either mixing them or keeping them separate, according to opinion obtained, would dispose of them as the highest grade of his product.

Discussion of this matter brings us to the ultimate analysis of "regularity." If pure strains are cultivated, and if pickings are so taken as to include only those days on which the cotton is all alike from day to day, there remain only two more ways in which the sample can be made irregular. These two are, firstly, individual fluctuation from boll to boll and from plant to plant, and, secondly, variation in lint properties of various parts of each seed involved.

Uniformity in Cotton.

The first cannot be eliminated in field crop conditions. If the plants were separated by intervals so wide that each one had all the soil it could occupy, if such spacing did not bring in secondary difficulties, and if the soil were absolutely uniform to a depth of 3 metres, then there would be no fluctuation from plant to plant, but there might still be differences from boll to boll. Conversely, there is a strenuous struggle for existence between plants crowded in field crop. This struggle is subterranean and invisible, but none the less bitter. Under Egyptian conditions, the success of any individual over its neighbours is partly rectified above-ground, since its consequently greater growth brings shade to them and lessens the strain on their root systems; but if a pure-strain population is closely crowded in a shallow soil, it will be found by the end of the season that a few plants have alone survived to mature their seed, the remainder being wizened sticks.

Plant-to-Plant Fluctuation.

The last component of "regularity" is the distribution over the seed. This can be partly controlled by the use of suitable strains, since the character of the distribution is inherited, and strains can consequently be isolated in which—when properly grown—the mean length and strength of the lint varies but little from the tip to the butt of the seed. In periods of unsuitable nurture, however, even these strains will make poor lint at the tip of the seed, farthest away from the food-distributing centre, which is situated where the incoming vascular bundles ramify in the butt-end of the seed-coat. All the changes we described in

Hair-to-Hair Fluctuation.

the previous chapter, such as the development of the palisades in the seed-coat, and the lengthening and thickening of the lint, appear to be begun simultaneously all over the seed, but completed first at its butt or thick end. Therefore, if the development of any feature is checked a little too soon, irregularity will follow.

Uniformity and Changes of Environment.

A natural consequence of this is that periods of change are also periods of irregularity. This applies not only to distribution on the seed, but also to the mean maximum length from seed to seed and boll to boll, as may be seen by examining the figures in the Daily Picking Series. When the conditions of the environment are kept constant for any length of time, the lint ultimately ripening from day to day may be good or it may be bad, but it will at least be uniformly one thing or the other, and as such it will be saleable for a definite purpose. On the other hand, when the conditions are changing from one day to another as when soil is drying up—the slight variations in the length of the maturation period from boll to boll will in themselves be sufficient to mix better bolls with worse ones.

Variation from seed to seed within the boll has been extensively discussed by other writers, but its case is covered by the preceding account.

Summarizing the results of this chapter, we have a result of fundamental importance in the confirmation which these Dated Series give to the deduction drawn from developmental evidence, that the same conditions of the environment affect the length and strength in the same way, but in bolls of different ages. The interval, in the case of a certain pure strain in a certain site and season, was twenty-three days.

Summary.

Absolute regularity of lint is unattainable, even with a pure strain, but apparently much might be done to improve in this direction by shortening the picking interval with discretion. Whether the cost of so doing would exceed the cost of producing the same result by Combing remains to be seen.

# CHAPTER V

## THE DEVELOPMENT OF COMMERCIAL LINT

In the previous chapter we have seen how some of the more obvious properties of the seed-cotton and lint are attained, and we have found that the story is an extremely simple one. If we avoid technical details, the whole matter resolves itself into this: that each characteristic depends on the reaction which takes place between the constitution of the plant and the circumstances of the environment, at the time when the characteristic is being built up by growth.

The minor circumstances which have tended to obscure this main issue are somewhat as follows:

(*a*) The climatic circumstances under which cotton grows are not favourable to the sustained and detailed research required.

(*b*) The age of the boll cannot be dated entirely by its external appearance.

(*c*) The results of self-poisoning or senescence have not been separated from the simpler direct effects of the environment.

(*d*) Until the conception of Limiting Factors was introduced by Mr. Blackman, the analysis of environmental effects was impossible.

(*e*) Until pure strains of cotton were available, the differences from plant to plant were sufficient to obscure the differences from day to day.

Having analyzed the problem of development down to its simpler constituents, it remains to build back into complexity. Interesting though our analysis may be, in itself it shows that the commercial crops are not likely to approximate to any sort of ideality for many years to come. We must therefore attempt to sketch the relation of these facts to the cops and hanks of yarn which the mills produce.

Spinning and Growing.

This task is one which any author might well forego with pleasure. If his acquaintance is with the grower's side of the matter—as in the present case—he cannot have more than an inkling of the work and problems of the mill; while if his knowledge is sound on the spinning side, he is not likely to have spent sufficient time in the cotton-fields to be familiar with the limitations which debar him from obtaining the ideal cotton.

There can be no doubt that the wisest course for the present author would be to leave the raw cotton in the open boll, but to do so would defeat one of the motives which have led to the writing of this book—namely, a desire to establish a common language between grower and consumer. A great deal has been done in this way of late years, especially as regards Egypt and Lancashire, and some of the most outstanding misconceptions have been abolished; but all that which has been done is not a tithe of what remains to do. When the Spinner can prescribe the cotton he desires in such a way that the Grower can read the prescription, and can in his turn set to work to sow the seed and grow the plants in such a way as to obtain it, the cotton trade will be homogeneous, and capable of a high degree of efficiency. That the trade of spinning alone is enormous, specialized, and intricate, comprising many separate trades within itself, will be admitted by everyone. It is probably not quite so intricate an organization as a cotton-plant, and its components have the advantage of articulate speech and of historical origin. So long as the Grower of cotton was content merely to do certain things because past experience had shown that they were, on the average, the best things to do, he could not expect much sympathy when he complained that the language of the Spinner was not comprehensible to him. At the present time, even though there is no millennium in sight, and although all the knowledge we are acquiring may not pay anyone to apply, there is a definite tendency towards this establishment of communications between the two ends of the cotton trade. The forces of curiosity are getting out of hand. Each end is beginning to wish to know more about the other end's business, and to realize that the Cotton Trade is not confined within the walls of the mills.

" Strength."

Now, when such intercommunication begins on the feature, let us say, of " strength," the common language is at once conspicuous by its absence. Well-intentioned authors write at length on the strength of single fibres tested by straining and by blows from a falling weight, graders take samples of lint and state their opinions as to strength with uncanny accuracy, and the spinner expresses most varied opinions as to the strength of the yarn he produces from that lint, according to the class of yarn he is making. The question naturally arises as to what "strength" is, and each person concerned gives an entirely different answer, which is quite correct in every case.

It should not be beyond human ability at least to construct a series of analyses in the precise form which science exacts, so that, even if the gap between grower and spinner cannot be bridged at one jump and by one man, a bridge might at least be built. It is with the intention of starting one abutment from the grower's side that this essentially impossible chapter is included in these pages, and the author hopes that criticism by the spinner may be tempered accordingly.

Impurity of Commercial Varieties.

It will save endless reservations if we first deal with the lumber brought in by varietal impurity, and clear it out of our way. There are no pure cottons in commercial cultivation at the present day. This statement is necessarily based on negation, but the standard varieties tested by the author for their composition are some fifty in number, including Sea Island, Upland, and Indian, as well as every known or unfamiliar Egyptian variety, and several semi-wild cottons. From any of these a number of strains can be isolated and bred true, or pure forms can be "split" out of individual hybrid plants.

It is possible, though very improbable, that a variety might consist of a dozen different strains, and yet all the plants might produce exactly the same lint. Perfectly definite differences in petal colour and suchlike can be quite independent of lint properties. Similarly, so far as our knowledge goes, white and brown lints may be otherwise identical, or two entirely different lints be borne on plant bodies which are externally indistinguishable. There is no limit yet known to the shuffling of characters which may take place in this way through deliberate or natural intercrossing within the main groups of the genus.

Independence of Inherited Characters.

The obvious characters make only half the story, however. We are beginning to realize, and in some ways to understand, how two kinds of cotton may show entirely different reactions to their environment, so that such a complication as the following example presents is well within probability: Two strains of cotton are growing a hundred miles apart, one on the sea-coast, the other in the interior, and appear to be exactly the same. When grown side by side in either site, the imported one is conspicuously unhappy, and plots of it can be recognized at the other side of the field. These differentiating characters which are not obvious include such reactions as tolerance of salt, liability to shedding, stage at which senescence sets in, and velocity of growth at given temperatures. In separate species of the genus these features may be most clearly seen, but in a less obvious degree they may be found in the strains isolated from the same variety. One of the most interesting sights of cotton-growing in the

Growth Habits.

PLATE IX.—CONSTITUTION OF COMMERCIAL VARIETIES.

Photographs of three representative plants in families descended from three plants of the Abbassi variety. One-thirtieth natural size, taken just before the opening of the first bolls. The three parent plants were chosen first by their seed-cotton, as lying in the centre of the Abbassi Target diagram (Fig. 16, p. 134). The lint was then submitted to an expert and graded as Abbassi. The three photographs only convey a faint impression of the differences between these three sets of offspring. Left: Wiry stem, semi-prostrate habit, practically no vegetative branches, leaves very small, joints long. Centre: Robust erect stem, slight development of vegetative branches. Right: Stout stem, semi-prostrate habit, vegetative branches strongly developed (*e.g.*, main stem is the left-hand shoot in the photograph).

author's experience was the annual growth-race between strains of cottons derived respectively from Willet's Red-leaf, King, Asia Minor, and the average Egyptian plants; first one and then another of the competitors would lead on the same dates each year, according to their specific peculiarities.

Natural Selection.

If the differences between the components which go to make up a commercial variety were confined to mere structure and colour, there would be very little material for natural selection to lay hands upon; but since there are also these physiological differences, it follows that some kinds of plants flourish best in one locality, and produce more seed, with the result that the sowing of the next season contains more of these plants, and the general properties of the variety alter accordingly. The name given to this alteration varies: if the change does not spoil the lint, it is called "acclimatization"; if the lint of these flourishing plants is inferior, the change is called "deterioration."

Uniformity and Cultivation.

Now, a commercial variety of cotton growing in any one site and year is made up of many different strains of cotton and of hybrids between them. Some of these plants are well suited to their environment, others are not. If cultivation is very good, or, in other words, if as little tax as possible is put upon the self-regulating functions of the plant, even those plants which are comparatively unsuited to the environment will grow fairly well, and will make as good lint as they can; the crop resulting will therefore be as uniform as it can. If, on the other hand, cultivation is poor, only those plants which happen to be thoroughly well suited to the environment will produce tolerable lint, and the presence of this lint in the sample will increase the irregularity of the sample.

Thus, if a commercial variety is well cultivated, it tends to greater regularity; and if badly cultivated, to greater irregularity. Since the brightness, cleanliness, lustre, etc., of the lint are all indices of good cultivation, they also go hand in hand with an approach to regularity.

**The Limitations of Good Cultivation.**

On the other hand, no amount of good cultivation can make a short-staple plant into a long-staple one, so far as our present knowledge of growth—and especially of senescence—can avail us. Consequently, any approach to real uniformity is impossible with impure varieties. It may possibly be thought that undue insistence is here being laid on varietal impurity; that the persons who introduce new cottons are not likely to introduce them in an obviously mixed condition; and that in speaking of such impurity the author is applying some hyper-critical botanical test. There is a very simple way of presenting data for varietal composition in respect of two commercial characters simultaneously, based on the statisticians' Correlation Diagrams, which we may term Target Diagrams, since the scatter of dots over the diagram is used in the same way as the shot-pattern of a shot-gun. We have seen that all these measurable characters, such as lint length and ginning out-turn, fluctuate to a definite degree round a mean value, within a pure strain. If, therefore, we grow a family of pure-strain plants, under uniform treatment, and determine the out-turn and length for each plant in a certain period of the season, we can draw curves showing the distribution of the variations in each respect through the family. If we now place these curves on two adjacent sides of a square, we can make a target diagram in the following way: Find the position of plant No. 1 in the length curve, and draw a line into the square at right angles to the side along which the length curve is plotted. Then repeat the process with the out-turn curve. At the point of intersection of these two lines make a conspicuous dot. Repeat the process for each plant, when it will be found that the group of dots thus made will give a picture of the amount of "scatter" in both characters at once, instead of only showing one at a time as the curves did (Fig. 16, p. 134).

If we are handling a pure strain in this way, the scatter in either character will be definite and regular, and the dots will form (with suitable plotting) a circular group, the centre of which is densely dotted, while the dots become fewer and fewer towards the margin of the group (Fig. 16, Targets 5-7, 10). The centre of the group lies at the mean for each character.

If we now mix two strains together, which are distinguished in their average out-turns and lengths, the dots will form two groups. If the two strains are very widely different, the groups will be quite separate. If they are only slightly different, the fact will still be recognizable when the diagram is viewed from a distance, for instead of blurring into a circular arrangement, with the darkest spot in the centre, the blurred diagram will be more or less oval, and instead of having one darkest spot in the centre, it will show two spots.

Again, if we take a pure strain which is suspected to have been contaminated by crossing, and make the diagram for all the plants, we shall probably be able to detect the hybrid rogues, since it is probable that their out-turn and length will be unlike that of the pure strain, and consequently the dots representing them will be likely to lie well outside the group. If we have four such measurable characters we can plot six such diagrams, and be practically certain of finding the rogue in one or more of the six.

Impurity of Egyptian Varieties.

With this description we may further examine the target diagrams (Fig. 16) which show the composition of the principal commercial varieties of Egyptian cotton, not in respect of any abstruse botanical features, but in the directly commercial characteristics of lint length and ginning out-turn. Side by side with them are plotted (Targets 5, 6, 7, 10) the target diagrams for pure strains, to compare the amount of scatter which need exist with that which actually does exist. The objection may be raised that the various plots might have received different treatment, hence accounting for the different degrees of scatter, but this is not the case; when the plants are grown for such comparison, they are all mingled together on the same piece of land, plant by plant, so that all share equally in any variation of soil or of cultivation.

One or two points in these diagrams, though of particular interest to Egyptian cotton-growers, have also some general significance. It will be noticed that Ashmouni (Target 9), the Upper Egypt variety, has a fairly compact diagram; this is mainly due to the fact that it has been comparatively isolated in Upper Egypt, and has not been offered the same opportunities for admixture as the Delta varieties ; at the same time it is by no means pure, and in other respects—such as lint colour—shows itself to be quite heterogeneous. The Delta variety of Egyptian which has deteriorated least, according to the spinners, is Yannovitch (Target 11), and the compactness of its diagram confirms this. On the other hand, Afifi (Target 12) has deteriorated very badly (according to the same authorities), and its target diagram shows a very wild scatter. Only one other variety is as wild, namely, Assili (Target 8), which was only introduced in 1910, showing that it was not so pure as it was at first claimed to be. In the case of this variety we can trace the deterioration by target diagrams for the best commercial seed of successive years (Targets 4 and 8), and can watch the gradual obliteration of the "type group" of dots by mixture and crossing with the outlying rogue dots. Sakellaridis is another new variety, also not as pure as it ought to be.

Relative Importance of Seed and Cultivation.

These diagrams have been included to show that varietal impurity is a real difficulty, and not merely the theoretical matter which it might appear to be. If a variety of cotton consists of plants which, when growing side by side, produce lints differing in length by as much as half an inch, it is waste of time to advise short-period pickings

Fig. 16.

FIG. 16.—TARGET DIAGRAMS SHOWING THE COMPOSITION OF VARIETIES AND PURE STRAINS.

Each of the twelve targets is a square, bounded as follows: Above, by a ginning out-turn of 21 per cent., and below by one of 35 per cent.; to the left by a lint length (combed) of 20 mm., and to the right by one of 34 mm.

Each dot represents a single plant.

The position of each dot thus shows the lint length and the ginning out-turn of the plant it represents.

If all the plants are identical in these and other respects, all the dots come together, except for accidental displacement. If the plants are not alike, the dots must obviously be scattered apart.

To realize the use of the diagram clearly, it should be viewed from about twelve feet away. Only the targets 5, 6, 7, and 10 are then clearly visible; 9 and 11 are faintly so. The others have their dots so widely scattered as to be invisible.

The kinds of cotton represented are—

| | | | |
|---|---|---|---|
| 1.<br>Abbassi | 2.<br>Nubari. | 3.<br>Sakellaridis. | 4.<br>Assili of 1911. |
| 5.<br>No. 77. | 6.<br>No. 111. | 7.<br>No. 310. | 8.<br>Assili of 1912. |
| 9.<br>Ashmouni. | 10.<br>D. F. | 11.<br>Yannovitch. | 12.<br>Afifi. |

" D. F." represents the daily samples of strain No. 77, discussed on pp. 90-109.

for the sake of reducing that irregularity which is due to environment, and which does not amount to more than a quarter of an inch (see Chapter IV.).

Colour Impurity.

As in the case of other peculiarities of the crop which we have discussed, the lint properties are therefore average properties, the deviations from the average being widest in bad cultivation, and least when cultivation is good. To conclude with an instance which is perhaps more striking, and certainly simpler, than these target diagrams. The colour of a sample of ginned cotton is an average colour. Thus the modern Ashmouni cotton has deteriorated in colour, losing the full, rich golden-brown which formerly characterized it, and becoming much paler. If we take a prize sample of modern Ashmouni, and raise thirty or forty plants from it, we shall find a few plants whose lint is nearly white, many creams and light browns, and perhaps about one quarter of the plants will be found to bear rich brown lint, which, when placed side by side with a sample of twenty years ago, matches exactly. The colour of a prize sample of Ashmouni is thus produced by placing together hairs of these various colours, the lighter hairs diluting the colour of the darker ones. The old colour can immediately be restored by propagating some of the plants which bear the rich brown lint.

The photographs we have given (Pl. IX.) show very imperfectly the differences from plant to plant within a variety. Cotton is a difficult photographic subject, except when single plants are taken with a background, and in that case much of the impression is lost, as compared with the view of a series of plots. The examples given (Abbassi) are interesting; in the first place, the target diagram of Abbassi (Fig. 16, Target 1) was made, and then nine plants were chosen from the type portion of the target group; all were graded and pronounced to be of Abbassi type, besides having the Abbassi colour. The seed from these nine plants was sown in nine adjacent plots, and in seven out of the nine the strains were pure as far as branching and leaf-form characters were concerned. None of these seven kinds in the least resembled one another, and all were more dissimilar than the plot of Abbassi had been from other Egyptian varieties in the previous year. From those plots with peculiarities which showed up well in the camera, photographs were made of average plants; and, striking though these differences appear in the photographs, they decidedly minimize, rather than exaggerate, the differences actually shown.

Plants of One Variety.

The commercial sample of lint thus consists of different kinds of lint mixed together, these different kinds having been borne on different types of plant, with different methods of reaction to their environment. Over and above all this are superposed the effects of the environment from day to day, causing variations in the length and breaking strain of the fibre in successive bolls, as we have shown, while incidentally there are differences between the individual experiences of particular plants of the same kind, and differences from one site to another. It follows from

Origin of the Commercial Product.

this complexity that, while an amateur can grade the lint from small plots of a pure strain fairly successfully, it takes an expert to grade commercial lint.

Properties of the Commercial Product.

Our next step is to attempt to connect these properties of the lint as shown by our methods, with those recognized by the grader, with those ascertained finally by the spinner, and to see how far our analysis will carry us.

Leaving the major characters of length and strength for the moment, there are minor characters such as colour, cleanliness, elasticity, and lustre. Elasticity is probably involved in uniformity; all cotton fibres are elastic to a high degree, and the resulting "feel" of the cotton in this respect is probably a combination of effects resulting from uniformity, fineness, and twist.

Colour Modifications.

Colour is, in the first instance, based on the inherited peculiarities of the variety, modified by subsequent events; if the seed-cotton remains too long on the plant, or is exposed to dew or strong sun, the colour fades; there also appear to be different inherited degrees of "fastness" of the colour, some strains bleaching more easily than others under similar conditions of exposure; consequently, while it is often contended that cultivation in a new country changes the colour, and while such change is quite probable, since colour fluctuates like any other character, many such examples can be analyzed to fading-phenomena when they are shown in the first year, or to natural selection in a mixture (such as Ashmouni mentioned above) when shown in subsequent years. Cleanliness hardly needs mention from our point of view, being the result of accidental episodes which happen after the boll has opened, or of insect attacks on the boll.

Lustre.

Lustre is somewhat peculiar, It would seem to have been insufficiently analyzed by investigators, and in the first place it is probably almost synonymous with twist; if all the hairs in a sample are well and evenly twisted, there will be an infinite number of convex surfaces, each reflecting a spot of light. In addition to this there is refraction of light, which may be seen by holding a well-twisted fibre against a dull background with a good north light well overhead. The fibre then shows slight diffraction colourings; this undoubtedly has considerable influence on the appearance of the sample, through the reflection of light back from the concave surfaces inside the fibre; it would necessarily involve the translucency of the fibre wall, since any opacity of the wall would obliterate it. Such opacity might result from prolonged exposure of the seed-cotton on the plants, or from irregular deposition of the thickening layers of the wall, in so far as single fibres are concerned, while irregularities from fibre to fibre would have a similar effect in a bulk sample of lint. In former discussions of lustre the major importance has been attributed to the cuticular skin of the fibre, and to variations in its reflection of light; but cuticle is one of the last plant tissues to be affected by ill-treatment, and it seems more than probable that the causes of lustre changes and variations lie behind the cuticle.

One point may here be mentioned which the author has been unable to elucidate, namely, the habit in the U.S.A. of storing seed-cotton for a month if possible before ginning,* and the reverse habit in Egypt of ginning as soon as possible after picking.

**The Storage of Seed-Cotton.**

This habit in the U.S.A. has always been ascribed to the protoplasm of the lint hair cell remaining alive, and, so to speak, finishing its work on thickening the wall while in the store. Upland cotton does not behave in this way when grown in Egypt, the cell-contents dying as soon as the boll opens; and either the accepted explanation is incorrect, or else the process is merely one of "conditioning," by effecting a more uniform distribution of moisture through the sample than when it was first picked. Sometimes the effect is ascribed to the oil from the seed working its way into the lint, but the author is not aware that any chemical proof of this statement has ever been brought forward, nor is it easy to see how oil (which is buried as droplets in the living protoplasm of the embryo only) can work its way out, through the dead tissues of the seed-coat, including the vegetable ivory of the palisade layer (Fig. 20), and ultimately into the lint.

We now turn to the major characters of length and strength, with the all-embracing feature of uniformity.

There is very little to be said regarding Length, other than our previous remarks in the foregoing chapters. If any of the many contributing causes have brought about irregularity in this respect, the sample will be unsatisfactory; it will not "pull to a hard edge" (Fig. 18, *B*),

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* But not in Texas.

and, since even the best machinery cannot completely equalize the distribution of tufts of varying length in the yarn, it will make weaker yarn than a similar sample in which the lengths of all hairs are the same and equal to the mean length of the irregular sample ; the old adage that the strength of the chain is that of its weakest link applies very completely to yarn strength.

Length.

The discussion of Strength embodies this adage, and also very much more. In the first place we must distinguish between the different kinds of "strength"; there are primarily, breaking strain or hair strength, hand-impact-testing or grader's strength, and the strength of the spun yarn. Secondarily there is the strength-variation from fibre to fibre, which affects all three classes.

The Kinds of Strength.

*Hair Strength.*—We have seen good reason for believing that the breaking strain or impact resistance of single fibres is almost entirely dependent on the sectional area of their walls, independently of their diameter.

Worked out in this way, it is not without interest to note that the tensile strength of a cotton fibre is about double that of wrought iron, so that lint is not quite such a delicate and fragile substance as one is inclined to imagine it. If the wall thickness is the same in two hairs, the hair strength will be proportionate to the diameter of the hair cell; while if the hair cell diameter is the same in both, the hair strength will be proportionate to the thickness of the wall. Our only reservation in this respect is that it is possible for the texture of the wall to affect the strength somewhat ; but—just as flowering is the main determinant of yield—wall thickness must be the main determinant of hair strength, while texture can only affect it secondarily as to strength, though possibly greatly in regard to lustre. We have also seen that hair strength is a definitely inherited peculiarity, though subject to much greater fluctuation than length, some strains never making a very thick wall, while others make very thick ones whenever they are given an opportunity.

A side-issue of great importance from this discussion of hair strength relates to the diameter of the fibre.

Diameter.

This we have seen to be comparatively constant within a pure strain; but since there is a little uncertainty in some previous writings on this subject, it may be well to discuss the matter more fully. The diameter of the developing hair cell is fully attained almost immediately, though the position of the maximum diameter in the full-grown lint hair may vary with different kinds of cotton, and cannot be settled till the hair has grown to its full length.

This diameter is that of a very thin-walled and more or less cylindrical tube. The diameter of the ripe lint hair

Diameter affected by Hair Strength.

is quite different: the walls of the tube have been thickened, and then have collapsed (Fig. 11). Obviously, if the thickening has been negligible, the width of the ribbon thus formed will be one-half the circumference of the original tube. If, on the other hand, thickening has been so complete that the tube becomes a solid rod, it will not only be incapable of collapse, but its diameter will be the same as that of the tube. The diameter of the ripe fibre may thus vary from 157 to 100, according to the amount of thickening, where 100 represents the diameter of the original hair cell (Fig. 17). Thus, in terms of width of the ribbon, the more a hair cell is thickened, the finer it will be, which is obviously absurd; thus the term "fineness" does not relate to the width of the ribbon, and has little to do with the maximum diameter of the collapsed cell.

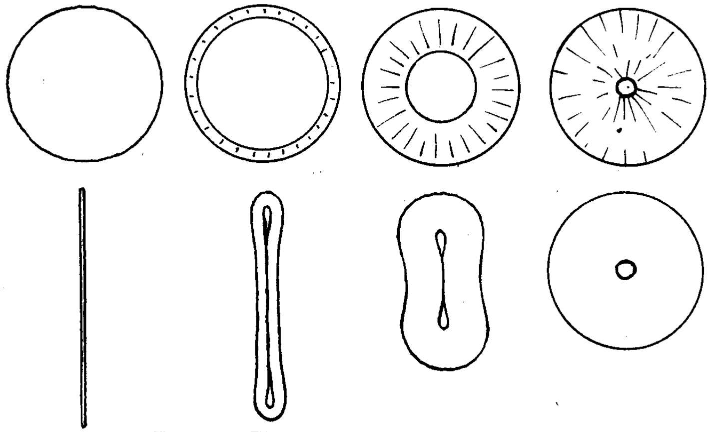

FIG. 17.—HAIR STRENGTH AND DIAMETER.

Diagrammatic transverse sections of lint-hairs, indicating how increased wall-thickness — *i.e.*, hair strength — must lessen the maximum diameter of the ripe hair.

Left, no thickening. Right, excessively thickened. Above, before the boll opens. Below, ripe and collapsed.

If again we compare the two pure strains already mentioned (p. 106), which had practically identical diameters, but very different hair strengths and very different designations in respect to fineness, we see that the maximum diameter of the lint has nothing to do necessarily with comparisons of fineness from one kind of cotton to another, as is so frequently stated.

Fineness.

On looking through published figures on this subject, one is struck with the way in which data for diameter have been stretched to make them fit the view that diameter and fineness are equivalents. The extreme range of mean fibre diameter in good samples of all commercial cottons may be taken as 0·016 millimetre for Sea Island, and 0·025 millimetre for some Indian cottons. The squares of these numbers stand in the ratio of, roughly, 2 : 5, and variations of this magnitude in fineness may be found within Egyptian cotton alone, where the diameters are practically constant. If, however, we consider the thickness of the wall of the fibre, which cannot well be measured except by cutting sections, and so obtain figures showing the thickness of the walls, they will follow the gradings for fineness much more closely.

Thus we reach a definition of fineness as practically equivalent to hair strength. Fineness is partly a matter of cell diameter, but more a matter of wall thickness.

The statement just made, that a fine lint is weak lint, may at first seem to be a *reductio ad absurdum,* but it needs further consideration from the grader's point of view.

*Grader's Strength.*—In the preceding chapter we saw that grader's strength and breaking strain were entirely independent, and that not merely from day to day in the same kind of cotton, but also between different cottons. We also concluded that the grader tested the lint for its resistance to impact, and that his comparisons were made for such resistance per equal weight of lint. The grader's decision as to fineness is really a decision as to hair strength, while his decision as to strength is largely a decision as to the uniformity of strength from fibre to fibre. Into this latter decision there enter other considerations, but it will suffice to leave the matter at this point, until one of the Graders shall also attempt to write a book on the subject. But it might be mentioned that the slipperiness of the lint has to be considered; it is almost impossible to break tufts of very " strong " fine cottons, because the hands cannot hold them firmly enough, but if the ends of the tuft are fastened with sealing-wax they can be broken with no more difficulty than any other cotton. Such slipperiness is partly due to the fineness of the individual fibres, but much more, in all probability, to the uniformity and frequency of the twist. Whatever the ultimate analysis may show, it is quite clear that the grader of cotton by hand is necessarily integrating a number of separate things under the name of strength, and we can now begin to see why graders' opinions are not always realized in the spinning-mill.

Interpretations of Grader's Terms.

In addition to this, it may be well to call attention to the fact that many of the features on which the grader bases his opinion are associative. Certain features of a cotton sample indicate that the crop was badly cultivated, and therefore the sample will possess certain other features. The substitution of pure-strain lint for commercial lint has

Familiar Associations of Features.

consequently some curious effects upon the grader. If the pure-strain lint has not been cultivated particularly well, it will show such "uglinesses" as would, in commercial variety samples, be necessarily associated with such irregularities of length and strength as a pure strain cannot show; the result is that the spinning-mill will give far better results than the grader would imagine possible.

Possible Mistakes in Grading.

Ignorance of this fact led to some serious consequences within the author's experience, and it would be well that those who may be concerned with the production of pure-strain cottons in the future should be aware of the risk.

*Yarn Strength.*—This is the only strength that really matters. Cotton is grown to be spun. If it spins well it is good cotton; if ill, bad.

Unimportance of Hair Strength.

We now meet with a new set of questions, many of which are still unanswerable in any exact expression; and although they have been dealt with more fully than other parts of our subject by previous authors, it may be well to present the case afresh. The main consideration is this: that the strength of yarn has very little to do with the hair strength as determined by breaking strain, only about a quarter of the available tensile strength being realized. The strength of yarn is thus almost entirely dependent on the hold which the individual hairs take upon one another. Yarn does not break primarily through rupture of hairs, but through slip of hair on hair. Strength of yarn, within limits, follows the amount of twist which is put into it, even the variation in strength of yarn after

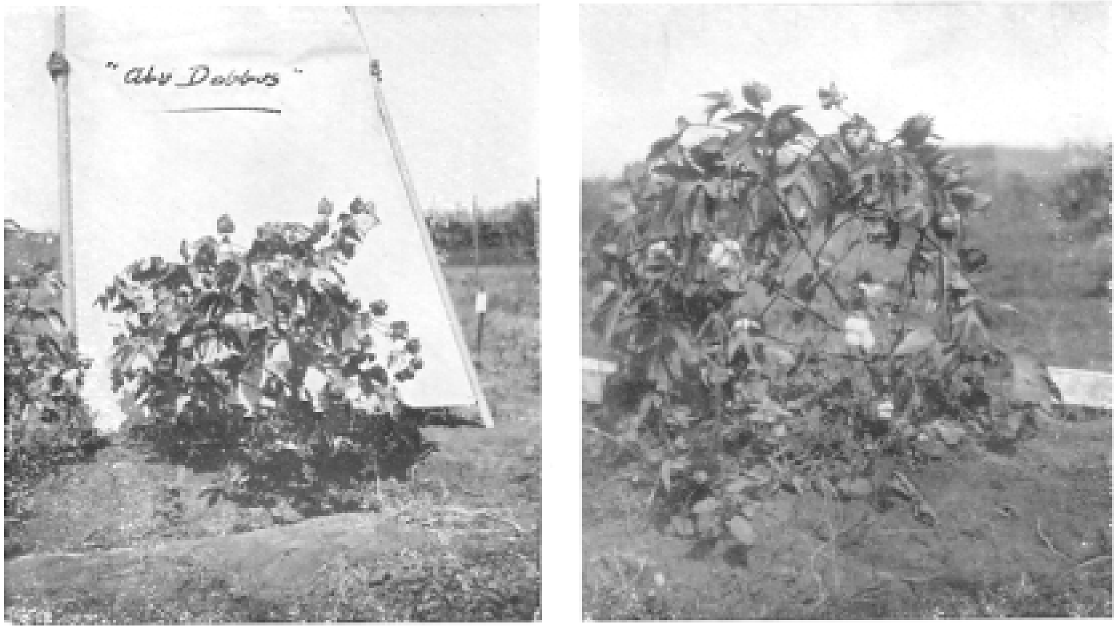

PLATE X.—AN IDEAL COTTON PLANT.

Photographs taken on July 25th (left), and August 27th (right), after several bolls had been picked. Giza, 1913, wide-sown. Christened the "Hedgehog Cotton" owing to the spiky appearance of the abundant floral leaves. This strain represents a rare combination of inherited factors, finally obtained in the fourth generation of a cross between two pure strains of Egyptian. There are no vegetative branches, all the stem joints are short, and the main stem ceases to grow at an early date. The result is a plant loaded with bolls, relatively free from shedding troubles. The lint of this strain is of the best Afifi type, and the author regards this as the ideal cotton-producing "machine." If subjected to natural crossing the stock would be entirely obliterated in a very few years.

mercerizing being accounted for in this way. If, therefore, yarn of a certain count and number of twists per inch is desired, the strength of it will depend almost entirely on the properties of the cotton employed, in respect to the grip which each hair takes on its neighbour. The author has practically no evidence to offer of the kind presented in respect of other characteristics, and our discussion must consequently be very general.

Uniformity.

In the first place, it is obvious that uniformity from fibre to fibre is a prime essential, on account of the weakest link. Uniformity in length must be of some importance, uniformity in diameter still more so, with uniformity in fineness, and probably uniformity in twist is the most important of all. Of these four features, the diameter is usually fairly constant; the length varies from the causes we have already discussed, and if its variation is excessive it can be regularized at the card or by combing; variation in fineness we have also discussed under the title of breaking strain, or hair strength, and there thus remains one important component—the twist of the lint hair.

Convolutions of the Lint Hair

Since the word "twist" has its special meanings in this connection, it may be advisable henceforward to refer to the twist of the fibre as "convolutions," in order to avoid confusion.

It was pointed out in Chapter III. on the Development of the Boll that the convolutions were caused by the presence of simple pits in the thickened wall, and were thus due to a definite structural cause, and not to any mystic gyrations of the protoplasm in the dying cell. This brings the whole question of these variations in the convolutions of lint hairs into line with other botanical investigations on pits in cell walls, and, although there are practically no data of the kind we require which are available at the moment, we shall be able to utilize them when they are obtained with other plants. The ideal cotton sample is one in which all the hairs are of the same length, diameter, and wall thickness, while all have the same number of convolutions per fibre in the same direction, spaced at equal intervals from end to end. Such a sample would interlock in spinning so as to give the maximum resistance to slip for whatever twist it received.

Reversal of Convolutions.

In the first place, the convolutions of the fibre do not always run in the same direction, but the direction reverses at intervals. It is not easy to say whether this is an advantage or not, under present conditions of spinning, for it should be remembered that, if all fibres were similarly convoluted, they would always have to be spun with the same direction of twist, if the maximum strength were desired. As to the causes of this reversal in twist, we can only conjecture that they result from some check in growth, taking place about the thirtieth day of boll development, when the secondary thickening is beginning, leading to irregular differentiation of the pit areas on the wall. They cannot be determined later than this, since otherwise the pits would not be formed through the whole thickness of the wall. They might possibly be determined earlier.

The spacing of the convolutions from end to end of the fibre would be determined at the same time as their direction, and in the same way.

Uniformity and Pitch of Convolutions.

In the third place we have to consider the "pitch" of the convolutions, which is of high importance. If the pitch is too low the fibres cannot interlock properly, and if too high they will be liable to "snarl" in preparation for spinning. At first sight it would appear that the pitch would be entirely dependent on the angle at which the pits were set to the axis of the cell, and this is undoubtedly an important component, as further investigations on the wild-cottons may show.

Pitch and Hair Strength.

In addition, however, the thickness of the wall affects the convolutions, as can be easily realized on considering two extreme cases. If a lint hair has an extremely thick wall, so that the central cavity is practically obliterated, it cannot shrivel on drying, and therefore cannot form visible surface convolutions, in spite of the presence of the pits; if the same kind of hair, with pits set at the same angle, is very slightly thickened, the collapse on drying will be at its maximum, and the convolutions will be entirely determined by the pitting. Thus intermediate stages will have intermediate pitch in their convolutions. Regarding the question in this way we bring the convolutions into line with other properties of the lint which we have studied in their development. Convolutions are primarily determined by the angle at which the pits are set—probably an inherited character—and are modified from this by the extent and regularity of the thickening of the wall, excessive thickening reducing the pitch of the convolutions. The pitch of the convolutions which gives the best result from any variety of cotton in any particular class of spinning operations is in all probability definite for that class.

It would seem, therefore, justifiable to assume that although no precise data of the kind we require have ever been obtained as to the varying development of the convolutions, yet in all probability the same considerations apply as in the case of length and hair strength. All the factors, constitutional or environmental, which modify the latter from ideal uniformity, also modify the convolutions in a parallel way.

*Uniformity.*—Throughout the whole of our discussion of the development of raw cotton there has been one recurrent ideal, namely, the production of uniform cotton. By various stages of analysis we have seen how it is possible to attain an approximation to this ideal, and how the difficulties may all be overcome—if it pays to do so—with the exception of such irregularities as are due to the "struggle for existence" between individual hairs on the same seed.

**Perfect Cotton Unattainable.**

The fact that we have had to carry our analysis into such minute details, and to link these up with such remote causes, shows very clearly that, however interesting the knowledge may be, a strictly uniform sample of cotton-lint can never be grown.

Equally, however, our analysis shows how very far

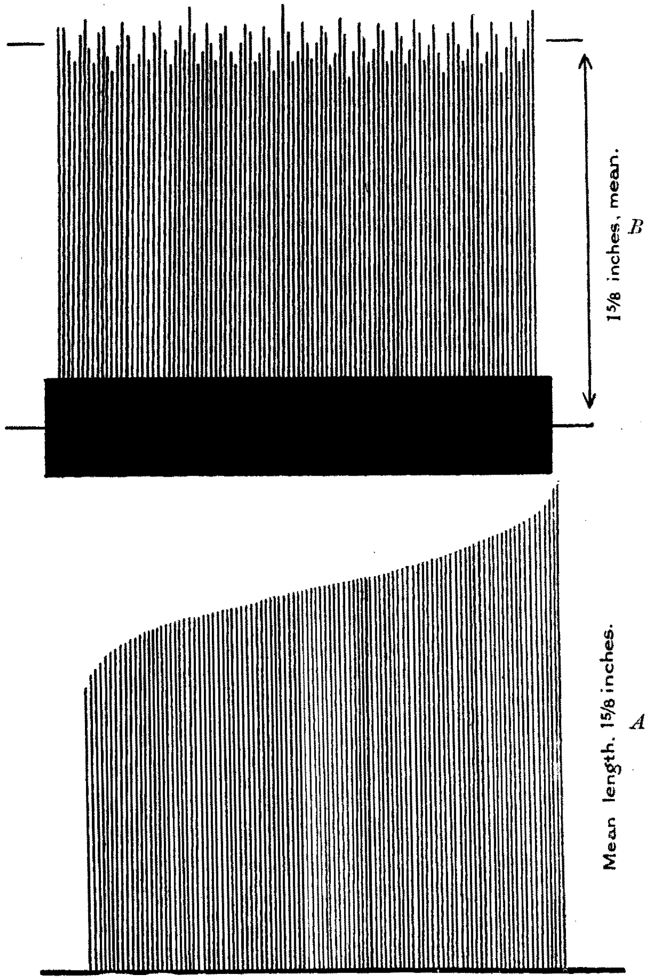

Fig. 18.—Lint Length of a Good Sample.

*A* represents the lengths of 100 lint hairs taken at random, and measured in a good commercial sample of Sea Island by O'Neill in 1863 (computed from O'Neill's figures), and checked by the author on samples of Egyptian varieties graded as "excellent" for regularity.

*B*, the same hairs as *A*, but mixed together and held in a clamp, to represent the grader's inspection in hand-pulling a sample. A sample which actually shows this amount of irregularity when sorted hair by hair is considered excellent, and pulls with a "hard edge."

remote from the practicable possibilities the best samples of to-day must be (Fig. 18). It is hard to believe this is so when one is handling some specially good St. Vincent cotton, or similar raw material; but nevertheless it is quite certain that the best cotton grown to-day is far from reaching the moderate uniformity which it would be quite practicable to attain by comparatively slight refinements in seed-supply and cultivation.

Ubiquity of Uniformity.

In the light of our analysis it is almost impossible to say what uniformity does *not* mean. Practically every property which a commercial sample possesses is partly the property itself, and partly uniformity of that property. Graders' strength is partly uniformity in strength, lustre is partly uniformity in cell-wall formation; deteriorated colour is non-uniform colour, and so forth. It is to be hoped that, even if the class of investigations described in this book has no direct applicability, they will at least facilitate the interpretation of these terms of common speech into their real components.

# CHAPTER VI

## THE DEVELOPMENT OF COTTON-GROWING

THERE is some peculiar fascination about cotton which defies analysis. Probably the enormous size of the industry, and the unsuspected revelations which it continually makes to the student, have something to do with its charm; the gap between the native cultivator and the mill-hand is so wide that any person dealing with any part of the cotton trade must of necessity take some interest in the other parts which only concern him remotely. It is a humiliating reflection on the intellectual effect of prosperity that the relations between science and the cotton trade became steadily less intimate during the past century, so that the sentiments expressed by writers on the subject read as if they had been written backwards, the writers of a hundred years ago summoning all the scientific knowledge at their disposal, while those of to-day frankly admit that the trade has been working by rule of thumb.

The obvious retort is that science was found a fallacious guide, and that the only path worth pursuing was the one which led to financial profit quickly. That the latter was the case till the end of last century is undeniable; the world had all the cotton it wanted for the time being, and no recondite study was necessary. Since A.D. 1900 the situation has altered enormously. Fears of dependence on the American crop in the event of a shortage, the developing uses for strong cotton fabrics in modern light and rapid instruments of locomotion, and the increasing accessibility of the colonies, have all led to initial steps in the development and control of raw cotton supplies, and to their better utilization when obtained.

Science.

To outline some of the principal ways in which these developments can most efficiently and rapidly be made should be of some use, if it be remembered that the suggestions are based merely on the author's personal opinion. The greater part of such development work is as yet but a stumbling attack on the problems involved, wasteful of time and money. If natural science is to take any concern in economic affairs, it should at least be able to offer some suggestions of a general nature which might facilitate the work of those who are clearing jungle, digging canals in the desert, and coping with the difficulties of administration, in order that more and better cotton may be swallowed up by the bale-breakers in the mills.

Finance.

In the first place, it should be clearly understood that science must follow the financier in the first instance. If transport, labour, water, are only to be obtained at a high price, cotton-growing must be a failure as a business proposition. Moreover, the scientific economist must follow close upon the financier, for the hasty development of cotton-growing in new country may lead to many troubles; the price of native labour may be raised to a prohibitive figure, from which it will not recover for years. Sometimes the scientist may be able to take the matter in hand, and by improving the value of the raw material, or by reducing the cost of production, compensate for these disadvantages; but this statement has been made so often, and so seldom realized, that it might be better not to repeat it.

Mechanical Pickers.

Essentially, then, cotton is a cheap-labour crop, and a hand-labour crop as well (Figs. 5 and 6), and will remain so until the dream of a mechanical means of picking has been realized. In this respect the author is inclined to think that the aim of inventors has ranged too far; a long experience of the routine repetition of operations, such as those on which the diagrams in this volume are based, has led him to value small refinements in method. The position in which a pencil is laid down by the side of the balance-case may make a difference of 10 per cent. in the number of weighings effected in an hour. Similarly, if a strip of bent tin or a curly piece of wire would enable the pickers to gather a few more bolls in the same time and with the same effort, it might make the difference between the success and failure of a new cotton-growing area. Even such trifles as dropping the load of picked bolls at the end of the row, instead of carrying it along other rows, make a difference in the amount picked, and some simple experiments of this kind might be quite usefully conducted, in order to ascertain how time might be economized, without extra labour from the operatives.

In developing a new district for cotton-growing, provided that the economic situation is satisfactory, two things are necessary. Firstly, a crop has to be grown in the field, and not merely in gardens; secondly, the reasons for its failure have to be ascertained. The author's use of the word "failure" is deliberately designed to draw attention to an aspect of agriculture which has not been fully viewed before; every crop is more or less a failure. More usually we say that it is more or less of a success, but in the case of cotton it is almost better to express it the other way.

The Failure of Cotton.

So long as good land in Egypt can produce a normal crop of 700 pounds of lint to the acre, with an average of over 450 pounds for the country, even now, while the U.S.A. averages about 200 pounds, and India less than 100, we have a definite basis of comparison for the degree of failure which we call success in cotton-growing.

To return to our second essential, namely, a knowledge of the reasons for the comparative failure of the crop. It is obvious that a full knowledge of this kind can never be obtained, and that it will take years of research to provide even reasonably intimate knowledge; but the immediate demand may be put in a simpler form, to wit, "How did the crop behave?" On the surface this would seem to be a childishly simple question, but it is one which no cotton-grower could answer in any form giving the scientist information from which to draw conclusions. With some crops it is a relatively simple matter to describe how the yield was attained, but when the yield is being

The Behaviour of a Crop.

built up day by day over a period of two or three months, ordinary casual (or even skilled) observation breaks down.

The first step in developing cotton-growing for a new country should be the procuring of records showing how the yield was built up under optimum conditions. This involves also determination of the optimum conditions.

Experimental Trials.

The optimum conditions of the site and year in which the trials were made are very simply defined as those which produced the largest crop, which also—other things being equal—will be the best crop. The conditions which produce the best crop can only be ascertained by trial and error, but there are right and wrong ways of so doing; much of this work as done to-day consists of very little trial and very much error. Certain conditions of the environment can be controlled in the trials, while others cannot. Weather is uncontrollable as regards temperature, and only as regards water when there is no rain; in irrigated land the water-supply should be made one of the subjects of experiment. Although the weather cannot be changed, its incidence on the plant may be changed, by making the time of sowing another subject of experiment. The soil may be modified by manurial treatment, though experiment in such direction should be restricted initially to those methods which are likely to be practicable for the general crop. Lastly there is the arrangement of the plants on the area cultivated, which is of more importance than has been realized in the past; there can, for example, be little doubt that the American crop would be about 30 per cent. larger if it were not necessary to put the rows far apart so that horse-hoes could work between them.

Taking three controllable variables only—manure, sowing-time, and spacing—a good deal of most practical

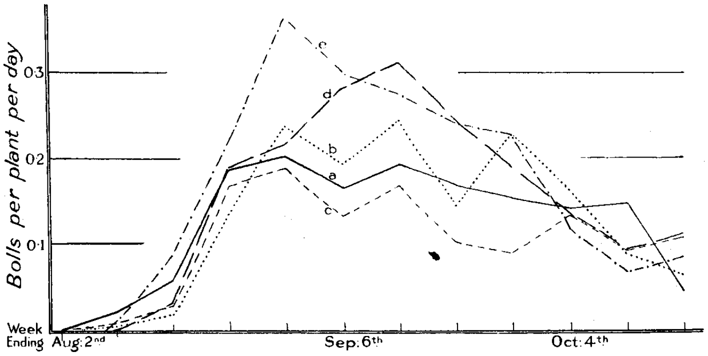

FIG. 19.—IDENTICAL PLOTS OF COTTON.

These curves show the number of bolls opening in each week of the season on five plots which were nominally exactly alike, in various parts of a single acre of land (shown in Pl. XI., XII.). Perfectly definite differences exist between them throughout the season, due to variation in the deeper layers of soil.

Fig. 2, p. 24, is constructed from the averages of such sets of five plots. Variety, Domains Afifi; site, Giza, 1913.

MEAN YIELD = 400 POUNDS OF LINT PER ACRE.

| | | | | | |
|---|---|---|---|---|---|
| *Per plot:* | | | | | |
| Total yield in pounds | 372 | 379 | 303 | 450 | 496 |
| Deviation { Actual | −28 | −21 | −97 | +50 | +96 |
| Deviation { Per cent. | −7 | −5 | −24 | +12 | +24 |
| Legend | ——— | ········· | – – – – | —— —— | —·—·— |

information can be obtained in a single year. It remains to consider how the optimum for each of these variables should be ascertained, and this brings us to the question of experimental plots.

PLATE XI.—CHESS-BOARD PLOTS.

Showing the arrangement of fifty small plots at Giza on April 12th, 1913. The size of the plots can be seen from the three lying next to the road, which are conspicuous through having recently been watered. Each plot consists of ten ridges, each of fifteen pairs of plants, and bears a serial number at the top of a tall stake. The results from these particular plots are used in Figs. 2 and 19, pp. 24 and 158.

Small Plot Trials.

In the last five years we have seen a revolution in our knowledge of field experiments, the methods of conducting them, and the errors inherent in them. The two chief features of this new knowledge are as follows: The increased precision obtained by increased size of plot is practically negligible beyond about one-tenth of an acre; the errors in comparison of plots which are supposed to be identical is such that with English wheat the plots may differ as 84 : 116 by pure accident, and only half of them will be as closely similar as 95 : 105.

Errors of Plot-Comparison.

A great part of this error is due to soil variations which cannot be eliminated. When we deal with a deep-rooted plant like cotton, which sends its roots through more than two metres depth of soil in a season, the errors are much greater from this cause. Identical plots of cotton may differ by nearly 75 : 125 through normal accidents alone. and half the plots are bound to differ more than 93 : 107, this degree of difference being shown on total yield, and being proportionately more on separate pickings (Fig. 19).

Need for Accurate Results.

Recognition of the existence of this very high degree of uncertainty in comparison will account for the uncertainty which attends on our present knowledge of the cotton crop. Practically the whole of the work of the past fifty years on experimental crops of cotton will have to be repeated in this new light, just as Mr. Leake has pointed out that nearly all the failures in introduction of new cottons into India have become devoid of significance in the light of recent discoveries about natural crossing. There is only one way in which certainty can be attained, and that way is a laborious one, though not at all impracticable ; by dividing the experimental area into small plots (Pl. XI.), putting five under each kind of treatment, and scattering these five over different parts of the area, the precision of the results with cotton may be increased to 9 : 11 as the maximum possible dissimilarity due to accident, when the five-plot averages are compared. It is frequently objected that the trouble and labour of handling small plots makes them impracticable; there is, however, no escape from the fact that only in this way can a reasonably correct answer be obtained; whether it is "practical" to obtain an answer which has practically no meaning, and "unpractical" to expend a little more on labour to obtain one which has a definable significance, must be left to the future to decide. It should be noted that the same amount of land and ordinary cultivation is required in both cases. The additional trouble is in the handling of the small plots, and especially in laying them out and sowing them. One working suggestion in the former respect may be useful, namely, that no attempt should be made to differentiate the plots in the field-work; each plot should have a serial number, be observed and treated under that number, and the final grouping effected only when working up the results of the observations. Working in this way it is not impracticable to combine two, or even three, experiments into one; thus sowing-time and spacing could be handled in one series of plots in the following way:

The Handling of Small Plots.

Four acres of land cut up into 125 plots, twenty-five being sown each week for five weeks grouped around the probable date of sowing, with five different spacings of five plots each. The data thus obtained could be taken as being correct within the 9 : 11 extremes for spacing and sowing combined, and for either spacing or sowing separately their extreme possibility of error would be 95 : 105. Whether such combined experiments were practicable, or whether each point would be investigated separately, would depend solely on the labour available. This class of experimental work requires either careful supervision at the times of sowing and picking, or else the training of a few natives to act as observers, with a modicum of thought in the arrangement of fool-proof methods for them to follow in making the observations.

Utility of Accurate Results.

By conducting experiments on these lines, so as to obtain a reliable answer, much time and money is economized in the following year, when the results from the plots are applied on a larger scale. The case of sowing-time in Egypt is very much to the point; the author has shown that the early sowing of cotton before a certain date is of no advantage, and may bring a loss, while sowing after that date delays maturity; the cause of the existence of this "critical date" would appear to lie in the temperature of the soil, which at depths of a foot or two undergoes practically the same seasonal changes in temperature every year.

So far we have sketched the methods only by which the optimum conditions of cultivation for a certain site and year can be determined. It still remains to answer the question as to how the plants behaved under those conditions?

Uncertainty of Subjective Opinions.

The cotton crop is thoroughly misleading in its appearance. A field may appear to have but little ripe cotton in it, and yet be full of open bolls which are obscured by the leaves. Another field may appear to be flowering profusely, and yet be about to stop flowering almost entirely. The best experts of those who spend their time in travelling about a cotton district and reporting on the crop condition are well aware, and will admit, that they cannot estimate the yield of cotton ripe in any particular field to within 10 per cent. Yet there is scarcely any crop which has been so entirely discussed on purely general ideas as to its appearance.

Elimination of Accidents.

The question arises as to whether any more accurate data are worth obtaining in the early stages of development, and the answer is most certainly affirmative. Take, for example, the case of a rain-storm occurring at an unusual time in the first season of experimental work; it is desirable to know whether the results obtained in that year are still generally applicable to future years, or whether they have been entirely falsified by the storm. To justify expenditure on elaborate small-plot experiments, it must be shown that their results can be made of general significance, and applied forthwith to other possible sites and seasons.

Fortunately it is a tolerably simple matter to obtain such records, given a few native labourers and a little training. The observations may be taken on the entire plots, or on groups of 200 plants each, counted and marked off by stakes in each plot. The observations which are practicable are those of bolling and flowering, and the object of these observations, as well as of others which are less easily obtained, is to present a continuous record of the behaviour of the plants. The ideal would be to take these records daily (Figs. 4 and 10), but this would rarely be practicable in early development work, and slightly longer intervals may be substituted.

Crop Records.

The records of bolling are obtained by picking or counting the number of bolls open on the observed groups of plants each week, so as to obtain the number ripening in each week per plant or per plot (Figs. 10, 13, and 16). When a large number of plots is being handled, it may be convenient to take one day of the week for one series, and one for another, but adhering strictly to the same day for each series. The figures may be expressed as the number of bolls ripening, or the weight thereof, or—best of all—both ways; if both are taken, the average boll weight each week is thus obtained, which is an important consideration. By plotting the results on squared paper, it is easy to see, not only which plots gave the best yield, but which were earliest, etc., and to deduce from these curves the reasons for failures.

Bolling Records.

The flowering records (Figs. 2 and 10) are even more valuable, but they necessitate daily observations, or alternate days at the least, if daily observations are absolutely impossible. They are more valuable because they are not subject to so many sources of error as the bolling records, and therefore give more accurate comparisons from plot to plot, especially as regards the early stages of growth. After the flower has opened, it may be prevented from ripening into a boll through shedding caused by water shortage or excess of water, or by weather; or through the attacks of insect pests or fungi. The bolling record thus merely shows how the crop was produced, but the flowering record helps to explain the why and wherefore. Flowering records cannot be taken satisfactorily on odd days, or even at regular intervals, because the flowers do not accumulate as the bolls do, and also because the rate of flowering varies very greatly from day to day, owing to previous variations in the growth-rate of the flowering branches. In spite of these disadvantages, if flowering records can possibly be obtained, they are well worth the trouble, on account of the insight they give into the way in which the yield was formed.

Flowering Records.

It is not always realized that the number of flowers opening is the main determinant of the final yield of a cotton-field; the yield may be less than the flowering would indicate (Fig. 10), but it cannot be more. The results can be plotted similarly into curves, on the same scale as the bolling records, per plant or per area; the difference between the two curves shows the loss on any day or in any week from shedding and from insects, and

Flowers and the Yield.

the departure of the flowering curve from a theoretical form gives evidence as to the nature and magnitude of the causes affecting the plants.

The utility of these Plant-Development Curves is almost endless, as the author has shown in Egypt. To

Use of Crop Records.

study the data obtained in ordinary field experiments, after being accustomed to using these continuous records, is like making use of a dictionary from which many pages have been torn away. The difference between them and the ordinary data for three pickings is similar to the difference between the inked trace of a barograph and the guesses founded on the tapping of the barometer. The trouble of obtaining them is appreciable, but the cost is trifling; one experiment with 100 plots on 2 acres, conducted by the author, in which many more data were taken than those sketched above, cost £30 more than the ordinary cost, for all observation salaries, stakes, headman's time, and clerical appliances. Three sets of plots of fifty each, directed to the examination of ten different spacings, sowing-times, and manurial arrangements, should, a year later, repay the outlay upon them many times over.

A modification of these methods may be used, with certain limitations, for testing varieties or strains when

Variety Testing.

only very small amounts of seed are available. A field of ordinary crop is taken, and in it are sown rows of the seed to be tested, replacing the ordinary crop seed which should have occupied the same places. These rows consist of about a hundred holes each, and not less than five such rows,

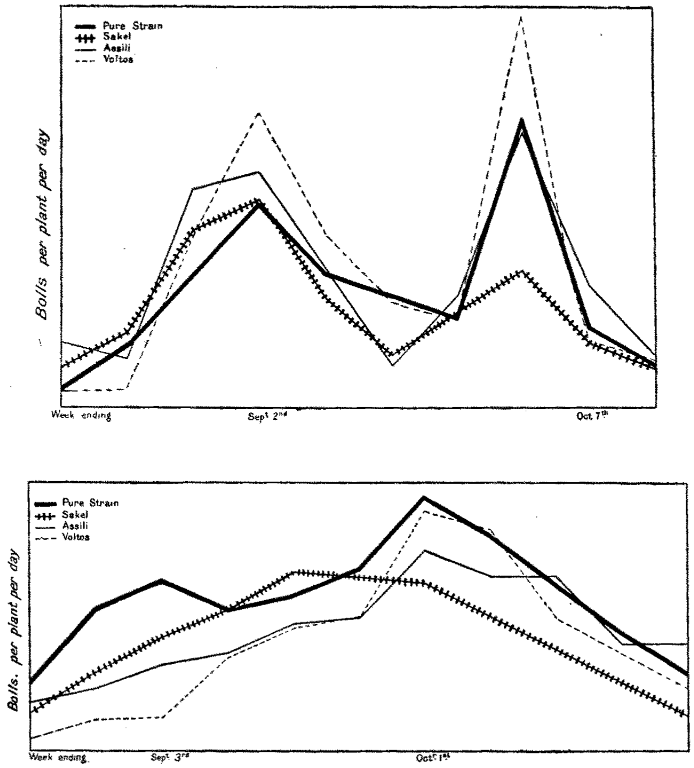

Fig. 20.—Variety Testing by Bolling Curves.

Illustrating the use of Plant-Development Curves for the comparison of varieties, using very small amounts of seed sown in scattered groups amongst ordinary field crop.

The 1911 comparison was made on land which had borne three successive crops of cotton, but was well cultivated.

The 1912 comparison was one richer land, and the curves consequently rise higher, but irrigation was delayed in July, causing shedding of the flowers, which consequently reduced the yield for a while in September.

In both years the slight lateness of the Voltos variety stands out, while Sakel clearly cannot tolerate water-shortage.

JUNE 25. JULY 21.

PLATE XII.--THE DEVELOPMENT OF A FIELD OF COTTON.

A portion of the same view as in Plate XI., showing how the soil becomes shaded by the densely crowded foliage.

preferably more, are scattered about the area. If more than one kind is to be tested, parallel and adjacent rows are used. Records are taken from these rows, showing their flowering and bolling, and from similar parallel rows of the ordinary field crop amongst which they are sown.

In this way it is possible to obtain remarkably exact comparisons when only a few ounces of seed are available, and a very marked economy may be effected in the following year when full field trials are undertaken, since not only have the useless varieties been eliminated, but valuable information about varietal peculiarities has been obtained (Fig. 20). Thus the accidental failure of a new variety can be distinguished from a real failure.

Meanwhile there is the question as to whether it is worth while attempting seed-breeding, and this is problematical. Seed-supply is only worth doing when it can be done very well, and a new country is rarely suitable for refinements of this kind, although it may be quite practicable to get minute data of the kind we have discussed from the land near a residence.

At the same time it would be well worth while attempting to make pure strains from the commercial varieties which were most successful, ultimately replacing these latter by them.

Pure-Strain Production.

The isolation of pure strains of cotton is another of the many commonplaces which the public likes to enshroud in mystery. There is nothing mysterious in the process; it is almost true to say that no skill is required, nor any knowledge of botany, nor even of cotton. The sole essential is ceaseless, unflagging, searching accuracy in handling the material (Pl. I., VI., X., XIII , XIV.).

Roughly summarized, but with most rigid definition of every word, it consists in obtaining seed from single plants by self-fertilization exclusively, until plants are found which give offspring all exactly alike constitutionally in every visible and measurable feature.

There seems to be some conviction at the back of many minds that a new kind of cotton can only be obtained by multiple crossing, destruction of organic stability, increase of tendency to reversion, interference with the balance of nature, and consequent aftermaths of like vagueness. Actually the production of pure strains is as straightforward and definite a process as the separation of sugar from sand.

The cost of such work is high, however, even if the actual purification research is not charged to it. To maintain a single pure strain from year to year, avoiding all contamination by crossing and mixture, cannot be done at a cost of less than about £50 per annum for a renewal supply of only 20 kilogrammes of seed, merely for appliances (Pl. XIII., XIV.), and without counting the cost of skilled labour. It would be to the interest of new countries to develop pure-strain cultivation as quickly as possible, when the old countries have strains to spare, for many such strains will be isolated and tested and found to be slightly unsuitable for the country of origin, and yet might be perfectly suitable for some other country. One of the coming features of the cotton trade in this respect will be an

Development of Pure-Strain Breeding.

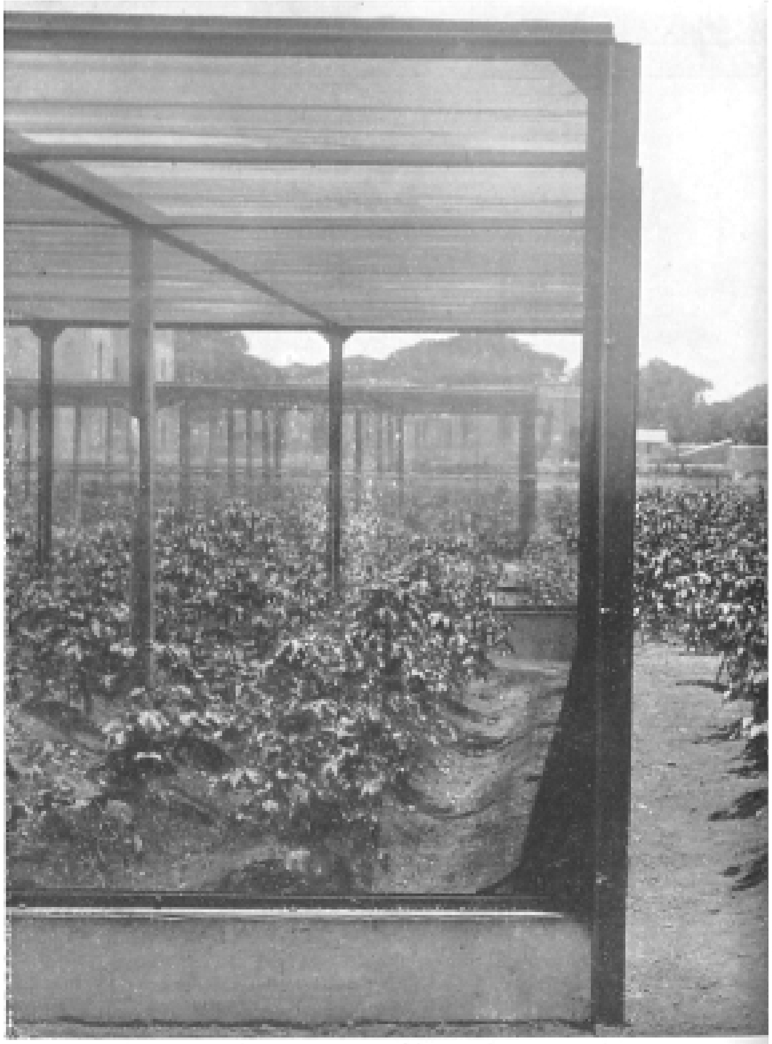

PLATE XIII.—MAINTENANCE AND PROPAGATION OF PURE STRAINS.

Bee-proof cages of brass gauze mounted in sectional panels of iron, each cage being one-thirtieth of an acre in area, costing about £70, and producing about twenty pounds weight of uncontaminated seed each year for the purpose of sowing propagation plots. This method is actually cheaper than bagging flowers by hand for the same purpose. View of, and through, the corner of two cages.

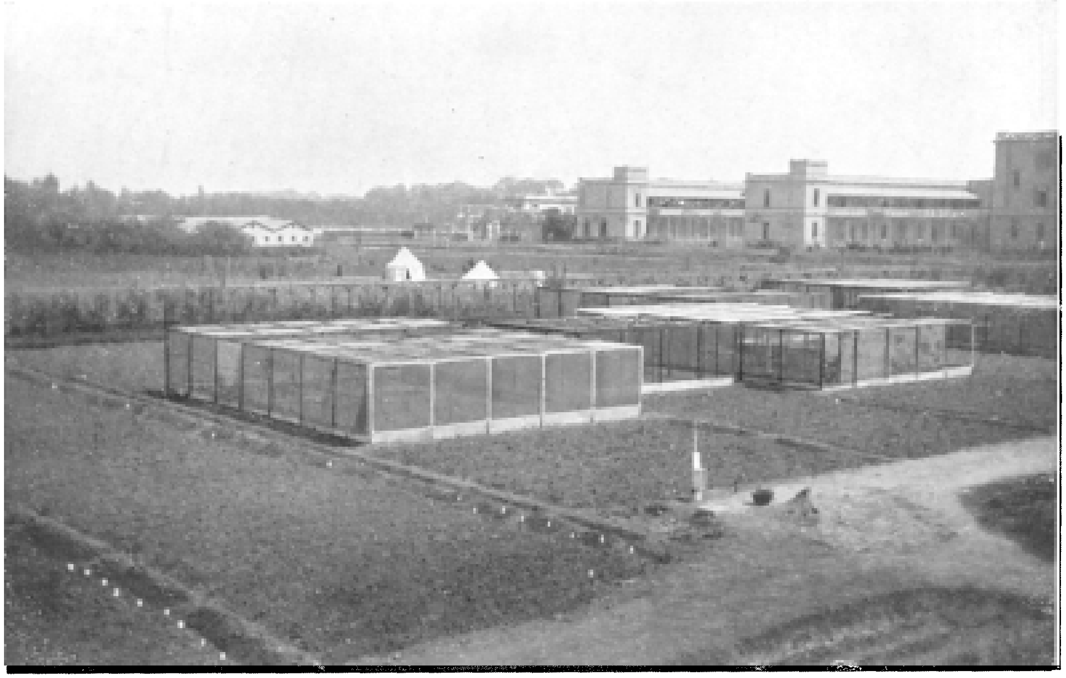

PLATE XIV.—A BIRD'S-EYE VIEW OF SMALL EXPERIMENTAL BEE-PROOF CAGES.

International Seed Register and Bureau, so that pure strains when once isolated shall not be left to die, but shall be kept alive in small quantities of seed, with accurate published descriptions of their performances in the conditions under which they have been tested, and shall be available for multiplication and further testing in any other country. The cost of such an organization will be borne by the trade as a whole, or by the consuming side of it alone, since it will be to the advantage of the spinner, and not to that of the successful grower, that such an organization should exist. At present not more than one per cent. of the work done on plant-breeding remains economically available. At the same time such an organization would have to be run very strictly, nothing but statistical evidence being admitted, either for purity, cropping capacity, or spinning properties.

Spinner's Testing-House.

This last brings us to another probable development of the future. At present it is very difficult to ascertain what is the comparative value of any sample of cotton, since there is no means of testing raw cotton. We have seen in the preceding chapter that the only test of value is the test of spinning, and some persons have suggested that miniature spinning-machine testers might be practicable. This is highly improbable, if not actually impossible, and in default of any existing indirect methods of analysis the cotton must be put through ordinary standard machinery. It is but rarely that any investigator has the good-fortune to have the courtesy extended to him in this respect which the author has received from the Fine Spinners' Association.

The trouble of conducting these tests in an ordinary mill is very considerable, but it should be practicable to establish a "Spinning Testing-House" for raw cotton, as suggested by Mr. J. W. McConnel, in which sets of machinery were installed for the special purpose of handling ten-pound samples. The fee would necessarily be fairly high, but the use of such an institution would not be confined solely to growers. The tests would have to be standardized for a range of counts and classes of yarn, and the results of the tests presented statistically as far as possible. An immense amount of uncertainty would thus be eliminated from the grower's work, and a series of standard records would accumulate.

Fifty Years Ago.

It is interesting to look back from the present day to the results obtained by the first of the author's predecessors, Mr. O'Neill. His papers were read in Lancashire in 1863, and from them we can make certain comparisons with the cottons of the present day. The intervening fifty years have heard much talk of progress, and have seen many extensions of cotton-growing areas. Nevertheless, the good cottons which Mr. O'Neill handled were every whit as regular and good as those of the present day. Modern civilization has scarcely begun to affect the cotton-plant.

This book has been written in the hope of clarifying ideas on the subject, and facilitating further inquiry, so that the cottons of fifty years hence may be more dependable than those of to-day.

# APPENDIX I

## METHODS OF INVESTIGATION

THIS appendix is intended rather for the use of those who wish to re-investigate this work. The subject is the methods of investigation employed in recording and controlling the condition of the plants, in the treatment of the developing bolls, in the examination of the seed-cotton, and in the presentation and analysis of the results.

*Crop-Records.*—A system of routine records of the daily condition of the crop was developed by the author, in the first instance for individual plants in breeding experiments, and later for field crop conditions. At the end of the author's service in Egypt these records had become so comprehensive that they gave information as to the state of the crop of the whole country, even when taken on a single site only. They consisted in measurements of the daily growth, of flowering, and of bolling, with subsidiary measurements of other features, such as shedding, and, in fact, of any character of the plant which the exigencies of research and convenience combined to render worth measurement. The cost of obtaining these data was slight, unskilled native labour being trained for the purpose, and checks imposed ultimately by the methods themselves. The headman checked the work of his subordinates, and very little supervision was required by the author or his assistant, since every set of plants recorded constituted a check on the exactness of the records from other sets. If the curves presenting the data from two identical sets of plots did not coincide after computation each day, slackness on the part of the Observers was suspected at once, and it is only fair to say that such occurrences were very rare. The Observers could not possibly concoct their results, since they had only a vague notion of the nature of the dozens of different groups of plants which they were observing, and the actual numerical records meant nothing even to us, until they had been grouped, totalled, divided, and plotted on squared paper. Our records of crop condition at Giza in 1913 attained nearly to absolute precision day by day from May to November.

All data were taken from definite groups of plants called "observation rows," containing a known number of individuals, and the results were all computed down to terms of an average plant. Presentation of the condition of such a plant as should be the average for a whole field, or even larger areas, was obtained by sampling various portions with a regular "scatter" of such "observation rows." Any one of these rows could be chosen for the source of such material as is required for investigating the development of the lint, whether for pickling or for testing, and reference to the routine records would show at a glance the daily rate of growth in tenths of millimetres, the fractional number of average daily flowers or bolls, dates of irrigation, and so forth; while against these could be plotted the corresponding data of each day for temperatures, sunshine, humidity, wind, evaporation, soil-water content, subsoil-water level, or any other data which might be relevant to the subject under investigation.

Presenting the state of the crop thus in the form of an ideal average plant at once brings the agricultural problems into directly botanical form, or, rather, propounds those problems in terms of plant physiology. With such exact records it is possible to trace most minute differences, of which one example may suffice:

In former years the author had ascertained the period of boll maturation for several varieties and strains by marking open flowers, and watching for their date of opening. Among these was a pure strain, No. 77, which in 1910 had a maturation period of forty-eight days, with a Probable Error of 3 per cent. In 1913 material was taken for these lint-development investigations from this strain, but no direct record of the maturation period was repeated; the question arose as to whether the change of plot and of year had altered the maturation period, or whether forty-eight days could still be taken as correct. A full set of daily observations of flowering and bolling upon the variety "Domains Afifi" were smoothed to five-day means, and the two curves superposed; they fitted with an interval of fifty-one days. The process was repeated with the relatively imperfect data from the observed group of No. 77, and indicated a slightly shorter period; then the dates of irrigation of the group of No. 77 were taken, fifty-one days added to them, and the dates thus obtained were marked on the bolling curve, when it was found that each date was three days later than a sudden rise in the bolling, which we knew to be due to diminished shedding; this marked the interval between the opening of the flower and the opening of the boll as 51 – 3 (or 48) days for strain No. 77 in 1913, repeating the conclusion formed by direct determination in 1910. A system of records obtained at very little personal trouble or official cost, which will thus cast up evidence at will, splitting apart differences of three days in a period of seven weeks, is obviously not without its uses.

Such an example also shows the precision to which field crop botany might be developed.

A fuller account has been given elsewhere of the methods by which these records were obtained, and only sufficient has been said here to explain the nature and purpose of them, and to make the appearance of the plant-graphs in the figures intelligible.

*Cytological Methods.*—The earlier part of this work was effected in 1905 and 1906, when technical difficulties and the absence of physiological data made it plain that no further real advance was possible until more had been found out concerning the physiology of Egyptian cotton. The indirect attack, or flanking movement, took years to develop, but in 1912 enough was known to justify a resumption of the direct cytological investigation, and material was collected which cleared up the whole story provisionally in about a week at the microscope, and was completely confirmed by the parallel and subsequent studies of cotton ripened from dated flowers and bolls.

For the later work we labelled batches of some 200 flowers on pure-strain families on a single day, and collected from these some three or four bolls every third day afterwards until maturity was complete. These were incised in each carpel wall, and pickled directly in acetic absolute. Most of the examination of this material was done in glycerine jelly, and without staining, though fuller methods were also employed. The technical difficulty of combing out long fibres devoid of any secondary thickening, so as to extricate them from the tangle of lint without breaking them, was solved by the simple plan of combing with a small-tooth comb in the usual way, but in warm water instead of in air, after pickling.

The microscope employed was the large Zeiss stand, with condenser, compensating oculars 2, 4, 12, and 18, objectives *a*2, A, D, and $\frac{1}{12}$ oil immersion, and the 3 millimetre apochromatic objective, all by Zeiss.

Sections were cut by hand on the hand microtome or on the Cambridge Rocker, embedding in 60° C. paraffin. The more strictly cytological material of the early investigations was fixed chiefly in strong Fleming, and stained chiefly with Heidenhain's hæmotoxylin. Some of the 1912 material was also examined with these reagents.

Sectioning of the lint itself deserves some additional mention, as the difficulties which the author encountered have caused him to wonder how the sections so freely figured in other works were obtained, and a special method had to be worked out to cope with them in the 1912 material. Part of these difficulties was due to the stroke of the Cambridge rocking microtome, which does not give a drawing cut, and is consequently helpless against cotton fibres, even when the paraffin is cooled to 0° C., these fibres being equal in tensile strength to wrought iron, much more elastic, and only 0·018 mm. in their widest sectional diameter. Tolerably satisfactory sections were obtained with a drawing cut on the Swift's hand microtome, once satisfactory embedding had been attained.

Embedding was found to be most difficult. Ordinary xylol infiltration, even in three-day steps, was useless, and finally success was attained with chloroform *in vacuo* at 100° C., with the added advantage of very rapid handling. Material which had been left in ordinary alcohol overnight could be in section under the microscope by noon, all operations being conducted in test-tubes connected with the vacuum water-pump by tubes passing through the thermometer hole in the roof of the water-jacketed drying oven, saving the expense of a vacuum embedding bath. The stages were: alcohol, absolute, absolute - chloroform equal, chloroform three times, chloroform-paraffin 60° C., paraffin 60° C. twice. In this way the lumen of the cell was thoroughly infiltrated, and clean sections could be cut, cemented with albumen-glycerine, and handled as smears.

*Preparation of Dated Samples.*—Samples of known history, upon which the physiological hypotheses based on the cytological evidence could be tested, were most simply and completely obtained by taking daily pickings. The result is material which has undergone an endless variety of environmental experiences, these latter being recorded in the routine records already described. Some severe maltreatment of the plants may be advisable in the first experiments, in order to provide an unmistakable effect as a base-line. The result is that such material provides not one experiment, but a series of some sixty experiments in one, with consequent economy of time and labour in handling the material.

*Continuity of Record.*—Such treatment involves a principle of considerable moment to biological research, and especially in agricultural matters — namely, the utility of continuity in data. Every additional point in a curve increases the definition of the curve, and a continuous projection is, moreover, much closer akin to the requirements of the practical man than the exact definition of a few isolated points. Much of the agricultural investigation of the past has been unconsciously an effort to draw complicated curves from the knowledge of only one or two points along their course, so that divergencies of opinion have naturally arisen—and have given a proverbially bad name to agricultural experts.

Continuous data are so much more easily interpreted, especially in field records. We are all familiar with the recording barograph, and find it much easier to observe the changes of the weather from the rise and fall of its inked trace than in the days when the old game of tapping the barometer prevailed in our households; the barometer might have fallen ½ inch and returned again during the night, but we were none the wiser. The physical laboratories think in continuous projection, but in many fields of biological work even the effort to obtain continuous data has not yet begun, especially in tropical agriculture.

Until the author had familiarized Egyptian workers in agriculture with his " bolling curves," even the best-informed of them were under the impression that the three " pickings " of cotton-fields corresponded to three separate orgasms of energy on the part of the plant; in point of fact there is some accidental justification for the origin of this belief, but the belief long outlived the circumstances which gave rise to it.

This idea of converting our fragmentary knowledge into a continous sequence was in the author's mind at the very beginning of his Egyptian work, but not definitely formulated in working methods, excepting for a conviction that, because much work on the cotton crop in bulk had failed to yield many generalizations, it would be worth while to work in the opposite way, by studying a few plants carefully, and from this—as methods developed to make possible the study of many plants carefully—the drift towards continuity became apparent.

The practical objection to developing continuous records is that, unless assistance in some form is available, there can be no day of rest for the observer, for a single day or period omitted from the records spoils two intervals, the one before and the one after.

The collection of bolls on successive days is not entirely satisfactory, since there is a slight subjectivity involved in deciding whether a boll is fully open or not; and unless the same observer can always collect the material each day, this may lead to slight irregularities, though only of a single day in either direction, the fully open bolls being fairly definite. More precision can be obtained by labelling flowers on successive days, and collecting the bolls which ripen from them some seven weeks later. In this case the boll can be left on the plant as long as may be convenient, but the method involves more trouble and risk of mistakes in identification.

In either case absolute exactitude is unattainable, since, although the maturation period is definite (*vide supra*) for any given strain, it also has a definite range of fluctuation from accidental circumstances acting on the individual boll or plant. The probable error of the maturation period is 3 per cent. in Egypt ; this on forty-eight days is one and a half days, or, in other words, half the bolls observed will mature between forty-six and a half and forty-nine and a half days, and no ordinary accident can make the boll take more than fifty-three or less than forty-three days. Therefore, even if we define either end of the maturation of the particular boll with complete precision, we cannot be quite sure of the age of the boll at the other end on any given day; we can, however, define exactly what the chances are, and from this we can deduce the size of sample necessary to smooth out these accidents. In practice a ten-boll sample is quite satisfactory, and fifty bolls are ample.

The seed-cotton so collected is weighed to determine the average weight of the boll-content, combed to determine lint length, and ginned with concurrent determination of the ginning out-turn and the mean seed weight. Subsequently the lint is graded, and tested for breaking strain. The numerical statements thus obtained

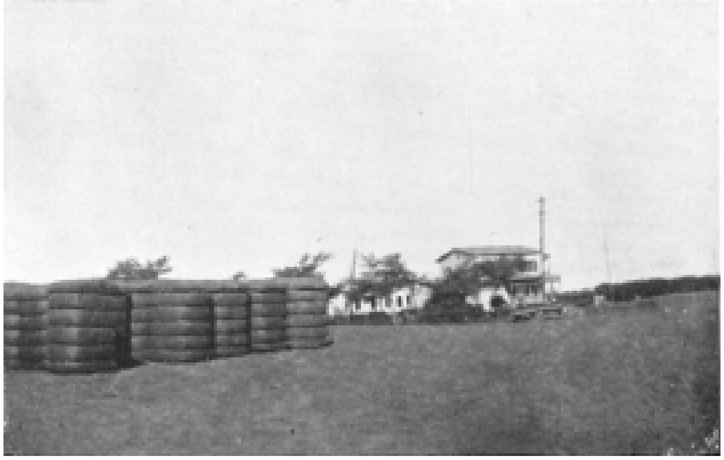

PLATE XV.—{ SACKS OF SEED-COTTON, LOWER EGYPT.
BALES OF LINT, LOWER EGYPT.

cover a great part of the results described in the text of this book. Other determinations, such as diameter of the lint hair, weight of a centimetre of the lint hair, thickness of the wall, amount of twist, etc., have been made only on samples chosen as typical of particular sets of circumstances.

*Ginning.*—The samples were ginned on a 12-inch roller gin made by Platt Brothers of Oldham. The author is indebted to this well-known firm for the very courteous loan of one of their 4-inch "Missionary" gins to use in England, while awaiting the arrival of a little Churka gin from India, but these two latter implements were only used for a small part of the work here described.

The 12-inch gin was run at about twenty-five revolutions of the roller per minute by hand, this slow speed being employed in order not to damage the fibre unnecessarily; in the ordinary way these hand-gins depreciate the quality of fine cotton very noticeably. For small samples the little Churka gin, or its modification with a twist-geared iron upper roller, is extremely useful, being so easily cleaned, and for work of this class it would be worth while for any investigator to make, or have made, a rather larger and improved form of this implement. The ordinary roller gin necessitates some troublesome attention to insure that the ginning out-turn is correctly obtained, since lint coming off the roller is liable to be lost by coiling round the roller axle. In any case a canvas shoot should be mounted on a light frame which is clipped under the beater-blade frame, in order to catch the seed, which otherwise has to be picked out of the interstices of the machine.

*Ginning Out-turn.*—The determination of this ratio of lint to seed-cotton, which we now know to be specific for each strain, just as lint length is, with fluctuations, is best effected by weighing the seed-cotton, and then the lint ginned from it.

From the figure thus obtained, together with the mean seed weight, one can obtain the weight of lint per seed by computation. Determinations by weighings of the seed are unsatisfactory, as a small percentage of seeds are always lost in the act of ginning, though the use of a canvas shoot and a loose overhead cover reduces this loss to about 1 per cent. with the 12-inch gin running as fast as two men can turn it.

The weighings and computation (by slide-rule) required to obtain the ginning out-turn can be done in about five minutes per sample. If the seed-cotton is weighed out against a fixed weight of 20, 50, or 100 grammes, there is then only one weighing to be done with loose weights, and the out-turn can be calculated by mental arithmetic without much risk of making a mistake. This reduces the time required considerably, but it still requires three or four minutes per sample. By a simple modification of the steelyard, provisionally patented as the "Slide-Rule Balance," this time was cut down to less than one minute, which is a matter of no little importance when hundreds of samples have to be dealt with. This balance works with two riders and two pans, movement of the primary rider bringing it into equilibrium with the seed-cotton on one pan, and movement of the secondary rider on the unaltered primary bringing the lint into subsequent equilibrium on the other pan. The primary rider is so graduated that the position of the secondary rider upon it shows the percentage of the second weighing to the first weighing, and thus there is only one figure to write down—namely, the ginning out-turn as desired. A simpler form with one rider operates for a fixed weight of seed-cotton only.

*Seed Weight.*—Speed and accuracy in determining the average weight of the seed in a sample are best obtained by weighing out 10 grammes of seed, and subsequently counting them.

It would appear quicker to count a hundred, weigh them, and obtain the mean weight of one seed by shifting the decimal point. Actually, however, the time occupied in weighing with loose weights is much more than in weighing out seed to a fixed weight and then using the slide-rule. Ten grammes is a useful size of sample.

*Lint Length.*—Throughout the author's work on cotton this important feature has been determined by measurements made on the seed, and not by "pulling" the lint. The disadvantage of so doing is that the measurements do not coincide with the length of the pulled lint, as the grader, spinner, and trade, express it, and, moreover, seed-cotton must be at hand to measure.

The advantages far outweigh these disadvantages, as the method is far more accurate, and the conventional statement can always be obtained by the addition of a number which is constant for any given strain. Thus 33 millimetres "combed" length is 40 millimetres ' pulled " length. Many of the uncertainties which have crept into our beliefs about cotton may be traced to this handling of lint only, though, if it were practicable to adopt the method of measuring single fibres initiated by O'Neill, many of these could be eliminated.

The three methods are as follows:

(*a*) *Single-Fibre Measurements.*—Lint hairs whose ends are visible on the outside of a loose heap of lint are pulled out one by one, laid down with the wet finger on black paper, and measured with dividing compasses. (In all measurement work it is necessary to use dividers which are afterwards placed on a scale, since subjective error comes in if the scale is directly applied.) Provided that microscopic examination is included in the programme to insure that each fibre is unbroken, the result in good samples has a probable error for single fibres of about 10 per cent. O'Neill's original figures for Sea Island work out at about 8½ per cent. Thus the measurement of 100 fibres gives a probable error of 1 per cent., or 25 fibres 2 per cent. We shall see below that the same precision may be obtained by combing six seeds only as by measuring 25 fibres. There can be no doubt as to the relative ease of manipulation; single fibres are quite easy to handle in a good light, but any prolonged work with them strains the eyes severely, as the author knows only too well.

(*b*) *Pulling.*—The grader takes opposite sides of a lump of lint in the whole grip of each hand and draws them apart; he then grips the projecting fringe of one half between finger and thumb along a straight line and draws again; the distance from the grip to the end of the fringe gives the length, and the "hardness of the edge" gives the regularity of length. The details of pulling vary between different places, and between the graders of different kinds of cotton, some laying the pulled fibres repeatedly over one another, and then extracting a tuft from this parallelized group and placing it on the coat sleeve. This latter method is the more objectionable of the two. in that it extricates the longest fibres every time; but the same objection applies to both, namely, that the measurement is a measurement of the longest fibres and of the strongest fibres. This is unimportant to the skilled grader, who knows instinctively how to allow for it, but it leads to complete misunderstanding on the part of amateurs who attempt to copy him; and it should be remembered that any person who has spent less than ten years in the daily grading of cotton, and has not in addition been born with the instinct implanted in him, is an amateur at cotton-grading.

Further, it is not easy to measure the exact length of a pulled tuft, it having two vaguely defined ends instead of one, as the lint has which is combed *in situ* on the seed, and measurements are therefore just four times as incorrect.

(c) *Combed Seed-Cotton.*—The sample of seed-cotton to be measured is broken up into five, seven, or ten bundles, according to the accuracy desired, seven being the usual number. Each bundle is picked up in turn, pulled into two halves, and the first seed seen separating from the rest in the gap is picked out for combing; the choice of the seed is this way is nearly random, and if it is dependent on any property at all, it probably depends upon the twist of its lint, and not upon length.

Each seed is then combed with a small-tooth comb from the tip of the seed towards the butt, and outwards, at first lightly to disentangle the basal portion of the hairs, and then firmly, holding the seed and all the disentangled basal portions tightly between the finger and thumb of the left hand to prevent them from being torn apart. Finally a few strokes of the comb carry away any broken or detached fibres, and the seed is left with a halo of lint around it, chiefly at the basal portion. If the regularity of the lint is also under examination, more careful combing is employed to set each hair out along the radius of a circle with its centre in the seed.

The seed with its flat halo of lint is laid on a dark background, held down by the forefinger of the left hand resting on the seed; one leg of the dividers is then brought up against the butt of the seed, and the other is swung around and adjusted until it moves along the edge of the halo. Successive measurements made in this way on the same seed vary only 1 millimetre, so that the halo edge is obviously quite definite, even in poor cotton.

The mean of seven measurements has a probable error of less than 2 per cent., even in samples which consist of cotton damaged by premature opening, boll-worm, etc., and is thus better than twenty-five measurements made on single fibres.

The time occupied in the complete cycle of operations is ten minutes, or, when two persons are working together, about four minutes.

The reason for the superiority of the seed-combing method is obvious; it eliminates systematic variations of length between various parts of the seed, and measures the mean maximum length, leaving only the fluctuation from seed to seed to be wiped out by sampling. The application of statistical methods has been of the utmost service in this matter, as may well be realized on consulting works which quarrel with O'Neill's original method, because damping causes the fibre to stretch a millimetre, or for similar reasons. We are now able to prepare a numerical statement, of any desired degree of precision, in a reasonably short time and without eye-strain.

But it should be observed that such a method is a research tool, or a means of exchanging ideas, and no more. While we amateurs are working out the lint length of a sample by ten minutes of effort, the grader will satisfy himself in as many seconds. It is also curious that the precise method should be the reverse of the convenient method, for the apparent length of cotton on the seed—even after combing—is most deceptive to the eye.

*Examination of the Lint.*—The chief characteristic examined in the ginned lint, apart from grading, is the strength, since length is preferably determined in the seed-cotton state. Before treating of strength-testing we may mention one or two minor features for which special methods have been found useful.

*Diameter.*—There is a more speedy way of determining diameter than by the micrometer eyepiece. If a camera lucida is set up, the magnification of its setting determined by drawing an object micrometer scale with it, and the diameter of fibres then drawn on a fresh sheet of paper, the mean diameter of a large number of fibres can be obtained very quickly. The fibres are mounted in a parallelized tuft, and observed in the middle of the tuft, or elsewhere as may be desired, and an **H**-shaped mark made on the drawing paper to define the two margins of each fibre, the cross-bar of the **H** tying together the two parallel margins in order to prevent confusion. The magnification should be so adjusted that each **H** is not less than 10 millimetres wide, and the mean width can then be taken with a millimetre scale, or by a simple form of instrument for totalling small lengths, which consists of a lever bearing a stylus and revolving a drum by means of a friction ratchet, or—where cheap labour is available—by cutting out each **H** from the paper, and placing them edge to edge in a row.

*Weight.*—The comparison of weight of equal lengths of fibre might be exceedingly useful, but until we can devise a machine which will count single lint hairs it must remain impracticable,* on account of the strain on the eyes, which is far worse than in isolating single fibres. When impact-testing of strength is employed, the two may be combined, and the fibre-counting necessitated by the one be utilized for the other.

Some seventy to a hundred fibres having been counted out, they are fixed across a gap in a piece of stout paper under slight tension by a drop of sealing-wax at either end. Twenty millimetres are then cut out of the centre by scissors, or by two safety razor blades mounted parallel in a brass holder. The bunch of 2-centimetre lengths thus obtained is bundled up and hung on the hook of a micro-

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* See, however, note on p. 102.

balance, and the weight calculated to that of 1 centimetre of a single fibre.

The micro-balance used by the author was home-made, the torsion spring being fine capillary glass rod, mounted with sealing-wax at either end into a frame made of glass tube. The transverse lever was made of fine capillary glass tube, with a hook at one end to hold the fibres, and a counterpoising tail, the motion of which was observed in a mirror; a drop of sealing-wax united the lever to the torsion rod where they crossed, and the particular instrument employed was thus easily made to give 50 millimetres deflection for 1 milligramme, which was sufficiently sensitive for preliminary purposes.

The probable error of fibre-weight determinations would seem to be high, but the greater part of this is due to difficulties in sampling.

*Strength.*—The original work upon the breaking strain of single fibres is that of O'Neill, who rightly observes that: "Experimenters appear to have been deterred from manipulating with the individual hairs, on account of their smallness and lightness." O'Neill's paper has suffered from endless citation, but it was a very neat and accurate piece of work. The number of fibres he examined was not sufficient to give the general certainty to his figures which have since been attributed to them, only 363 fibres in all having been tested from seventeen different samples, representing about two weeks' steady work with the method he employed. But he published all his figures. From these we can work out the statistical significance, which is the same as Mr. Hughes and the author have found—namely, for length a probable error of about 10 per cent., and for breaking strain about 15 per cent.

O'Neill used a cylinder floating in water which could be withdrawn from a stopcock, thus increasing the strain on the fibre fastened to the top of the cylinder. Subsequent workers have modified his apparatus, notably Yves Henry; but the method remained slow—about fifteen minutes per test—and required the use of skilled labour throughout. Mr. F. Hughes made a great advance in the method by mounting the fibres across a hole in a piece of black paper with sealing-wax; this paper could then be hooked into the testing apparatus, the sides of the hole cut through, and the fibre was then free to be strained; we subsequently found that this device had been employed independently by other workers, but the merit of it from our point of view was that all the preparation could be put into the hands of a native lab-boy, and only the actual testing done by skilled labour, at the rate of about five minutes per test. Mr. Hughes further arranged that the load should be applied at a fairly constant velocity, by putting a fine-drawn tube in the stopcock outlet, and thus obviated one of the main objections to the old form of the appliance.

The immediate cause of this strength-testing work was our mild dissatisfaction with the spinning industry, who complained that Egyptian cotton was not so strong as it used to be, but could not produce sufficient figures to carry conviction to the growers and official bodies concerned, although many were prepared to believe it. It was felt, quite rightly, that some beginning must be made in keeping numerical records of some sort; and since it was obviously impossible to set up spinning tests in Egypt, data as to breaking strain of single fibres were better than nothing.

From Mr. Hughes' data it appeared that with proper sampling the probable error of single fibres was 15 per cent., so that a test made on fifty-six fibres would have a probable error of 2 per cent., or, in other words, that strength-testing could be made as accurate as length-testing without using an enormous number of fibres. Even at five minutes per fibre this meant an hour for each sample, and, as the author had one series requiring testing which alone consisted of sixty samples, he cast about for some method of speeding up the process.

*Automatic Tester.*—The outcome of some weeks of instrument-making in spare moments was a home-made machine which tested fibres one by one automatically, at the rate of one in twenty-five seconds, and single-fibre testing became practicable on a large scale. At the same time the instrument is—or, rather, was—a purely laboratory appliance, since it necessitated the native lab-boy's assistance to mount up the fibres on cards somewhat similar to those used by Mr. Hughes; these cards were loaded in a magazine, and the author's part in the testing consisted in aligning the magazine to the tester proper, cutting the cards and pulling over a switch. The magazine then swung in to the testing-points and placed a pair of half-cards upon them, with 10 mm. of fibre connecting them, moved away, and stopped. The tester then strained the fibre at a constant rate against a spring-balance which

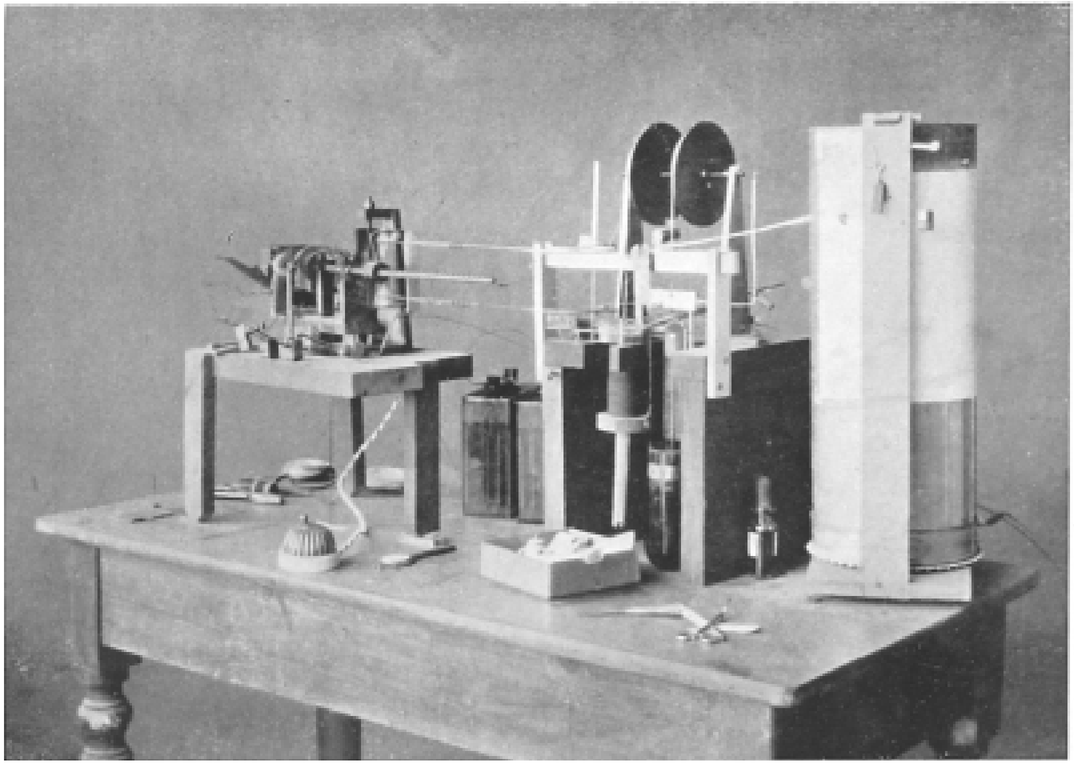

PLATE XVI.—AUTOMATIC FIBRE-TESTER.

Instrument for testing the breaking-strain of single fibres, which are mounted on cards, loaded upon the magazine (left), which passes them one by one to the tester (centre), the strain being recorded on the drum (right). (See p. 190.)

recorded the strain on a drum. When the fibre gave way the balance returned to rest, the drum moved on to receive a fresh trace, the broken fibre with its cards was thrown off, and, the clutch of the magazine being pulled out at the same time, the cycle of operations started again.

The set of cards in the magazine having been dealt with, the paper was removed from the drum, and a fresh magazine inserted, with a fresh batch of fibres. The mean breaking strain was obtained quickly by adding up the total deflections of the balance as marked on the drum with a map-measurer, the whole operation with a magazine of twenty fibres taking eight minutes, most of which was simply spent in watching the machine do the work (Pl. XVI.).

*Impact Testing.*—On leaving Egypt the author lost this automatic tester, because some parts of it had been made with Government material. The task of reconstructing it was rather formidable, and a timely suggestion was derived from a paper by Mr. J. H. Lester, in which he points out the value of ballistic testing of yarn. The chief feature, from the author's view-point, is that bunches of yarns or fibres can be tested together. If several fibres are slowly strained to determine the breaking strain, the rupture of the first one throws its share of the load on the others, which therefore yield in rapid succession, and the result is meaningless.

In impact testing, on the other hand, the force measured is kinetic, the breaking of each fibre subtracting a definite amount of kinetic energy.

The simple home-made form of the implement devised by the author consists of a pendulum, a catch to hold it at a definite altitude, and a smoked plate on which the pendulum traces its swing with a delicate bristle stylus. At the lowest point of the swing the apex of the pendulum meets the end of a slot in a piece of tough paper and carries it along with it. In so doing a bunch of fibres is broken, these fibres having been mounted across a gap 10 millimetres wide in the after-portion of the paper, and left to bear the shock of the impact by cutting the sides of the gap as before, the portion of paper remaining behind the gap being held firmly by a peg. The pendulum swings up to a certain point when it has only the inertia of the slotted piece of paper to overcome; when it also has to fracture a fibre or bunch of fibres, it swings up to a less extent; the difference is measured from the smoked trace, and gives by calculation the number of gramme-centimetres of energy expended in breaking the fibres, or (on dividing by the number of fibres) the resistance to impact of a single fibre.

The method has great advantages, but requires very careful sampling, if the full advantage of speed is to be secured, and it also necessitates the counting of single fibres. It will probably be possible to introduce a machine which will obviate both these disadvantages, and make such testing a practicable piece of routine. The time occupied in making the tests with the ordinary machine works out at ten minutes for each complete cycle of operations on each bunch of ten to twenty fibres, five of these being tested for each sample. The probable error of determinations thus made is very low, since a bunch of sixteen fibres has only a quarter of the probable error of a single fibre. The whole difficulty lies in sampling, and the results obtained with the impact tester will serve to illustrate the points in general.

*Sampling.*—It might appear easy to obtain a uniform lot of fibres by repeated drawing of the lint, overlaying tufts on one another, and drawing again from these. In point of fact the only reliable way is to pick the hairs one by one at random from those projecting out of a loose lump of lint, as O'Neill did. Again, it should be noticed, the amateur and the grader obtain the best results from exactly opposite methods.

Illustrating the difficulty of sampling from numerical obtained with the impact tester, and leaving the numbers in their arbitrary scale, taken direct from the notebook, we obtain such results as the following:

Small tuft of about 500 fibres taken from a square millimetre of the butt of a single seed, and tested in bunches of 4, 5, 7, 10, 12, 14, 16 and 18 fibres respectively, worked out at the following strengths per fibre: 1·25, 1·60, 1·85, 2·00, 1·40, 1·85, 1·70, and 1·60. The variation is slight, though the absolute strength is very low.

Another seed of the same sample was tested from six points round it, two on either side—one from the short hairs near the tip, and one from the butt; twelve hairs in each sample; strength per fibre was—Tip 2·5, butt 4·2, left side 5·4 and 6·4, right side 3·1 and 3·1. The variation is increased, probably because the nutrition varies according to the proximity of the particular hairs to the vascular bundles which supply food-substances.

Taking next a small tuft picked at random from a good sample of pure-strain ginned lint, and testing successive bunches from it, we find a moderate amount of variation due to the previous causes: Six fibres, 2·8, 3·3, 3·5, 3·7, 4·0; eight fibres, 3·5, 2·2; ten fibres, 3·2, 4·1; twelve fibres, 4·2, 5·9; fourteen fibres, 3·6, 3·4, 3·4, 3·3. It will be noticed with sufficient clearness for our present purpose how the probable error is decreasing as larger bunches of fibres are taken, and the fibre to fibre variation is eliminated thereby.

If now, instead of taking a small tuft from one part of a good ginned sample, we take tufts from seed-cotton, such as were used in one of the series hereafter to be described, we find that it is impossible to sample effectively. The strength of the lint in the 1913 series of dated bolls was—owing to circumstances—necessarily determined from unginned cotton. In order to obviate the disadvantage of losing the mixing action of the gin, the following routine was practised. Each sample was broken into five lots, one for each impact test; each lot contained usually from fifty to 500 seeds, and ten tufts of lint were drawn from each lot, each tuft taking some fibre from not less than three seeds. These ten tufts were rolled up together, then pulled straight, and a wide layer drawn out as in grading for regularity; this layer was then drawn down right and left until a countable number of fibres remained, and these were tested. The figures obtained with all these precautions are given subsequently, and it will be seen that, although they give five-day means with a probable error of 5 per cent., which is good enough for our purpose, the bunches so carefully extracted in such a way as to include fibres from all parts of each of the five lots are very often extremely wild; the probable error for the average of a single bunch is 24 per cent. Had it been practicable to effect the work on ginned lint, this figure would have been very much lower; but it is quite useful to have a detailed example of these sampling difficulties, for the routine method just described was most strictly followed in obtaining every bunch tested in the Daily Picking Series of 1912.

*Grading.*—The only grading data included in the account of the dated samples are those for strength. The determinations were made by Mr. Harold C. Thomas, of the National Bank of Egypt, Alexandria, and they are a striking instance of the accuracy to which the grader's hands can attain; the samples graded were about 8 grammes in weight, and were given to Mr. Thomas in irregular sequence, in three separate batches, marked with dummy reference numbers which bore no relation to their actual daily sequence; Mr. Thomas knew only that he was grading these dated samples from a familiar pure strain. In spite of these precautions against subjectivity, it will be seen that his hands assigned sample after sample to what was obviously its correct place in relation to its neighbours, and that there are only one or two wild points in his strength curve.

Such results emphasize the futility of attempting to introduce so-called "scientific methods" into the ordinary commercial practice; grading by hand has its limitations, and so have the scientific methods; each has its proper function, and the results of each are of interest to the other.

# APPENDIX II

## TABLES OF STATISTICAL DATA

THESE tables embody the results discussed in Chapter IV., and they show the properties of samples of cotton formed on successive days of the season. The same " pure strain " of cotton was employed in both the Dated Flowers Experiment of 1912 and the Daily Picking Experiment of 1913, so that any differences between different samples are solely due to the action of the environment on the plants, and not to any differences of inherited constitution.

The differences between various samples as numerically expressed in these tables embody in addition certain unavoidable experimental errors, so that two samples might be identical and yet not give exactly the same numerical results. These errors have been reduced as far as was practicable in the execution of the work, and have been further obliterated by working out "five-day means."

Tables I. and III. present the actual experimental figures for each lint hair, seed, or sample, examined in the two experiments. Tables II. and IV. summarize the average results for each five days. Thus the figures given in these tables on August 14 are the means of the corresponding figures for August 12, 13, 14, 15, and 16, in Tables I. and III.; while the figures for August 15 are the corresponding means for August 13, 14, 15, 16, and 17. The five-day means thus obtained are the data plotted in the curves of Figs. 14 and 15.

# TABLE I.

## DATED FLOWERS, 1912 (ACTUAL EXPERIMENTAL DATA).

| Flower opened. | Lint Length (Combed on Seed). | | Breaking Strain of Lint Hairs. | | Seed-Cotton. | | Seed Weight in Grms. | Lint Weight in Grms. | Grader's "Strength." |
|---|---|---|---|---|---|---|---|---|---|
| | Each Seed in Millimetres. | Mean. | Each Hair in Grammes (about). | Mean. | Weighed in Grms. | Out-turn Per Cent. | | | |
| July 7 | 27, 27, 31, 31, 32, 33, 33, 34 | 31·0 | 3, 5, 5, 6, 6, 7, 8 (3), 9, 10, 10, 11 (3) | 8·0 | 19·58 | 26·2 | 0·0990 | 0·0351 | W |
| 8 | 27, 28, 28, 30, 30, 30, 31, 33 | 29·5 | 1, 3, 3, 4, 4, 5, 6, 6, 7, 7, 8, 9, 9, 10 (3), 11 (3), 12, 12 | 7·6 | 21·75 | 28·3 | 0·1060 | 0·0417 | M |
| 9 | 26, 27, 28, 28, 30, 30, 33, 33 | 29·4 | 2, 3 (3), 4 (3), 5 (3), 6, 7, 7, 8, 8, 10, 12, 13 | 6·0 | 22·13 | 26·8 | 0·0980 | 0·0359 | S |
| 10 | 24, 28, 28, 30, 31, 31, 33, 34 | 29·9 | 2, 2, 3, 3, 4, 5, 5, 6, 6, 7 (3), 8 (3), 10, 12, 13 | 6·8 | 19·79 | 25·8 | 0·1080 | 0·0376 | S |
| 11 | 28, 30, 30, 31, 31, 32, 33, 35 | 31·2 | 4, 5 (3), 6, 7 (3), 8, 8, 10, 10, 11, 11, 12, 12, 13, 14 | 8·4 | 22 51 | 27·5 | 0·1090 | 0·0412 | SS |
| 12 | 28, 29, 29, 29, 30, 31, 32, 33 | 30·1 | 3, 3, 4, 5, 7, 8 (4), 9, 9, 10 (3), 12, 12, 13, 13 | 8·3 | 25·86 | 26·5 | 0·1080 | 0·0390 | SS |
| 13 | 28, 29, 30, 30, 30, 31, 31, 32 | 30·1 | 2, 2, 3, 3, 4, 4, 5, 6, 6, 7, 7, 8, 8, 9, 9, 10, 10 | 6·0 | 26·13 | 29·6 | 0·1080 | 0·0455 | SSS |
| 14 | 27, 28, 29, 29, 30, 30, 31, 33 | 29·6 | 3, 3, 4 (4), 6, 6, 8, 9, 11, 11, 12, 13, 13, 14, 14 | 8·1 | 21·18 | 28·8 | 0·1070 | 0·0433 | SSS |
| 15 | 27, 28, 28, 29, 29, 30, 31, 31 | 29·1 | 3, 4 (4), 5, 5, 6, 7, 8 (3), 10, 10, 11, 11, 14, 14, 15 | 8·1 | 23·63 | 30·0 | 0·1110 | 0·0475 | SSS |
| 16 | Ginned, by mistake | — | 1, 2, 2, 3, 3, 4, 4, 5, 6, 6, 7, 7, 8, 9, 9, 11, 12, 13 | 6·3 | 22·90 | 29·7 | 0·1050 | 0·0444 | SSS |
| 17 | 27, 28, 28, 29, 29, 31, 32, 32 | 29·5 | 3, 3, 5 (4), 6, 8, 8, 9, 9, 10 (3), 11, 12, 12, 14, 14 | 7·6 | 22·08 | 27·7 | 0·1080 | 0·0415 | SSS |
| 18 | 25, 29, 29, 30, 31, 31, 32, 32 | 29·9 | 1, 2, 6, 9, 9, 10, 12, 12, 13 (3), 15, 15, 16, 17 | 10·9 | 23·11 | 29·5 | 0·1100 | 0·0461 | SSSS |
| 19 | 26, 27, 28, 29, 29, 30, 30, 31 | 28·7 | 3, 6, 8 (4), 9 (3), 10 (4), 12, 12, 13, 14, 15, 16, 17 | 10·0 | 21·85 | 29·5 | 0·1100 | 0·0461 | SSSS |
| 20 | 26, 28, 29, 30, 30, 30, 31, 32 | 29·5 | 2, 3, 4, 5, 7, 7, 8, 8, 9, 10, 11, 11, 13, 14, 17, 20 | 9·7 | 18·71 | 30·8 | 0·1080 | 0·0480 | SS |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 21 | 27, 28, 29, 29, 30, 30, 30, 31 | 29·2 | 2, 3, 4, 6, 7, 8, 8, 10, 11, 12, 13 (3), 14, 14, 17, 17, 22 | 10·5 | 19·45 | 28·9 | 0·1070 | 0·0436 | S |
| 22 | 26, 26, 27, 28, 29, 30, 33, 34 | 29·1 | 3, 4, 4, 5 (3), 6, 6, 7, 7, 10 (3), 11, 12, 12, 14, 14, 15, 15 | 8·7 | 18·87 | 30·1 | 0·1050 | 0·0452 | SS |
| 23 | 26, 26, 27, 28, 28, 29, 30, 31 | 28·1 | 1, 4, 6, 7, 7, 8, 9, 9, 10 (3), 11, 12, 12, 13, 13, 14 (3) | 10·0 | 10·11 | 28·9 | 0·1060 | 0·0431 | S |
| 24 | 27, 29, 30, 31, 32 | 29·8 | 4, 6, 7, 7, 9, 9, 10 (3), 11, 12, 13, 13, 16, 18, 22 | 10·5 | 21·11 | 32·8 | 0·1110 | 0·0541 | SSS |
| 25 | 28, 29, 30, 30, 31 | 29·6 | 1 (3), 2, 2, 4, 5 (3), 6, 7 (3), 8, 8, 9, 12, 15 | 6·5 | 19·77 | 30·0 | 0·1000 | 0·0428 | SSS |
| 26 | 30, 30, 30, 31, 31 | 30·4 | 3, 4, 4, 5, 6, 6, 7, 7, 8 (3), 9, 9, 11, 12, 14 (3) | 8·6 | 18·79 | 29·1 | 0·0960 | 0·0393 | SS |
| 27 | 25, 26, 28, 28, 29 | 27·2 | 2, 3, 4, 4, 5, 5, 6 (3), 7, 8, 8, 9, 9, 11, 11, 13, 14, 19 | 7·8 | 26·69 | 27·8 | 0·1010 | 0·0388 | SS |
| 28 | 27, 28, 28, 28, 30 | 28·2 | 2, 7, 9, 10 (3), 11, 11, 12 (3), 13 (3), 14, 16, 17, 17, 18, 20, 21 | 12·4 | 24·78 | 28·8 | 0·1030 | 0·0417 | SSS |
| 29 | 25, 26, 26, 27, 28 | 26·4 | 1, 4, 4, 5, 6, 6, 7, 8, 8, 8, 9, 10 (3), 11, 12, 13 (3), 14, 15, 16, 19 | 11·1 | 14·31 | 29·0 | 0·0960 | 0·0392 | SS |
| 30 | 25, 27, 28, 30, 30 | 28·0 | 1, 3, 4, 6, 6, 9, 9, 10, 10, 11, 11, 13 (3), 14, 18, 22, 22 | 11·6 | 21·04 | 31·3 | 0·1070 | 0·0488 | SS |
| 31 | 23, 26, 31, 31, 34 | 29·0 | 3 (3), 5, 6, 6, 7, 8, 9, 9, 12, 12, 13, 14, 14, 16, 17 | 9·5 | 22·94 | 29·2 | 0·1070 | 0·0448 | SS |
| Aug. 1 | 27, 28, 29, 29, 30 | 28·6 | 2, 2, 3, 3, 4, 4, 5, 5, 6, 7, 8, 10 (3), 11, 13, 14, 17, 19 | 9·0 | 25·39 | 29·0 | 0·1020 | 0·0415 | W |
| 2 | 28, 28, 29, 30, 31, 32, 35 | 30·4 | 4, 5 (3), 6, 7, 8, 8, 9, 10, 10, 11 (4), 12, 12, 13, 18 | 9·5 | 19·20 | 31·0 | 0·0950 | 0·0426 | SSS |
| 3 | 27, 28, 29, 31, 30, 30, 33 | 29·7 | 2, 3 (3), 4, 4, 5 (4), 6, 10, 11 (3), 12, 15 | 6·5 | 16·53 | 29·7 | 0·0970 | 0·0411 | SSS |
| 4 | 25, 26, 27, 27, 29, 30, 32 | 28·0 | 1, 6, 6, 8, 8, 9, 11, 12, 12, 13, 15, 18, 24 | 12·5 | 15·54 | 29·7 | 0·0950 | 0·0403 | M |
| 5 | 29, 29, 29, 31, 31, 32, 32 | 30·4 | 1, 2, 3, 4, 6, 6, 7, 8, 9 (3), 10, 10, 11, 12, 12, 21 | 8·4 | — | — | 0·1010 | — | M |
| 6 | 27, 30, 31, 31, 31, 32, 32 | 30·6 | 1, 4 (3), 5, 5, 6, 6, 7 (3), 8 (4), 11, 12, 13, 13, 15 | 7·5 | 15·76 | 28·6 | 0·0860 | 0·0398 | M |
| 7 | 28, 30, 30, 30, 31, 32, 32 | 30·4 | 2, 3 (3), 4, 5, 5, 6 (3), 7, 7, 9, 10, 10, 11, 13, 14, 15, 17 | 8·7 | 21·47 | 31·6 | 0·0990 | 0·0457 | SSS |
| 8 | 29, 29, 29, 30, 31, 31, 32 | 30·1 | — | 9·3 | 23·91 | 27·9 | 0·1060 | 0·0410 | SSS |
| 9 | 26, 30, 30, 30, 31, 32, 34 | 30·4 | 4, 5, 7, 9, 9, 10, 11, 12, 13, 15 (4), 18, 23 | 12·5 | 18·41 | 29·9 | 0·0980 | 0·0418 | S |
| 10 | 30, 31, 32, 32, 32, 33, 33 | 31·8 | 1, 2, 2, 3, 3, 4 (4), 5, 5, 6 (3), 9, 10, 14, 18, 21 | 7·4 | 20·60 | 26·5 | 0·0980 | 0·0354 | SSSS |

## TABLE I.—*Continued.*

### DATED FLOWERS, 1912 (ACTUAL EXPERIMENTAL DATA).

| Flower opened. | Lint Length (Combed on Seed). | | Breaking Strain of Lint Hairs. | | Seed-Cotton. | | Seed Weight in Grms. | Lint Weight in Grms. | Grader's "Strength." |
|---|---|---|---|---|---|---|---|---|---|
| | Each Seed in Millimetres. | Mean. | Each Hair in Grammes (about). | Mean. | Weighed in Grms. | Out-turn Per Cent. | | | |
| Aug.<br>11 | 29, 30, 30, 30, 30, 31, 33 | 30·4 | 1, 3, 3, 4, 4, 8, 10, 10, 11, 13 (3), 16, 20 | 9·4 | 20·00 | 30·3 | 0·1000 | 0·0434 | S |
| 12 | 28, 30, 30, 31, 33, 34, 34 | 31·4 | 1, 1, 2, 4, 4, 5, 5, 6, 7 (3), 8, 9, 9, 11, 11, 12, 14, 21 | 8·0 | 17·05 | 28·3 | 0·0860 | 0·0340 | SSS |
| 13 | 31, 31, 31, 32, 32, 32, 33 | 31·7 | 1, 2, 2, 3, 4, 5, 5, 7 (3), 8, 8, 9, 9, 10, 11, 12, 13, 18 | 7·3 | 19·55 | 31·4 | 0·0870 | 0·0398 | SS |
| 14 | 25, 26, 26, 28, 29, 32, 32 | 28·3 | 1, 3, 3, 4, 6 (3), 7, 7, 8, 8, 9, 10 (3), 11, 11, 13, 14 | 7·5 | 16·98 | 29·6 | 0·0930 | 0·0392 | SSS |
| 15 | 27, 28, 30, 31, 31, 32, 33 | 30·3 | 2 (4), 3 (4), 4, 7, 8 (3), 9 (3), 11, 13 | 6·0 | 10·63 | 31·3 | 0·0920 | 0·0418 | S |
| 16 | 28, 28, 29, 29, 32, 32 | 30·0 | 2, 3, 4, 4, 5, 6, 7, 8, 8, 11, 11, 12, 13, 13, 14, 19 | 8·6 | 20·66 | 30·0 | 0·0930 | 0·0398 | S |
| 17 | 28, 29, 30, 30, 30, 31, 33 | 30·1 | — | 9·2 | 17·58 | 29·6 | 0·0990 | 0·0415 | SS |
| 18 | 26, 29, 29, 30, 30, 32, 32 | 29·7 | 3, 5, 6, 8, 10 (3), 15 | 8·0 | 13·86 | 30·7 | 0·0880 | 0·0389 | W |
| 19 | 26, 28, 29, 31, 31, 32, 32 | 29·9 | — | 4·5 | 13·28 | 30·5 | 0·0810 | 0·0355 | VW |
| 20 | 28, 33, 32, 32, 32, 32, 35 | 31·9 | 4, 5, 5, 7, 7, 8, 9 (4), 10 (4), 11, 12, 12, 16 | 8·8 | 24·32 | 31·6 | 0·6860 | 0·0396 | MS |
| 21 | 28, 30, 30, 31, 31, 31, 31 | 30·3 | — | 6·5 | 16·66 | 30·7 | 0·0880 | 0·0388 | S |
| 22 | 29, 30, 31, 31, 31, 33, 33 | 31·1 | — | 8·0 | 15·35 | 31·0 | 0·0790 | 0·0355 | SSS |
| 23 | 25, 26, 27, 29, 29, 30, 31 | 28·1 | — | 8·0 | 7·56 | 32·3 | 0·0840 | 0·0401 | W |
| 24 | 24, 27, 27, 28, 28, 29, 30 | 27·6 | 1, 1, 2 (3), 3, 4, 4, 5, 6 (3), 7, 8, 9, 9, 10, 11, 13 | 6·0 | 17·04 | 29·5 | 0·0830 | 0·0347 | VW |
| 25 | 28, 28, 29, 29, 30, 31, 32 | 29·6 | 2, 3 (4), 4, 4, 5, 7, 7, 8, 8, 10, 10, 12, 15, 14, 14, 15 | 7·0 | 12·71 | 30·9 | 0·0780 | 0·0349 | MS |
| 26 | 24, 28, 28, 29, 29, 30, 32 | 28·6 | — | 7·5 | 14·39 | 31·5 | 0·0760 | 0·0349 | W |
| 27 | 30, 31, 31, 31, 32, 32, 33 | 31·4 | — | 7·5 | 16·08 | 30·5 | 0·0780 | 0·0342 | M |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 28 | 26, 28, 28, 28, 28, 29, 32 | 28·4 | 4, 4, 8 (5), 9 (4), 10 (4), 12, 13, 13, 15 | 9·0 | 6·95 | 28·9 | 0·0720 | 0·0342 | VW |
| 29 | 25, 28, 28, 29, 31, 32, 32 | 29·6 | — | 11·8 | 15·59 | 29·6 | 0·0880 | 0·0370 | S |
| 30 | 26, 28, 28, 30, 30, 31, 32 | 29·1 | — | 5·0 | 15·40 | 31·4 | 0·0810 | 0·0370 | S |
| 31 | 25, 29, 29, 30, 30, 30, 31 | 29·1 | 4 (4), 5, 6 (4), 8, 8, 9, 10, 10, 11, 13, 14 | 7·5 | 9·77 | 31·0 | 0·0780 | 0·0350 | W |
| Sept. | | | | | | | | | |
| 1 | 25, 25, 25, 28, 29, 30, 31 | 27·6 | — | 6·8 | 18·16 | 30·2 | 0·0770 | 0·0332 | MS |
| 2 | — | — | — | 5·0 | 9·19 | 31·5 | 0·0710 | 0·0325 | SS |
| 3 | — | — | — | 4·5 | 3·72 | 32·3 | 0·0660 | 0·0315 | M |
| 4 | — | — | — | 3·7 | 5·97 | 29·1 | 0·0550 | — | VW |
| 5 | — | — | — | 2·8 | 3·81 | 27·2 | — | — | MS |
| 6 | — | — | — | 1·7 | — | — | — | — | SS |

## NOTES TO TABLE I.

The breaking strains for each hair tested are given. Where more than two hairs gave the same breaking strain, the number so doing is given in brackets after the breaking-strain figure.

The breaking strain is given in "grammes (about)." Actually the unit was slightly under 1 gramme, so that the strongest fibre broke under a load of about 22 grammes, and not of 24 grammes as denoted. The difference is almost negligible. The figures for each hair are omitted in certain samples, owing to the original record on the drum of the fibre-tester having been lost. The mean value had alone been preserved in a duplicate entry.

The column "Seed-Cotton" gives the actual weight of sample handled, as well as its out-turn. "Seed Weight" gives the average weight of a single seed in each sample, and "Lint Weight" gives the average weight of lint on a single seed as computed from the ginning out-turn.

The column headed "Grader's 'Strength'" gives the strengths assigned by the grader to each sample, using the following scale:

| | | | |
|---|---|---|---|
| Very weak .. .. .. | VW | Strong .. .. .. | S |
| Weak .. .. .. | W | Stronger .. .. .. | SS |
| Moderate .. .. .. | M | Very strong .. .. | SSS |
| Medium strong .. .. | MS | Superlatively strong .. | SSSS |

## TABLE II.

### DATED FLOWERS, 1912

(Data smoothed to Five-Day Means).

| Date. | | Lint. | | | | Out-turn per Cent. | Seed Weight in Grammes. |
|---|---|---|---|---|---|---|---|
| | | Length in Millimetres. | Breaking Strain in Grammes. | Weight per Seed in Grammes. | Weight Regression. | | |
| July | 7 | — | — | — | — | — | — |
| ,, | 8 | — | — | — | — | — | — |
| ,, | 9 | 30·25 | 7·2 | 0·0385 | 0·0365 | 27·0 | 0·104 |
| ,, | 10 | 30·15 | 7·6 | 0·0390 | 0·0375 | 26·8 | 0·106 |
| ,, | 11 | 30·15 | 7·7 | 0·0398 | 0·0372 | 27·1 | 0·106 |
| ,, | 12 | 30·20 | 7·7 | 0·0412 | 0·0372 | 27·7 | 0·107 |
| ,, | 13 | 29·10 | 7·8 | 0·0432 | 0·0400 | 28·6 | 0·108 |
| ,, | 14 | 29·60 | 7·6 | 0·0438 | 0·0410 | 28·8 | 0·107 |
| ,, | 15 | 29·50 | 7·6 | 0·0445 | 0·0415 | 29·2 | 0·108 |
| ,, | 16 | 29·50 | 8·2 | 0·0442 | 0·0420 | 29·2 | 0·108 |
| ,, | 17 | 29·40 | 8·4 | 0·0450 | 0·0425 | 29·2 | 0·108 |
| ,, | 18 | 29·50 | 9·0 | 0·0451 | 0·0430 | 29·5 | 0·108 |
| ,, | 19 | 29·30 | 9·7 | 0·0451 | 0·0428 | 29·2 | 0·108 |
| ,, | 20 | 29·35 | 10·0 | 0·0451 | 0·0440 | 29·8 | 0·108 |
| ,, | 21 | 29·90 | 9·9 | 0·0451 | 0·0440 | 29·6 | 0·107 |
| ,, | 22 | 29·25 | 9·9 | 0·0475 | 0·0452 | 30·3 | 0·107 |
| ,, | 23 | 29·25 | 9·4 | 0·0451 | 0·0448 | 30·2 | 0·105 |
| ,, | 24 | 29·45 | 9·0 | 0·0450 | 0·0442 | 30·2 | 0·104 |
| ,, | 25 | 29·20 | 8·6 | 0·0435 | 0·0435 | 29·6 | 0·102 |
| ,, | 26 | 29·30 | 9·0 | 0·0438 | 0·0430 | 29·6 | 0·101 |
| ,, | 27 | 28·70 | 9·3 | 0·0400 | 0·0430 | 29·0 | 0·099 |
| ,, | 28 | 28·40 | 10·3 | 0·0412 | 0·0440 | 29·2 | 0·100 |
| ,, | 29 | 28·20 | 10·4 | 0·0422 | 0·0445 | 29·0 | 0·102 |
| ,, | 30 | 28·30 | 10·7 | 0·0455 | 0·0445 | 29·4 | 0·103 |
| ,, | 31 | 28·50 | 10·0 | 0·0442 | 0·0448 | 29·8 | 0·102 |
| Aug. | 1 | 29·15 | 9·2 | 0·0435 | 0·0442 | 30·0 | 0·101 |
| ,, | 2 | 29·10 | 9·2 | 0·0422 | 0·0440 | 29·8 | 0·100 |
| ,, | 3 | 29·50 | 9·2 | 0·0415 | 0·0438 | 29·7 | 0·098 |
| ,, | 4 | 29·80 | 8·8 | 0·0410 | 0·0430 | 29·7 | 0·095 |
| ,, | 5 | 29·90 | 8·6 | 0·0410 | 0·0428 | 29·6 | 0·096 |
| ,, | 6 | 29·85 | 9·1 | 0·0410 | 0·0430 | 29·2 | 0·098 |
| ,, | 7 | 30·30 | 9·4 | 0·0415 | 0·0420 | 29·1 | 0·098 |
| ,, | 8 | 30·60 | 9·4 | 0·0408 | 0·0410 | 28·6 | 0·097 |
| ,, | 9 | 30·65 | 9·6 | 0·0412 | 0·0402 | 28·9 | 0·100 |
| ,, | 10 | 30·85 | 9·3 | 0·0395 | 0·0400 | 28·6 | 0·097 |

## TABLE II.—*Continued*

### DATED FLOWERS, 1912
(DATA SMOOTHED TO FIVE-DAY MEANS).

| Date. | Lint. | | | | Out-turn per Cent. | Seed Weight in Grammes. |
|---|---|---|---|---|---|---|
| | Length in Millimetres. | Breaking Strain in Grammes. | Weight per Seed in Grammes. | Weight Regression. | | |
| Aug. 11 | 31·10 | 9·0 | 0·0392 | 0·0400 | 29·2 | 0·094 |
| ,, 12 | 30·80 | 8·0 | 0·0382 | 0·0405 | 29·3 | 0·092 |
| ,, 13 | 30·40 | 7·6 | 0·0395 | 0·0425 | 30·2 | 0·091 |
| ,, 14 | 30·30 | 7·4 | 0·0392 | 0·0430 | 30·1 | 0·090 |
| ,, 15 | 30·10 | 7·8 | 0·0408 | 0·0440 | 30·4 | 0·092 |
| ,, 16 | 29·95 | 7·9 | 0·0405 | 0·0435 | 30·1 | 0·093 |
| ,, 17 | 29·95 | 7·4 | 0·0402 | 0·0438 | 30·4 | 0·090 |
| ,, 18 | 30·30 | 7·8 | 0·0385 | 0·0432 | 30·3 | 0·089 |
| ,, 19 | 30·45 | 7·4 | 0·0383 | 0·0438 | 30·5 | 0·089 |
| ,, 20 | 30·60 | 7·3 | 0·0380 | 0·0440 | 30·9 | 0·085 |
| ,, 21 | 30·30 | 7·2 | 0·0378 | 0·0450 | 31·1 | 0·085 |
| ,, 22 | 29·85 | 7·4 | 0·0375 | 0·0452 | 31·0 | 0·085 |
| ,, 23 | 29·30 | 7·2 | 0·0372 | 0·0480 | 30·9 | 0·082 |
| ,, 24 | 29·00 | 7·2 | 0·0358 | 0·0520 | 30·9 | 0·080 |
| ,, 25 | 29·00 | 7·2 | 0·0358 | 0·0525 | 31·1 | 0·080 |
| ,, 26 | 29·10 | 7·3 | 0·0348 | 0·0525 | 30·3 | 0·077 |
| ,, 27 | 29·50 | 8·5 | 0·0348 | 0·0515 | 30·3 | 0·078 |
| ,, 28 | 29·35 | 8·4 | 0·0350 | 0·0490 | 30·3 | 0·079 |
| ,, 29 | 29·40 | 8·4 | 0·0360 | 0·0470 | 30·2 | 0·079 |
| ,, 30 | 28·70 | 7·7 | 0·0355 | 0·0480 | 30·2 | 0·080 |
| ,, 31 | — | 7·2 | 0·0348 | — | 30·7 | 0·079 |
| Sept. 1 | — | 6·0 | 0·0338 | — | 31·2 | 0·075 |
| ,, 2 | — | 5·0 | 0·0315 | — | 31·0 | 0·070 |
| ,, 3 | — | 4·4 | 0·0305 | — | — | — |
| ,, 4 | — | 3·7 | — | — | — | — |
| ,, 5 | — | 2·8 | — | — | — | — |
| ,, 6 | — | 2·0 | — | — | — | — |

### NOTES TO TABLE II.

July 7 and 8 are necessarily blank because there are no precedent data with which to form a five-day mean for them.

The columns for " Length," " Breaking Strain," " Lint Weight per Seed," " Out-turn," and " Seed Weight," are computed to five-day means directly from the daily data in Table I.

The column headed " Lint Weight Regression " is additional. It represents the weight of lint which the seed would have borne each day *if* the seed had been constantly 0·100 gramme in weight, and *if* the lint had been constantly 30 millimetres long.

# TABLE III.

## DAILY PICKINGS, 1913 (ACTUAL EXPERIMENTAL DATA).

| Date of Picking. | Number of Bolls picked per Plant. | Length of Lint in Millimetres by combing Seed-Cotton. | | Strength of Lint (in Arbitrary Scale) by Impact Testing of Five Bundles of Hairs. | | |
|---|---|---|---|---|---|---|
| | | Each Seed combed. | Mean. | Each Bundle tested (Number in Bundle). | Total tested. | Mean. |
| Aug. 12 | 0·008 | — | — | 1·61 (13), 1·71 (14), 3·50 (16), 5·91 (12), 8·00 (11) | 64 | 4·03 |
| 13 | 0·008 | — | — | 1·45 (9), 2·41 (12), 4·18 (11), 8·60 (10), 6·57 (14) | 57 | 4·65 |
| 14 | 0·015 | — | — | 2·64 (14), 5·43 (16), 7·06 (13), 6·48 (19), 4·50 (27) | 89 | 5·25 |
| 15 | 0·061 | — | — | 3·78 (9), 3·78 (9), 5·81 (11), 5·50 (16), 7·50 (14) | 59 | 5·39 |
| 16 | 0·054 | — | — | 2·00 (10), 2·33 (12), 2·26 (15), 2·50 (12), 2·87 (16) | 65 | 2·60 |
| 17 | 0·031 | — | — | 1·13 (16), 3·00 (14), 3·57 (14), 4·83 (12), 3·89 (18) | 74 | 3·24 |
| 18 | 0·092 | — | — | 1·55 (11), 1·59 (17), 3·67 (12), 2·61 (18), 3·47 (15) | 73 | 2·57 |
| 19 | 0·107 | — | — | 2·44 (18), 5·22 (9), 4·14 (14), 8·46 (15), 5·30 (24) | 80 | 5·07 |
| 20 | 0·107 | — | — | 2·00 (11), 1·86 (14), 2·45 (22), 2·72 (22), 4·66 (18) | 87 | 2·78 |
| 21 | 0·069 | — | — | 2·88 (17), 3·29 (17), 3·36 (19), 3·95 (20), 3·76 (25) | 98 | 3·47 |
| 22 | 0·038 | — | — | 3·33 (9), 2·46 (15), 2·93 (15), 3·22 (18), 3·31 (23) | 80 | 3·05 |
| 23 | 0·077 | — | — | 2·00 (6), 1·80 (11), 4·66 (6), 6·55 (9), 4·20 (16) | 48 | 3·21 |
| 24 | 0·200 | — | — | 3·58 (12), 3·61 (13), 3·26 (15), 3·94 (15), 4·61 (13) | 68 | 3·80 |
| 25 | 0·115 | — | — | 3·60 (13), 3·50 (14), 5·00 (13), 6·78 (14), 4·40 (22) | 76 | 4·65 |
| 26 | 0·031 | — | — | 3·86 (14), 5·00 (12), 6·80 (10), 6·07 (13), 7·07 (13) | 62 | 5·73 |
| 27 | 0·207 | — | — | 1·00 (16). 1·77 (22), 4·29 (14), 3·79 (19), 5·35 (17) | 88 | 3·20 |
| 28 | 0·115 | — | — | 5·00 (13), 5·61 (13), 3·70 (14), 5·85 (20), 4·90 (21) | 81 | 4·95 |
| 29 | 0·107 | — | — | 1·70 (10), 7·00 (7), 5·42 (12), 4·71 (14), 4·12 (16) | 59 | 4·52 |
| 30 | 0·177 | — | — | 1·14 (7), 2·89 (9), 2·61 (13), 5·34 (9), 6·11 (16) | 54 | 3·79 |
| 31 | 0·215 | — | — | 2·33 (12), 5·08 (12), 6·50 (12), 5·73 (15), 4·50 (28) | 79 | 4·87 |

| Sept. | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 0·200 | 32, 32, 33, 34, 36, 36, 37 | 34·3 | 7·25 (12), 6·63 (14), 6·50 (16), 5·90 (19), 6·89 (17) | 78 | 6·61 |
| 2 | 0·185 | 32, 33, 33, 33, 36, 37, 38 | 34·6 | 2·63 (11), 5·81 (10), 4·61 (13), 4·81 (16), 5·76 (17) | 67 | 4·76 |
| 3 | 0·215 | 29, 33, 33, 34, 35, 37, 37 | 34·0 | 1·40 (10), 2·75 (8), 2·31 (13), 2·89 (18), 4·68 (22) | 71 | 2·99 |
| 4 | 0·253 | 35, 35, 35, 35, 36, 36, 36 | 35·4 | 2·16 (12), 2·53 (13), 2·80 (15), 2·00 (29), 6·00 (16) | 85 | 3 05 |
| 5 | 0·130 | 29, 30, 32, 32, 34, 35, 35 | 33·9 | 6·25 (8), 5·30 (13), 5·50 (16), 6·06 (16), 6·42 (19) | 72 | 5·91 |
| 6 | 0·338 | 29, 31, 33, 34, 34, 35, 35 | 33·0 | 1·45 (18), 3·73 (15), 3·73 (15), 4·76 (13), 4·89 (18) | 79 | 3·67 |
| 7 | 0·138 | 32, 33, 34, 34, 35, 36, 38 | 34·6 | 1·66 (15), 1·58 (19), 2·50 (14), 3·12 (16), 5·25 (16) | 80 | 2·81 |
| 8 | 0·469 | 28, 32, 35, 35, 35, 36, 36 | 33·9 | 2·74 (12), 3·00 (9), 2·60 (13), 1·88 (15), 4·24 (22) | 71 | 2·96 |
| 9 | 0·315 | 31, 32, 34, 36, 36, 36, 36 | 34·4 | 2·82 (12), 2·40 (10), 1·84 (11), 1·18 (17), 5·84 (17) | 67 | 2·88 |
| 10 | 0·215 | 30, 31, 33, 34, 34, 35, 37 | 33·4 | 4·26 (12), 5·29 (12), 3·24 (7), 6·35 (8), 5·52 (16) | 82 | 5·00 |
| 11 | 0·261 | 32, 33, 34, 34, 35, 35, 36 | 34·1 | 1·69 (13), 2·53 (17), 5·76 (17), 6·00 (19), 5·65 (23) | 89 | 4·45 |
| 12 | 0·146 | 31, 32, 33, 33, 33, 34, 36 | 33·1 | 1·08 (12), 1·07 (13), 2·00 (16), 5·19 (21), 4·10 (30) | 92 | 3·92 |
| 13 | 0·069 | 28, 29, 31, 31, 34, 37, 38 | 32·6 | 2·61 (13), 6·55 (9), 4·80 (15), 5·06 (15), 4·30 (20) | 72 | 4·60 |
| 14 | 0·515 | 29, 31, 32, 35, 35, 35, 37 | 33·4 | 1·25 (12), 1·33 (18), 2·75 (20), 4·61 (18), 5·95 (19) | 87 | 3·25 |
| 15 | 0·491 | 30, 31, 31, 35, 35, 36, 37 | 33·6 | 2·56 (9), 3·00 (14), 4·33 (15), 4·10 (18), 6·67 (18) | 74 | 4·25 |
| 16 | 0·484 | 32, 32, 32, 33, 33, 35, 35 | 33·1 | 1·37 (16), 2·21 (14), 3·70 (10), 3·64 (14), 4·93 (15) | 69 | 3·14 |
| 17 | 0·491 | 33, 33, 34, 34, 35, 36, 37 | 34·4 | 3·18 (11), 5·20 (10), 5·06 (16), 6·50 (14), 6·52 (15) | 66 | 5·35 |
| 18 | 0·177 | 31, 33, 34, 34, 34, 35, 35 | 33·7 | 1·30 (10), 2·16 (12), 5·21 (14), 5·54 (11), 5·85 (20) | 67 | 4·17 |
| 19 | 0·276 | 31, 31, 33, 34, 34, 35, 36 | 33·4 | 0·83 (17), 1·07 (13), 2·18 (17), 2·38 (13), 4·53 (15) | 75 | 2·19 |
| 20 | 0·591 | 33, 35, 35, 35, 35, 35, 36 | 34·9 | 1·78 (18), 3·90 (10), 4·46 (13), 4·61 (13), 5·18 (16) | 70 | 3·94 |
| 21 | 0·376 | 32, 32, 34, 34, 35, 35, 36 | 34·0 | 2·00 (15), 2·80 (21), 2·84 (13), 3·16 (24), 3·92 (12) | 85 | 2·93 |
| 22 | 0·277 | 31, 32, 32, 34, 34, 35, 37 | 33·6 | 0·91 (11), 1·00 (10), 3·66 (12), 4·11 (19), 6·00 (19) | 71 | 3·37 |
| 23 | 0·353 | 32, 33, 33, 34, 35, 35, 36 | 34·1 | 2·31 (16), 3·87 (16), 5·61 (18), 6·10 (20), 6·80 (15) | 85 | 4·97 |
| 24 | 0·599 | 31, 32, 33, 35, 35, 36, 37 | 34·1 | 2·00 (10), 5·00 (14), 5·90 (11), 6·50 (10), 6·70 (16) | 61 | 5·29 |
| 25 | 0·246 | 30, 31, 32, 34, 37, 37, 37 | 34·0 | 2·00 (16), 2·78 (9), 2·79 (12), 5·31 (19), 7·38 (8) | 64 | 4·05 |
| 26 | 0·323 | 32, 32, 33, 34, 35, 35, 38 | 34·1 | 4·07 (14), 4·30 (13), 4·30 (13), 4·57 (14), 4·90 (11) | 65 | 4·42 |
| 27 | 0·376 | 31, 33, 33, 33, 35, 35, 36 | 33·7 | 1·89 (9), 4·33 (15), 4·73 (15), 5·26 (15), 6·16 (12) | 66 | 4·55 |
| 28 | 0·276 | 32, 33, 33, 33, 35, 36, 37 | 34·1 | 2·00 (12), 2·07 (13), 3·60 (20), 4·90 (11), 11·00 (11) | 67 | 4·58 |
| 29 | 0·315 | 27, 32, 33, 33, 34, 34, 36 | 32·7 | 4·08 (27), 4·61 (13), 5·62 (16), 5·93 (15), 6·50 (20) | 91 | 5·31 |
| 30 | 0·161 | 29, 30, 30, 31, 33, 36, 36 | 32·1 | 1·23 (13), 1·66 (9), 1·85 (13), 1·88 (8), 1·92 (26) | 69 | 1·73 |

## TABLE III.—*Continued.*

### DAILY PICKINGS, 1913 (ACTUAL EXPERIMENTAL DATA).

| Date of Picking. | Number of Bolls picked per Plant. | Length of Lint in Millimetres by combing Seed-Cotton. | | Strength of Lint (in Arbitrary Scale) by Impact Testing of Five Bundles of Hairs. | | |
|---|---|---|---|---|---|---|
| | | Each Seed combed. | Mean. | Each Bundle tested (Number in Bundle). | Total tested. | Mean. |
| Oct. | | | | | | |
| 1 | 0·261 | 31, 31, 32, 33, 33, 34, 38 | 33·1 | 1·58 (11), 3·11 (8), 3·73 (30), 4·20 (8), 5·05 (17) | 74 | 3·61 |
| 2 | 0·238 | 32, 32, 32, 33, 33, 34, 35 | 33·0 | 4·85 (13), 5·71 (14), 6·18 (16), 6·33 (15), 7·00 (15) | 73 | 6·03 |
| 3 | 0·077 | 29, 32, 32, 33, 34, 35, 36 | 33·0 | 1·00 (16), 1·10 (10), 1·71 (14), 2·17 (18), 4·31 (16) | 74 | 2·10 |
| 4 | 0·307 | 31, 33, 33, 33, 34, 35, 35 | 33·4 | 1·41 (12), 1·55 (20), 2·86 (14), 4·25 (12), 5·05 (18) | 76 | 3·02 |
| 5 | 0·069 | 32, 32, 33, 33, 35, 35, 36 | 33·8 | 3·23 (13), 3·67 (18), 4·12 (17), 4·83 (12), 5·12 (16) | 76 | 4·18 |
| 6 | 0·123 | 32, 33, 34, 35, 35, 36, 37 | 34·4 | 2·35 (17), 4·29 (7), 5·00 (13), 5·23 (9), 5·34 (18) | 64 | 4·39 |
| 7 | 0·130 | 31, 33, 33, 35, 36, 36, 37 | 34·4 | 4·80 (15), 4·86 (14), 5·50 (10), 6·00 (15), 6·75 (12) | 66 | 5·56 |
| 8 | 0·108 | 28, 30, 33, 34, 35, 36, 37 | 33·3 | 3·10 (10), 5·08 (12), 7·23 (17), 7·69 (16), 8·20 (15) | 70 | 6·42 |
| 9 | 0·130 | 31, 32, 32, 33, 34, 35, 36 | 33·3 | 0·83 (12), 1·28 (18), 2·00 (13), 4·82 (17), 5·64 (14) | 74 | 2·94 |
| 10 | 0·292 | 30, 30, 32, 32, 33, 34, 35 | 32·3 | 7·55 (18), 3·56 (18), 4·00 (21), 6·00 (17), 6·42 (14) | 88 | 4·40 |
| 11 | 0·100 | 29, 30, 30, 31, 34, 34, 34 | 31·7 | 1·37 (8), 2·22 (17), 2·45 (11), 4·17 (13), 7·20 (10) | 59 | 3·45 |
| 12 | 0·184 | 30, 32, 32, 33, 34, 34, 35 | 33·0 | 1·78 (14), 3·18 (11), 4·00 (9), 4·36 (19), 5·35 (20) | 73 | 3·82 |
| 13 | 0·130 | 31, 32, 33, 33, 34, 36, 38 | 33·8 | 5·66 (12), 5·70 (17), 6·62 (16), 8·64 (14), 9·76 (12) | 71 | 7·22 |
| 14 | 0·200 | 30, 32, 32, 33, 33, 35, 37 | 33·1 | 3·92 (13), 4·45 (18), 4·91 (12), 5·33 (21), 6·15 (13) | 77 | 4·92 |
| 15 | 0·184 | 31, 31, 34, 34, 35, 36, 36 | 33·9 | 0·77 (17), 0·82 (11), 0·84 (19), 1·38 (13), 1·47 (34) | 94 | 1·09 |
| 16 | 0·123 | 32, 33, 34, 35, 36, 36, 37 | 34·7 | 0·80 (10), 1·00 (10), 1·18 (28), 1·41 (12), 2·08 (12) | 72 | 1·29 |
| 17 | 0·092 | 31, 32, 32, 34, 35, 37, 37 | 34·0 | 3·46 (13), 4·28 (14), 4·40 (20), 4·68 (16), 5·38 (13) | 76 | 4·44 |
| 18 | 0·085 | 32, 33, 34, 34, 34, 36, 38 | 34·4 | 1·18 (11), 1·30 (10), 2·06 (16), 5·60 (15), 6·43 (14) | 66 | 3·41 |
| 19 | 0·069 | 29, 33, 34, 35, 35, 35, 37 | 34·0 | 0·92 (13), 3·85 (20), 5·21 (14), 5·55 (11), 6·08 (12) | 70 | 4·27 |
| 20 | 0·054 | 27, 32, 33, 34, 35, 36, 36 | 33·3 | — | — | — |

| | | | | | | |
|---|---|---|---|---|---|---|
| 21 | — | 27, 30, 31, 31, 31, 34, 36 | 31·4 | — | — | — |
| 22 | — | No sample | 33·9 | | | |
| 23 | — | 31, 33, 33, 34, 34, 36, 36 | 33·9 | — | | |
| 24 | — | 27, 27, 28, 30, 30, 31, 34 | 29·6 | — | — | — |
| 25 | — | 27, 28, 30, 30, 31, 33, 34 | 30·4 | — | — | — |
| 26 | — | 26, 28, 30, 31, 31, 32, 35 | 30·4 | — | — | — |
| 27 | — | No sample | 31·6 | | | |
| 28 | — | 28, 28, 32, 32, 32, 33, 36 | 31·6 | | — | — |
| 29 | — | 29, 30, 32, 33, 34, 35, 36 | 32·7 | — | — | — |
| 30 | — | 28, 30, 30, 31, 31, 33, 34 | 31·0 | — | — | — |
| 31 | — | No sample | 29·7 | — | — | — |
| Nov.<br>1 | — | 29, 29, 29, 29, 30, 31, 31 | 29·7 | — | — | — |
| 2 | — | 27, 29, 31, 31, 32, 33, 35 | 31·1 | — | — | — |
| 3 | — | 25, 26, 27, 27, 28, 31, 31 | 27·4 | — | — | — |
| 4 | — | 25, 26, 30, 31, 31, 32, 32 | 29·6 | — | — | — |
| 5 | — | No sample | 29·9 | — | — | — |
| 6 | — | 23, 25, 30, 31, 32, 33, 35 | 29·9 | — | — | — |
| 7 | — | No sample | 28·9 | — | — | — |
| 8 | — | 27, 28, 28, 29, 29, 30, 31 | 28·9 | — | — | — |
| 9 | — | 27, 28, 28, 28, 29, 29, 30 | 28·4 | — | — | — |

## NOTES TO TABLE III.

Lengths of lint before September 1, and strengths after October 19, were not determined.

The column headed "Number of Bolls Picked per Plant per Day" gives the average number of bolls picked each day *per plant*. The family of plants studied consisted of 130 individuals; thus, 0·100 boll per plant per day implies that every tenth plant had an open boll on it, or that thirteen bolls were picked on that day.

The column headed "Strength of Lint," etc., is given in the arbitrary scale resulting from measurements made on the particular pendulum apparatus employed, as the arithmetical labour of conversion would have served no useful purpose.

The column "Each Bundle tested" gives the number of lint hairs in each bundle in brackets, preceded by a figure showing the mean strength *per hair* in each bundle.

The last two columns give the mean for all the hairs, together with the total number tested. The number given for the mean strength is actually the mean of (*a*) strength of all the hairs individually, and (*b*) all the bundles; in this way any errors due to inequality in bundle size are reduced.

## TABLE IV.

### DAILY PICKINGS, 1913
### (DATA SMOOTHED TO FIVE-DAY MEANS).

| Date of Picking. | Lint. | | Length by Pulling in Inches. |
|---|---|---|---|
| | Length in Millimetres. | Strength in Arbitrary Scale. | |
| Aug. 12 | — | — | — |
| ,, 13 | — | — | — |
| ,, 14 | — | 4·38 | — |
| ,, 15 | — | 4·22 | — |
| ,, 16 | — | 3·81 | — |
| ,, 17 | — | 3·77 | — |
| ,, 18 | — | 3·25 | — |
| ,, 19 | — | 3·42 | — |
| ,, 20 | — | 3·38 | — |
| ,, 21 | — | 3·51 | — |
| ,, 22 | — | 3·26 | — |
| ,, 23 | — | 3·63 | — |
| ,, 24 | — | 4·09 | — |
| ,, 25 | — | 4·12 | — |
| ,, 26 | — | 4·46 | — |
| ,, 27 | — | 4·60 | — |
| ,, 28 | — | 4·44 | — |
| ,, 29 | — | 4·26 | — |
| ,, 30 | — | 4·95 | — |
| ,, 31 | — | 4·91 | — |
| Sept. 1 | — | 4·60 | — |
| ,, 2 | — | 4·45 | — |
| ,, 3 | 34·4 | 4·66 | $1\frac{43}{64}$ |
| ,, 4 | 34·2 | 4·07 | ,, |
| ,, 5 | 34·2 | 3·68 | ,, |
| ,, 6 | 34·1 | 3·69 | $1\frac{11}{16}$ |
| ,, 7 | 34·0 | 3·68 | ,, |
| ,, 8 | 34·0 | 3·49 | ,, |
| ,, 9 | 34·1 | 3·65 | $1\frac{43}{64}$ |
| ,, 10 | 33·9 | 3·87 | $1\frac{21}{32}$ |
| ,, 11 | 33·5 | 4·19 | $1\frac{39}{64}$ |
| ,, 12 | 33·3 | 4·24 | $1\frac{5}{8}$ |
| ,, 13 | 33·4 | 4·09 | $1\frac{39}{64}$ |
| ,, 14 | 33·2 | 3·83 | ,, |
| ,, 15 | 33·5 | 4·12 | ,, |

## TABLE IV.—*Continued.*

### DAILY PICKINGS, 1913
### (DATA SMOOTHED TO FIVE-DAY MEANS).

| Date of Picking. | Lint. |  | Length by Pulling, in Inches. |
|---|---|---|---|
|  | Length in Millimetres. | Strength in Arbitrary Scale. |  |
| Sept. 16 | 33·7 | 4·03 | $1\frac{5}{8}$ |
| ,, 17 | 33·7 | 3·82 | ,, |
| ,, 18 | 34·0 | 3·76 | ,, |
| ,, 19 | 34·1 | 3·71 | ,, |
| ,, 20 | 33·9 | 3·32 | ,, |
| ,, 21 | 34·0 | 3·48 | $1\frac{39}{64}$ |
| ,, 22 | 34·1 | 4·10 | ,, |
| ,, 23 | 34·0 | 4·12 | ,, |
| ,, 24 | 34·0 | 4·42 | ,, |
| ,, 25 | 34·0 | 4·65 | $1\frac{19}{32}$ |
| ,, 26 | 34·0 | 4·58 | $1\frac{19}{32}$ |
| ,, 27 | 33·7 | 4·58 | ,, |
| ,, 28 | 33·3 | 4·12 | ,, |
| ,, 29 | 33·1 | 3·81 | $1\frac{37}{64}$ |
| ,, 30 | 33·0 | 4·11 | $1\frac{9}{16}$ |
| Oct. 1 | 32·8 | 3·61 | $1\frac{37}{64}$ |
| ,, 2 | 32·9 | 3·15 | ,, |
| ,, 3 | 33·3 | 3·44 | $1\frac{9}{16}$ |
| ,, 4 | 33·5 | 3·94 | ,, |
| ,, 5 | 33·8 | 3·85 | $1\frac{19}{32}$ |
| ,, 6 | 33·9 | 4·71 | $1\frac{39}{64}$ |
| ,, 7 | 33·8 | 4·70 | $1\frac{19}{32}$ |
| ,, 8 | 33·5 | 4·74 | $1\frac{39}{64}$ |
| ,, 9 | 33·0 | 4·55 | ,, |
| ,, 10 | 32·7 | 4·20 | $1\frac{19}{32}$ |
| ,, 11 | 32·8 | 4·36 | $1\frac{39}{64}$ |
| ,, 12 | 32·8 | 4·76 | $1\frac{39}{64}$ |
| ,, 13 | 33·1 | 4·10 | $1\frac{19}{32}$ |
| ,, 14 | 33·7 | 3·67 | $1\frac{9}{16}$ |
| ,, 15 | 33·9 | 3·79 | ,, |
| ,, 16 | 34·0 | 3·03 | $1\frac{35}{64}$ |
| ,, 17 | 34·2 | 2·90 | $1\frac{17}{32}$ |
| ,, 18 | 34·1 | — | — |
| ,, 19 | 33·4 | — | — |
| ,, 20 | 33·4 | — | — |

## TABLE IV.—*Continued.*

### DAILY PICKINGS, 1913
### (DATA SMOOTHED TO FIVE-DAY MEANS).

| Date of Picking. | Lint. | | Length by Pulling, in Inches. |
|---|---|---|---|
| | Length in Millimetres. | Strength in Arbitrary Scale. | |
| Oct. 21 | 32·3 | — | — |
| ,, 22 | 32·4 | — | — |
| ,, 23 | 31·8 | — | — |
| ,, 24 | 31·6 | — | — |
| ,, 25 | 31·2 | — | — |
| ,, 26 | 30·7 | — | — |
| ,, 27 | 31·3 | — | — |
| ,, 28 | 31·5 | — | — |
| ,, 29 | 31·3 | — | — |
| ,, 30 | 30·9 | — | — |
| ,, 31 | 30·8 | — | — |
| Nov. 1 | 29·9 | — | — |
| ,, 2 | 29·5 | — | — |
| ,, 3 | 29·5 | — | — |
| ,, 4 | 29·6 | — | — |
| ,, 5 | 29·1 | — | — |
| ,, 6 | 29·4 | — | — |
| ,, 7 | 29·2 | — | — |
| ,, 8 | — | — | — |
| ,, 9 | — | — | — |

## NOTES TO TABLE IV.

The columns for " Length " and " Strength " are obtained in the same way as in Table II.

The column headed " Length by Pulling, in Inches " has been added to give a basis of comparison with the ordinary expression of lint length, and also to show the unreliability of length determinations made by " pulling," as compared with combing the seed-cotton. This determination was made on each sample from September 1 to October 20.

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