MINISTRY OF AGRICULTURE

SUDAN GOVERNMENT

BULLETIN

No. 15

NOTES ON COTTON GROWING FROM THE RESEARCH DIVISION

by

H. FERGUSON

AGRICULTURAL PUBLICATIONS
COMMITTEE
KHARTOUM
1954

PRICE - - 12 P.T.

NOTES ON COTTON GROWING FROM THE RESEARCH FARM

by H. Ferguson

LIST OF CONTENTS

This Bulletin is the English version of a series of Arabic articles on the cultivation, pests, diseases and protection of cotton which were written by Mr. H. Ferguson, Chief Agronomist, Research Division, Wad Medani, for the Gezira cultivators. The articles appeared in *El Gezira,* the Gezira tenants' newspaper, and have been reprinted as an Arabic booklet by the Agricultural Publications Committee. In view of their interest and value, they have been printed in English for the benefit of field inspectors and agriculturists.

These notes first appeared in 1950 and 1951 and so do not incorporate the results of recent research.

No. 1

INTRODUCTION

The Sudan Plantations Syndicate has gone, but the efficient and up-to-date methods of agriculture introduced by them must remain if the Gezira Scheme is to continue its success and the Gezira community retain its prosperity.

Present agricultural practice in the Gezira is the result of three things: (1) experience accumulated by the S.P.S.; (2) the accumulation of new knowledge by the Gezira Research Farm; and (3) the efficient application of this experience and knowledge by both management and tenants in the scheme. It is the purpose of this series of articles to explain the reasons for the most important agricultural practices and to show how some of the important problems in the Gezira are being tackled.

Though the sowing of cotton does not take place till the second half of August the new agricultural season starts long before that and much has already happened which will affect the yield of the next season.

Ploughing and ridging are done from October onwards and should be finished as early as possible. This is necessary because the clods of earth must be exposed, first to the sun and heat in April, May and June, and then to the rain in July to make them break down into fertile crumbs. Also, exposing the roots of seid and nageel for a long time helps to kill these weeds.

Everybody knows that good cultivation is essential, and this is usually achieved where the work is done by machines. Bull work is often not deep enough, but if the bulls are strong and ploughmen skilled it is also satisfactory. Good ridging and cross ridging not only improve the cotton crop, but make watering easier. For this reason also land levelling and the cleaning of water channels must be well done.

Two other very important things are done in preparation for the new crop. One of these is the clean up of the last season's cotton crop and the other is the application of manure. These will be dealt with in later notes.

The weather before sowing cotton has a marked effect on the yield of the following cotton crop. By comparing the yield and the

weather of different seasons the late Dr. Crowther, who worked at the G.R.F., made two interesting discoveries. One was that heavy rains during the six weeks before sowing cotton meant a good yield of cotton and the other was that a low rainfall one year before sowing meant a good yield of cotton. Thus the record crop in 1944/45 followed poor rains in 1943 and good pre-sowing rains in 1944. We shall explain these interesting correlations later.

We see from the above that even before cotton is sown we can get some idea of the size of the crop.

No. 2

THE CLEAN UP

The cleaning up and burning of debris of the old cotton crop is without doubt the factor which most affects the yield of the new crop. It prevents the new crop from being heavily infected by certain pests and diseases which would destroy it. The most important of these are *blackarm* and *leafcurl,* which are diseases, and *bollworm,* which is an insect pest.

Blackarm disease occurs on the leaves, stems, bolls and seeds of infected plants of the old crop. If these are left on the ground the wind may carry small pieces of them on to the field where the new crop is being sown and thus infect the soil or the crop itself. This is prevented by pulling the old stems and sweeping up the dead leaves and other debris and burning them. Cotton seedlings which come up in the rains must also be hoed out as they may come from infected seed and so spread infection.

Though leafcurl appears as a disease of cotton leaves, the infection is present in all parts of the plant. If cotton stalks are chopped off at ground level the roots may remain alive and send up new shoots and leaves. If the old plant suffered from leafcurl these shoots will be infected also and will be a source of infection for the new crop. It is because of this that pulling roots must be done at the time of the clean up, and that all ' ratoon ' cotton plants must be destroyed as soon as they are seen. Bamia also suffers from leafcurl, and this is one of the reasons why bamia has to be pulled up at the same time as cotton stalks. It is because a few ratoon plants and some bamia are missed each year that leafcurl continues, and it is certain that if the cleaning up were not thorough the loss from this disease would be tremendous.

Bollworm is an insect which feeds inside the cotton boll and destroys the lint and seed. It can remain alive between one cotton season and the next on old bolls and in cotton seed, especially if it is kept in a shady place, and on certain 'alternative host' plants, the most important of which is bamia. These bollworms are the source of infection for the new crop. The clean up kills those remaining on old cotton plants. The other sources of infection can be controlled by not growing bamia between cotton seasons and by disposing of all cotton seed at the end of each season. It is for this reason that regulations have been made forbidding bamia cultivation and forbidding the storage of unginned cotton in houses between cotton seasons.

If there were no 'clean up', immense damage would result from these pests and diseases and crops as poor as those of 1929-33 might be expected.

These poor crops were largely due to blackarm and leafcurl disease before the clean up was strictly carried out. The clean up must be done over the whole Gezira area, as one small uncleaned area may be a source of infection for a very much larger area. It is impossible to make the clean up perfect, and so these pests and diseases always remain. However, the sources of infection are so much reduced that infection now takes place only in isolated patches and only spreads late in the season when little damage can be done.

We shall consider blackarm, leafcurl, and bollworm in more detail later and see what other steps are being taken to control them.

No. 3

SOILS AND CULTIVATION

In order to make crops grow well two things are necessary, a good soil and plenty of water. Where rainfall is not good, crops have to be watered by irrigation, if river water is available for them. Irrigation water is very valuable and it is not worth wasting it on bad soil. It was because the Gezira had reasonably good soil which could grow good crops of cotton if it had enough water, and was flat and easily irrigated, that it was decided to start the Gezira Scheme.

The Gezira soil is a very heavy clay which is very impermeable compared with most other soils. This is an advantage from the

point of view of irrigation because it means that the canals do not leak and that they do not need an expensive cement lining. It also means that no water passes below the depth of the plant root and none is lost. Plant roots do not grow as well in clay soil as in sand. This is partly because the compactness of the soil makes it difficult for the roots to grow and partly because it prevents sufficient air reaching them. After rain and heavy watering the soil holds too much water and this keeps out even more air and actually damages the roots. These are two disadvantages of clay soils.

It is thus a good thing to open up and loosen clay soils. The Gezira clay cracks as it dries out when irrigation is stopped. This cracking is very important in breaking up the soil and allowing air to get into it. Ploughing also helps loosening and breaking up the soil. The plough partly breaks up the soil and partly turns up the clods. When these clods are exposed they are further broken up by the sun, air and rain. Thus the soil is in a loose crumbly condition at sowing time, suitable for sowing and early growth of the crop.

The soil is set up in ridges mainly to make irrigation easier. They also help the plant a great deal by allowing it to get its water by 'nazz' and not by direct soaking. This helps to prevent waterlogging.

II

For those who are scientifically minded we might say that we have dealt above with the 'physical properties' of the soil, especially the 'texture' and the 'structure'. The 'texture' of the soil refers to the amount of sand or clay in it, and the 'structure' refers to the size of the soil crumbs which are produced by natural breaking up and by cultivation. Texture and structure are important because of their effect on the growth of plant roots and the movement of water and air in soil.

In the next article we shall deal with the 'chemical properties' of the soil which are important in the feeding of the plant.

No. 4

SOIL FERTILITY

Soils contain different kinds of salts. If these are present in large amounts they are seen as a white crust on the soil. Some

kinds, such as the 'atrun' which occur in patches in the north of the Scheme are harmful to plants and cause poor growth. Certain others are used by plants as food, and a fertile soil contains adequate amounts of these useful salts.

Gezira soils are well supplied with all the useful salts except one very important salt called 'nitrate', which is the source of 'nitrogen'. However, two things prevent the plant from making the fullest use of them. One is the harmful salts which prevent the plant from absorbing the useful ones; the other is the poor root growth in clay soils, which means that the plant is only able to seek the useful salts in a small part of the soil. These two things greatly reduce the actual fertility of Gezira soils.

We saw above that cultivation and ridging helped to improve root growth, but there is no effective way of reducing the amount of harmful salts in Gezira soils. An interesting experiment was done at the research farm in this connection. A plant called 'salt bush' was found which absorbed some of the harmful salt, and crops of this plant were grown. By taking these crops away from the land they reduced the salt content of the soil. However, it was found that they removed large quantities of nitrogen as well as harmful salts and so reduced fertility. In other experiments attempts were made to wash the harmful salts into underground drains but this is not possible because of the impermeable soil.

Shortage of nitrogen in Gezira soils is one of the main causes of poor fertility. If crops of cotton or dura were grown continuously they would use up more and more nitrogen and make the soil very poor. Thus fallows are left between these crops. During this fallow period dead plant roots and other debris rot and return nitrogen to the soil in a form available to the plant roots. Nitrogen occurs in the air in the form of a gas, and certain kinds of microscopic 'nitrogen-fixing bacteria' can use this nitrogen gas from the air. These bacteria increase the soil nitrogen, especially in the fallows.

Lubia and other bean crops have little nodules on their roots which contain large numbers of one kind of nitrogen fixing bacteria. These nodules provide the lubia and other 'legume' crops with nitrogen so that they do not use up soil nitrogen. In fact they increase the nitrogen in the soil when their roots and nodules rot away.

Thus, as far as nitrogen is concerned, the use of fallows and 'legume' crops maintains and even increases the nitrogen content

of the soil. We shall see later that nitrogen can be added to the soil in the form of artificial fertilisers.

No. 5

ROTATIONS

A crop rotation means the regular sequence in which crops are grown. For instance, the rotation in most of the Gezira is Fallow—Fallow—Cotton—Fallow—Dura—Lubia—Fallow—Cotton, and then the same again.* Crops have to be grown in rotation so that watering and all kinds of farm work can be planned and thus carried out without muddle. The maintenance of soil fertility and the control of pests and diseases are the two main things considered in arranging rotations. This is the case in the Gezira eight-course rotation. To maintain fertility by rotation of crops, fallows and legume crops must be included in the rotation. It will be noted that in the Gezira rotation two fallows come before one cotton crop and lubia and fallow before the other. Soil nitrogen is increased and made available by the fallows and lubia crop so that cotton comes in the most fertile part of the rotation. One fallow comes before dura, thus increasing the nitrogen available for dura. In the old Gezira rotation, Cotton—Dura—Fallow—Cotton—Lubia—Fallow, dura follows immediately after cotton. The yield of dura in this rotation is only about half of that in the eight-course rotation, because cotton has used up the nitrogen and there is no fallow or legume to replenish it. It will be noted that lubia follows immediately after dura since it does not require nitrogen.

The part played by the rotation in controlling pests is very important. It is essential that the same crop should not be grown on the same land two years in succession. If this happened, many of the pests and diseases attacking the crop would be present in the field and attack the crop severely as soon as it started growing. In the case of cotton, one fallow always follows the cotton crop so that the clean up can be thoroughly carried out, and no seedling or ratoon plants will be encouraged by irrigation. Fallows also help to keep down obnoxious weeds such as ' seid '.

Many experiments comparing different rotations are being carried out at the Research Farm, and some in the Gezira Scheme. These have proved that fallows or lubia or lubia and fallows before cotton increase the yield of cotton per feddan. However, over a period of

* Usually only half the lubia area is taken up, as there is not enough water to grow the full five feddans.

years the six-course rotation, Cotton—Dura—Fallow—Cotton—Lubia —Fallow, will produce more cotton than the eight-course because cotton crops are more frequent, thus making up for the lower yields. Dura, however, produces less because its yields in the six-course are so low. All yields can be increased by manuring, but this costs money; whereas using fallows and lubia to produce good yields costs nothing. In any case the use of manure on cotton in the eight-course rotation is just as profitable (if not more so) than in the six, and dura prices may be altogether too low to bear the cost of manure.

The most important consideration, however, is the amount of irrigation water available. The Gezira is using all the water available at the present time, and water for the extra cropping required by the six-course rotation could only be provided by cutting out irrigation completely in some part of the scheme. There are still large areas of land outside the scheme which can be irrigated, and until there is water available for all this land, a shorter rotation could be introduced only by depriving the poor people in these areas of the benefits of irrigation.

No. 6

MANURING OF COTTON

As we saw in a previous article, the soil contains certain salts which are used by plants as food, and it is important that there should be a good supply of these in the soil. If the supply of these useful salts is low, then growth of cotton is poor and yields are low.

Useful salts are specially manufactured and are called artificial fertilisers. These can be added to the soil if the soil is poor in them. There are several kinds of artificial fertilisers supplying different kinds of salts for plant food.

As we saw earlier in the note on the Gezira soil, only one plant food, 'nitrogen', was insufficient. It was found that increases of yield of nearly 1 kantar of seed cotton per feddan could be obtained by applying 'nitrogen' salts to the soil. The fertiliser called Nitrate of Ammonia, which is supplied to Gezira tenants in drums and applied by them to the soil, is a 'nitrogen' salt. It increases the amount of nitrogen available to the plant and so improves the growth and yield of the crop. At the present time, 3 drums of nitrate of ammonia per hosha are applied where fertiliser is most necessary. This is enough for the requirements of the cotton plant and usually

increases the yield per hosha by 5 to 10 kantars. Nitrate of ammonia is expensive to buy, and it is easy to see that it will only be profitable to use if the price of 3 drums is less than the price of, say, 5 kantars of cotton. At present* cotton prices are very high and manuring is very profitable. The Gezira Board therefore buys as much nitrate of ammonia as it is able to find.

Certain other kinds of nitrogen salts are manufactured. These have been tried at the Research Farm and have been found to be practically as good as nitrate of ammonia, though heavier applications are needed. Two of these, called Sulphate of Ammonia and Nitrate of Chalk, are available and are being used in the Gezira area. Urea, which has a high percentage of nitrogen, is now also being used.

Though fertiliser is spread by hand in the Gezira, this operation can be done by machinery. Machines are available which can scatter the fertiliser uniformly over the unploughed land, or which can place the fertiliser in the cotton ridges. The latter is best, because the fertiliser is placed where the cotton roots will grow. Machine application is being tried by the Gezira Board

Cotton needs most of its nitrogen when the plant is small, and this is one of the reasons why fertiliser must be applied before sowing. Another reason is that cultivation mixes it well into the soil. Experiments at the Research Farm showed that fertiliser applied immediately before sowing was slightly better than that applied a long time before sowing.† This is because some is lost from the cotton root zone if it is applied too early. The Gezira Board is now trying application at sowing time, using a machine which sows cotton seed and fertiliser at the same time.*

In some experiments at the Research Farm, fertilisers have been applied to the same plots for many seasons. This is done to find out if continued use of fertiliser either (a) increases permanently the fertility of the soil, or (b) has some harmful effect on the soil. Except for some fertilisers already known to be harmful in Gezira soil, no permanent increase in fertility or harmful effects have yet been found.

No. 7

FALLOW HOEING

It was mentioned in a previous note that one of the important

* Written in 1950. The use of fertilisers is still very profitable: now that adequate supplies are available, the Sudan Gezira Board has decided to increase the application.

† This is not strictly true. Other experiments have shown that fertiliser can be applied up to a year before sowing with little or no loss.

factors affecting the yield of cotton was the amount of rain that fell in the year before sowing the cotton. If the rainfall is high a year before sowing, then the yield of cotton will be poor; if it is low, the yield of cotton will be high. When this discovery was first made it was difficult to believe that rain falling a full year before the cotton crop could affect it, but the explanation is simple.

In the Gezira rotation, cotton always comes after one or two years of fallow. If the rainfall is heavy, these fallows produce a thick covering of weeds. These weeds require the same kind of salts as cotton and remove from the soil much of the 'nitrogen' salts which are so important to the cotton crop. Thus a heavy growth of weeds reduces the fertility of the soil and results in a poorer cotton crop. If rains are poor, there is little weed growth and the nitrogen remains in the soil and is available for the cotton crop in the following season. This is how the cotton crop is affected by the previous season's rains.

It was obvious that the bad effects of heavy rains on the fallows could be counteracted by hoeing the fallows to keep them free from weeds. A number of experiments were done at the Research Farm, and it was found that cotton which followed hoed fallows gave better yields than cotton following an unhoed fallow. It was found that increases of up to 1 kantar per feddan resulted from hoeing in seasons of high rainfall, and smaller increases in seasons of low rainfall. Two hoeings were better than one, and early hoeing generally better than late. In fact, the sooner the weeds were destroyed, the less the reduction in fertility. It is interesting also to note that fallow hoeing is not very effective in the Northern Gezira, where there is less rain, and fewer weeds on the fallows. Grazing in the north is also heavier and thus reduces weed growth.

The Sudan Plantations Syndicate has carried out fallow hoeing experiments for several seasons throughout the Gezira. Hoeing by hand, by bulls and by machines has been done, and in the south, at least, the increased yield of cotton profitably repays the cost of hoeing. Despite this, the management thinks it unwise to make the hoeing of fallows a general practice. There are several important reasons for this. One of the most important is that if all fallows were hoed there would be much less grazing for cattle, sheep and goats. Another is that fallow hoeing to be effective must be done about cotton-sowing time. Labour is scarce and expensive then, and there is little time for the tenant or inspector to supervise this work.

At this time, too, and especially in rainy seasons, the soil is often too wet to allow machines to work on it.

If weeding of fallows is carried out for many seasons, it may have harmful effects on the soil. Weed roots open the soil and make it break into small fertile crumbs, and if they are absent the soil may become hard and cloddy. A weed cover also prevents the wind from blowing away the soil. Dust blown from hoed fallows has occasionally caused damage to cotton in the Gezira. A number of experiments are being carried out at the Research Farm with the object of studying these secondary effects of fallow hoeing.

It will be seen from the above that, although fallow hoeing increases cotton yields, there are some disadvantages and some possible harmful effects to be overcome before it can be accepted as sound agricultural practice.*

No. 8

THE EFFECT OF PRE-SOWING RAINS

We have seen how the rainfall of one year earlier affects the cotton crop. The other important rainfall is that which falls during the six weeks before sowing. If this rainfall is high, then the yield of cotton is high; if it is low, the yield of cotton will be low. In general, it is safe to say that seasons of high rainfall are good cotton seasons.

This was not always so. A high rainfall before and after sowing encourages the spread of blackarm disease, and therefore years of high rainfall used to be bad blackarm years. However, since blackarm has been controlled (i.e., since 1934), the effects of rain before sowing are entirely beneficial.

There are several reasons why pre-sowing rains are beneficial. Rain improves the fertility and tilth of the soil. It can easily be seen that the soil is in a loose, crumbly condition after rain. Fertility is improved in two ways. Rain helps to increase the nitrogen salts in the soil and it washes some of the harmful salts down into the deeper parts of the soil away from the region of the young cotton roots. Rain makes the atmosphere and the soil cooler at sowing time, and the early growth of the crop is better in a cool soil and a cool atmosphere. Pre-sowing rain causes weeds to germinate and grow before cotton is sown. These can be destroyed before cotton is sown, and

* The Gezira Board now plan more extensive fallow hoeing, for the time being at least.

not compete with it. If rains have been poor, the weeds and cotton come up together and the weeds do much damage to the cotton.*

Irrigation water put on before sowing improves soil conditions slightly, but not nearly as much as rainfall. This is because it runs down cracks instead of entering the soil slowly and soaking the surface soil.

Rain has a very important effect on jassids, which are very harmful insect pests of cotton. Irrigation water does not affect them in any way. During the period before cotton, jassids live on weeds and garden plants. The beating of rain and the splashing of muddy water caused by it kill large numbers of these jassids. Thus fewer jassids are left to attack the cotton, and damage is much less.

The spraying done in the Gezira is done to kill jassids on the cotton plant. This spraying counteracts part of the effect of poor pre-sowing rains on cotton yield, and its importance was well illustrated in the 1949/50 season. The pre-sowing rains in 1949 were poor, and a poor crop was forecast. As was expected, jassids were very severe, but the management of the Sudan Plantations Syndicate arranged for large areas to be sprayed. The result was that the 1949/50 crop was a good one, giving an average yield of 4½ kantars per feddan over the whole Scheme. It is estimated that if spraying had not been done, the crop would have averaged about 3 kantars per feddan.

The Research Farm is continuing to study the effects of the pre-sowing rains, and though it is not likely that the rainfall itself can be increased, we may discover other ways of counteracting the effects of poor rains.

No. 9

THE BEST SOWING DATE FOR COTTON

Cotton is now sown in the second half of August throughout the Gezira Scheme. This date has not been decided on by chance, but is the result of experience and trials.

The first factor which limits the sowing date of cotton is the availability of water. There is no water for irrigation till the Blue Nile starts rising and until it has filled the Sennar Dam to the level of the inlet of the main canal. Dam water usually reaches the scheme at the end of July, and in the early days of the scheme cotton was

* This is now thought to be of less importance.

sown at this time. It was found, however, that blackarm disease was more severe during rainy weather, and that cotton sown at this time suffered severely from blackarm. It was found that cotton sown after the rainiest weather was over, suffered less from blackarm and thus gave a better yield.

Experiments were carried out in which the yields of cotton sown in late July, mid August, early September and late September were compared. The best date over a number of seasons was found to be mid August, and now this is the date set for sowing throughout the scheme.

Cotton sown in September usually does not grow to the same size as cotton sown in August, because its growth is stopped by the arrival of the cold weather in November. Late-sown cotton also produces poorer grade. If cotton sowing is delayed, or if resowing is heavy, the seed should be sown a little closer than normal, because the plants will be smaller and will need less space. In some seasons (e.g., if the weather in August is very hot), later sowings may give better yields, but it is wise to sow as soon after August 10th as the weather and labour situation permit.

As mentioned above, cotton sown in July may be badly damaged by blackarm. The Cotton Breeding Section at the Research Farm has bred types of Sakel and 1730 cottons which are resistant to blackarm, and therefore do not suffer from the disease. These cottons can be sown in July without any possibility of loss from blackarm. Trials with these cottons have been carried out both at the Research Farm and in the scheme, and results indicate that grade and perhaps yield also may be better from July sowings.

There is one very important point about early sowing of cotton which interests all concerned in the scheme: that is the possibility of saving water at the end of the season. Water after January 1st is rationed, and any saving possible at this time would mean that larger areas could be irrigated. This is a point of great importance. It must be mentioned, however, that sowing a fortnight earlier does *not* mean that the crop will be finished a fortnight earlier. It means that the period of growth will be longer, that flowering and fruiting will take place a little earlier, and that the main crop will be a little earlier. The crop finishes at about the same time no matter when it is sown, but early sowing does mean that the bulk of the crop is

picked earlier. This means that the loss from early stoppage of water may be negligible.

No. 10

SPACING OF COTTON

The distance between cotton ridges is about 80 cm. throughout the scheme. This distance suits the size of the ridging ploughs and is wide enough to allow bulls to pass through the cotton to reridge it. If this spacing were smaller it would not be possible to make such high ridges, and low ridges would make watering difficult.

The distance between plants in the ridge should be that which will give the biggest yield of cotton. Experiments were carried out at the Research Farm, and it was found that spacings of 25 cm. to 75 cm. gave practically the same yield if cotton were sown early. Fifty centimetres between plants is a good average spacing for early-sown cotton plants. Wider spacings are not advised in case growth is poor and thus space is wasted. If cotton were sown late, closer spacings (25 to 30 cm.) gave the best yields. Experience throughout the scheme has confirmed these experimental results, and tenants are encouraged to use these spacings.

Plants which are spaced far apart do not use all the space which is available to them. Above the ground, plants which do not touch each other obviously do not use all the available space. Below ground we cannot see what happens, but it is obvious that spacing would be too wide if there were parts of the surface soil out of reach of cotton roots. Early-sown cotton grows larger and more vigorously than late sown, and so if widely spaced the plants grow to fill the spaces. Late-sown plants may stop growing before they have filled the space available.

The important lesson to learn from this is that if sowing has been delayed, or when resowing is heavy, seed should be sown close —at, say, 25 cm.

If cotton plants are sown very close or left unthinned, then the soil cannot provide them with enough plant food; and instead of having a few good plants there are many poor ones. In extreme cases—for example, where there is no thinning—these plants may be so starved that they cannot even produce flowers. For this reason it has been found that fertiliser benefits close-spaced plants more than wide spaced. Sometimes the plants compete for water as well as food,

and for this reason it was found that close-spaced plants need heavier waterings than wide spaced.

No. 11

THINNING OF COTTON

The question of thinning cotton is closely associated with spacing, because unthinned cotton is the same as closely spaced cotton. The harmful effects of bad thinning and very close spacing are exactly the same. As we saw in a previous note, plants which are very closely spaced suffer from shortage of plant food and water, and may be so starved that they never produce a single flower.

It is necessary to sow 10 or 12 cotton seeds in one hole so that even if conditions for germination are bad some seeds will germinate. A number of seedlings can push their way through the soil much more effectively than one, and when up they protect each other from heat and strong winds. Pests which attack seedling cotton may completely destroy single plants, but often cannot destroy a large number of seedlings. These are the reasons why cotton seed has to be sown thickly.

Experiments conducted on thinning showed that the best results were obtained when thinning was done at about three weeks after sowing, and that it was best to leave three plants. The best time to thin is just before the watering. This is because thinning disturbs the roots of the remaining cotton plants and might cause them to dry up if they were not watered. Reridging and thinning take place about the same time—just before the second water. It is usually better to thin after reridging and just before watering again to prevent the plants drying up. Sometimes, if plants are not well grown before the second water, thinning can be done, leaving four or five plants, and then before the third water they can be thinned to two or three.

Though three plants per hole were found best in most circumstances, there is not much difference between two, three and four plants per hole. Two or four are sometimes better than three, and it is only the farmer or inspector who actually sees the crop who can decide on this.

If the crop is early and vigorous, two plants per hole may be best. One plant per hole is never best. The main reason for this is that if some damage may happen to this plant, there is not another

one to replace it. If the crop is not vigorous, it may be best to leave four plants per hole. In experiments it was found that late-sown and resown cotton thinned to four plants per hole gave the best yields. This is because late-sown plants were small, and it needed four plants and not two or three to make full use of the space available.

It will be seen from the above that, while the best time and method of thinning are known approximately, the details of the operation have to be decided on the spot by the inspector and the tenant.

No. 12

WATERING OF COTTON

When irrigation of cotton first started in the Gezira, one of the most important things to find out was the amount and frequency of watering required to produce the best growth of cotton. The soil of the Gezira requires heavy watering to make plants grow well, for two reasons: first, to make the water penetrate into the impermeable clay; and second, to reduce the concentration of the harmful salts in the soil.

Special plots were laid out at the Research Farm in which the water put on the land could be measured accurately, and experiments were carried out in these for a number of years. It was found that light waterings reduced the growth and yield of cotton and that heavy ones increased it, especially if growth was not slowed down by lack of nitrogen. Different intervals between waterings were tried, and it was found that intervals of 12 days during the hot weather and 14 or 15 during the cooler weather were best. These results were also proved by large-scale experiments in the scheme as a whole, and are now standard practice.

If there are heavy rains, or if rain follows irrigation, then the soil becomes waterlogged and air is kept away from the cotton roots. This reduces growth and causes the plant to turn yellow. If waterlogging lasts for a long time, it permanently reduces the size of the plant and affects the yield; but if it lasts for a short time only, the cotton plant recovers and again grows satisfactorily. It is to prevent this check in growth that excessive water is drained off cotton plots during the rains.

Sometimes irrigation of cotton land before sowing improves

growth and yield. Pre-watering helps to wet the soil in the deeper layers and makes the growth of cotton roots into these layers easier. It improves the soil by filling up cracks, breaking down clods and rotting plant debris before sowing. It also helps to bring up weeds before the cotton, so that they do not compete directly with it. Rain does all these things more effectively than pre-watering, so that pre-watering is usually done only in seasons of poor rains. Waterlogging before sowing cotton does not harm the cotton crop.

No. 13

WATER ECONOMY

The object of the experiments mentioned in the last article was to find the best amount of water required to produce the largest yield of cotton. However, one of the main problems in the Gezira is how to save water without causing any great loss in yield of cotton. This problem was studied both at the Research Farm and on a much larger scale in the Gezira.

As everyone knows, the total amount of water available for irrigation in the Sudan after January 1st is fixed, by an agreement with Egypt, at the amount of water which can be stored in the Sennar Dam. Under the present agreement, the Sudan is using practically all its allocation. The height of the Sennar Dam has recently been raised, and this will increase the amount of stored water. This will all be used up for the new cotton area in the north-west extension and for new pump schemes. Most stored water is now used on the Gezira crop, and water to irrigate new areas can now only be obtained by reducing the amount of water put on cotton after January 1st. This will be necessary when the full cotton area of the north-west extension has to be irrigated.

Many experiments in saving stored water were carried out at the Research Farm, and it was shown that it could be saved in three ways:—

(1) Putting on less water per watering;

(2) Leaving longer intervals between waterings (i.e., three weeks); and

(3) Stopping the last one or two waterings.

Applying a small amount of water is difficult in the scheme, and so only the last two methods were tried on a big scale in the Gezira. After three-week intervals, the soil had cracked and absorbed more

water than usual and more than the plot needed. This method therefore could only be effective if watering could be very carefully done, and so was not considered to be of practical value. Stopping of the last one or two waterings was entirely satisfactory in saving water because the water was stopped before it reached the land and thus there was no chance of waste.

At the Research Farm the average loss of yield from the early stoppage of watering was never more than 2 or 3 per cent of the crop, and in the large-scale Gezira trials there was often no loss at all. If the last two waterings are stopped, there are four waterings instead of six after January 1st, giving a saving of 30 per cent in the stored water. This means that water is available for 30 per cent more cotton crop. This large gain in cotton production is achieved at the expense of practically no loss in the yield per feddan.

No. 14

PLANT GROWTH

After the cotton crop has been established satisfactorily—that is to say, when sowing and resowing have been completed—the season of growth starts. The plant increases in size, and in due course flowers and produces bolls. If it grows well throughout this season, a good yield of cotton can be expected.

In order that a plant may keep alive and grow, it must be adequately supplied with water and plant food. Everyone knows how essential water is, and therefore how important is regular irrigation.

One type of plant food comes from the soil, and another from the air. The plant needs both types.

The plant takes up its water and its soil plant food through its roots, and it will be obvious that it cannot do this successfully if it has few roots, or if they do not function properly. Roots need a loose or well-cultivated soil to grow in because they cannot push through hard or compact soil. They also need a certain amount of air. This air penetrates through small cracks in the soil between irrigations. If the root is growing in good conditions and the rest of the plant is strong and healthy, it will do its work satisfactorily. The soil must also be rich in plant food, and we have shown in an earlier article how the plant food in the soil could be improved by manuring.

Adequate plant food from the soil is required to produce large,

healthy leaves, which are most important to the plant because it is the leaves which absorb plant food from the air. They do this in the presence of sunlight which, of course, is never lacking in the Gezira. This plant food from the air, called ' carbon ', is required by all parts of the plant, but especially to produce lint in the case of cotton. It will be seen, therefore, that a large number of good, healthy leaves are essential for a good yield.

We have already seen that a number of things which happen before the cotton crop is sown affect its growth and therefore its yield. There are also several factors throughout the growing season which improve or depress growth and which affect the development of bolls. From what we have said above, it will be seen that all parts of the plant are essential to its growth, and the yield of cotton will be reduced if any one part does not function properly. In later notes we shall see what the main factors affecting the cotton plant are and how they act.

No. 15

GROWTH AND DEVELOPMENT OF THE COTTON PLANT

In the study of growth, scientists frequently use the terms ' growth ' and ' development '. ' Growth ' is taken to mean simply the increase in size and weight of the plant. ' Development ' is taken to mean the change from one phase of growth to the next.

The first stage of development is the phase of ' vegetative growth ', when the plant increases in size and produces new branches and leaves. The cotton plant produces two kinds of branches, and it is important to distinguish between them. ' Primary branches ' arise at the bottom of the plant and are really new stems. There may not be any of these, and seldom more than two or three. At each joint (or ' node ') on the stem of the cotton plant there is a leaf, and usually a short branch grows from the same joint. These short branches are the ' secondary branches ', and they bear the flowers and fruit. At each joint on the secondary branch, as well as a leaf, there is a flower bud which will ultimately produce a boll if the cotton plant is able to give it enough nourishment. It will be seen, therefore, that a good yield of cotton can be expected if there is a large number of secondary branches and there are many joints on each branch. If you examine a cotton plant any time in November and December,

you can see the pattern of the branches and flower buds. In December the lowest leaves on the main stem will have fallen off and those at the top will not yet be formed.

The next stage of development is 'flowering'. When the plant is in full flower it does not increase much in size, because most of the plant food it absorbs goes to the production of flowers and, later, bolls, instead of to new branches or leaves. Following flowering is the 'fruiting' phase, when the bolls ripen. In cotton, flowering and fruiting go on at the same time, though in many plants (e.g., dura) these phases are quite separate. During the fruiting phase all the food the plant can absorb and all that is stored in the stems and leaves goes to the nourishment of the bolls. Even so, the plant cannot nourish all the bolls which it produces, and some of them always fall off before they are ripe.

After the main crop of bolls has matured, the plant reaches a phase of exhaustion, when the main fruiting branches dry up and leaves fall off. These have been depleted of all their nourishment to supply the bolls. If irrigation is continued, however, the plant does not die. This is primarily due to the fact that cotton does not bear flowers at the top of its stems, but has leaf and branch buds there which can produce new vegetative growth at the top of the plant. After the crop is picked, the plant still absorbs some plant food and, as this is no longer needed for the bolls, it goes to these buds, causing what is called 'second growth'. This second growth produces only very short fruiting branches and bolls of very poor quality. These are of little value and not worth picking.

No. 16

THE EFFECT OF WEATHER ON THE GROWTH OF THE COTTON PLANT

During the cotton growing season, the weather is an important factor affecting the cotton crop. The effects of the weather on the cotton plant itself are important, but even more important to the crop are the effects of the weather on the pests and diseases which attack it.

Germination of seed and growth of plants can only take place if the soil and atmosphere are neither too hot nor too cold. For cotton, the best temperatures are those occurring in a cool Gezira kharif. If the kharif is hot, early growth will be slower than if it

is cool. A moist atmosphere helps the early growth of cotton. Thus, cool moist weather till the end of September gives excellent growth of cotton. There is a good comparison between 1949 and 1950. Hot weather at flowering time does not harm cotton and is thought to improve the quality of the crop. After flowering, spells of hot weather may cause shedding of bolls or loss of quality. Thus the best cotton season is one which is cool and moist at sowing time, gradually getting hotter and drier till the end of October, and, after that, cooling off without any severe hot spells or severe cold spells.

Rain after sowing time benefits cotton by making the atmosphere cool and moist. However, it has some bad indirect effects, as we shall see below. It may also cause the soil to become too wet, and prevent drying out between irrigations. If this happens, the roots cannot get air and do not function properly. This is why 'water-logging' causes the plants to look yellow and stops growth. Wind has little direct effect on the cotton plant, unless it is strong enough to break the branches or blow the plants out of the ground. This sometimes happens in September or October.

Weather affects the cotton crop indirectly by its effects on the pests and diseases which attack cotton.

Rain encourages weeds, and makes weeding difficult because the land is often too wet to work on. For this reason also rain may delay other operations such as resowing or thinning. Rains after sowing encourage the spread of blackarm disease, especially if they are accompanied by strong winds. This can do great damage to the crop. Rains tend to encourage whitefly, but on the other hand they reduce jassids.

It will be seen, therefore, that if the cotton crop is to benefit from a cool, moist season there must be efficient control of blackarm (i.e., a very thorough clean up), and the farmer must be prepared to take extra trouble with his cultivation and weeding.

No. 17

EFFECT OF PESTS AND DISEASES ON COTTON GROWTH

A 'cotton pest' is something (usually an insect) which causes damage to the cotton plant by feeding on it. A 'cotton disease' is something which upsets the proper working of certain parts of the

plant. The most important cotton diseases are caused by infections such as cause diseases in human beings.

Several pests attack the leaves of cotton either by eating holes in them or by sucking them and thus causing them to become dry and fall off. In both cases they remove from the plant some of the food it has absorbed for itself and thus cause partial starvation. The damage to the leaf also prevents the leaf from manufacturing food from the air. Thus the plant is starved in two ways, the rate of growth is lessened, and the final yield reduced. Blackarm disease also affects the plant in this way, causing death of part or all the leaves, and severe defoliation.

Other insects attack the flower buds and young bolls, deprive them of their nourishment and kill part of them. This causes some flowers and young bolls to die and fall off. Others are not completely killed, but do not mature properly and produce weak and damaged lint.

Leaf curl disease shows itself mainly in the leaves, but it is present throughout the whole plant, and upsets the nutrition of young leaves, flowers and bolls so that they do not form properly.

Any disease or pest affecting the roots of the cotton plant is likely to interfere with the absorption of water and food from the soil. This causes the plant to become dry. Sometimes the remaining healthy roots supply a little water and food, and the plant only droops or 'wilts'. Shortage of water inside the plant reduces its rate of growth and causes leaves and flower buds to fall off, thus directly and indirectly reducing the yield. If the whole root system is damaged, the plant will die. These effects are caused by termites and by wilt disease.

Weeds are not classed as pests or diseases because they do not attack the plant itself. However, their effect on the cotton plant is practically the same as that of pests and diseases. Their roots remove the soil water and plant foods which are needed by the cotton plant, and thus reduce growth. If they are large weeds they also compete with cotton above ground, taking up the space which should be occupied by the cotton leaves.

Thus, pests, diseases and weeds reduce growth and yield in three ways, either together or separately: they cause (a) water shortage,

(b) food shortage to the plant, and (c) they cause the flowers and bolls to fall off.

No. 18

WEEDS

We saw in the previous article that weeds robbed the cotton crop of food and water.

There are two main classes of weeds — annual weeds and perennial weeds. Annual weeds are those which grow from seed during the rains or when the ground has been watered, and die off when they have flowered and produced seed at the beginning of the dry season. The main annual weeds include rehan, tebr, sureib, molokhia, etc. All these have shallow roots and so can be destroyed by light tools or implements. Perennial weeds are those which keep alive all the year round. We shall deal with perennial weeds in the next article.

In the seventh article (on fallow hoeing), we saw that annual weeds, growing a full year before cotton, impoverished the soil before the crop was sown. In a season of early rains, annual weeds germinate before cotton sowing and would do the same thing, but these are usually hoed when they are small and soft so that they rot and return to the soil all that they have removed from it. Hoeing of these weeds can be done by hand, or by bull-drawn implement if the soil is dry enough.

In years of poor rains, the weed seeds germinate after irrigation at the same time as the cotton germinates. These weeds compete directly with cotton, and if left alone would starve and smother the cotton completely. Often cotton becomes yellow and stunted in a bad weed season before the tenant has time to clean it. These weeds amongst the cotton must be destroyed as soon as possible, and it is because all tenants know this that they are prepared to pay so much for weeding the crop.

Weeds in the crop can be killed by hand-pulling or by hoeing with kadunka or malod. They can also be killed by bull-drawn hoes designed to leave the tops of the ridges unhoed and thus avoid the cotton. If implements are used, hand-hoeing must be done to clean the ground near the cotton plant. Chemical weed-killers cannot be used for killing weeds amongst cotton, as they would also kill the

cotton. It is also dangerous to use them just before sowing cotton, as their effect remains in the soil and they might damage the cotton or prevent its germination.

The thickness of weed growth in the crop depends on the number of weed seeds in the ground. Hoeing or grazing of fallows and careful weeding of all crops prevent weeds from seeding, and thus help to reduce the weeds in the cotton crop.

No. 19

PERENNIAL WEEDS

Perennial weeds keep growing all round the year because they usually have very deep roots that bring them water from deep down in the soil in the dry season. Thus they use up nitrogen and impoverish the soil during the whole of the fallow period, and some of them which are difficult to kill keep on growing after cotton is sown and compete directly with it too. For example, seid and nageel do this.

The main perennial weeds in the Gezira are seid, nageel, adan el far, ankuj and moleita.

Seid (*Cyperus rotundus* L.)

This weed, in addition to deep roots, has underground tubers which keep it alive and help to spread it even if it is hoed. At the Research Farm it was found that these tubers did not occur below the top twelve inches of soil, and it was found that during the dry weather they were kept alive by water brought to them by roots growing deeper into the soil. Thus, if the tubers were cut off from their roots in the dry season they were killed, and growth and spread of the weed stopped. It was found that this could be done by deep ploughing, to more than a foot depth, and this method of control has been used on bad seid areas by the Gezira Board. Large ploughs, which some tenants may have seen, were bought specially for this purpose.

Seid grass is also spread by seed, and thus it is a good thing to let animals graze seid and prevent it from seeding. Small patches of seid can be killed by constant hoeing, which starves the tubers. It is a good thing to do this where new patches of seid are noticed.

Nageel (*Cynodon dactylon* Pers.)

Nageel is kept alive and spread by thick underground stems

which can be seen when a patch of nageel is hoed. Because of this, it can be grazed and hoed without it being killed, and like seid it is very difficult to eradicate. The best thing to do is to hoe up the underground stems during hot, dry weather and leave them exposed to the sun.

Ankuj (*Ischaemum brachyatherum* Fenzl.)

This weed occurs in low-lying parts of the Gezira in the south where rainfall is higher, and because of its local occurrence is not as important as those mentioned above. It can be controlled in the fallow by digging out the strong tufts which this grass forms. The Gezira Board uses a heavy blade weeder pulled by a strong tractor for hoeing fallows which contain this weed.

Adan el Far (*Rhynchosia memnonia* (Del.) DC.)

This weed can be destroyed by keeping it hoed.

Moleita (*Sonchus cornutus* Hochst. ex Oliv. & Hiern.)

This weed is not a problem in the Gezira, as livestock are very fond of it, grazing it down, and as it has no underground parts which keep it alive or spread it, like seid and nageel.

No. 20

INSECT LIFE HISTORIES AND FEEDING HABITS

In carrying out research work on insect pests, it is essential to find out, first, the different stages in the life of each insect (i.e., its life history), and second, what and how each stage eats. This information is essential before control measures to destroy the insect can be worked out.

Entomologists know that there are two main types of insect life histories. All insects lay eggs. In one case the egg produces a young insect which is the same as the adult in appearance, though smaller. These small insects increase in size and grow wings if they have them, but do not change their form. When they are adult they lay their eggs again and repeat the same life history. The other type of insect has three different forms after hatching from the egg. The egg hatches out into a larva or caterpillar. This caterpillar usually feeds voraciously and grows very fast. It is usually the caterpillar (but not always) which damages the plant. When the caterpillar has grown to its full size, it goes into a resting stage called a pupa. This

does not feed and is usually formed during the season when no food is available. While the pupa is resting, changes take place inside it and when conditions are favourable an 'adult' insect emerges. This adult lays eggs, and the cycle starts again. The adult insect is usually quite different from the larva, and in the case of most cotton pests has wings and is the stage which moves freely and carries infestation to new plants.

The following insect pests of cotton belong to the first type: jassids, whiteflies and aphids; and the following to the second type: flea beetles, stemborers and bollworms. Termites and thrips do not quite fit into either class, though for practical purposes termites can be considered to belong to the first and thrips to the second.

Insects have two main ways of feeding. One type of insect obtains its food by eating and chewing it, and the other obtains it by sucking it in the form of juice. Cotton pests which do the latter, pierce small holes in cotton leaves or bolls and suck the juices from inside the plant. Cotton pests which chew plant material are flea beetles, termites, stemborers and bollworms. Pests which pierce the leaves and suck out the juices are jassids, thrips, whitefly and aphids.

In controlling pests by insecticides, it is most important to know how the pest eats. If the pest eats leaves, it can be poisoned by spraying poison on the surface of the leaves; but if it pierces the surface and sucks the juice from inside, it escapes the poison. Sucking insects, and some chewing insects which live inside the plant, can be poisoned by 'systemic' insecticides which penetrate into the inside of the plant. Both chewing and sucking insects can be destroyed by 'contact' insecticides which kill when they touch the outside of the body instead of when eaten.

No. 21

FLEA BEETLES AND OTHER LEAF-EATING INSECTS

Flea beetles are usually the first pest to attack the cotton crop. They are small, light-brown insects which jump like fleas. They eat small round holes in cotton leaves, and if there are many of them they may eat all the leaf except the veins. Flea beetles occur throughout the cotton-growing season, but it is only when the cotton is in the seedling stage that they do serious damage. When the cotton plant is in the seedling stage, the entire beetle population, congregating on the few leaves there are, may eat them all and so kill the

plant. Larger plants generally suffer little damage because the population of insects spreads itself out over the whole plant.

Flea beetles eat some other plants as well as cotton, and if there are plenty of weeds available they attack them as well as the cotton. Thus cotton tends to be more severely attacked in seasons of poor rains when there are fewer weed plants to attract the flea beetles. In the same way, early-sown cotton plants are most severely damaged.

As flea beetles tend to attack the first cotton they come to, they are found at the edge of the cotton plot and do most severe damage there. They are sometimes carried to the plots by the wind, so that at the beginning of the cotton season the southern edges of cotton numbers tend to be the most severely infested. These particular features of flea beetle attack make control measures possible. Flea beetles can be killed by an insecticide known as 'gammexane', which is used in the form of a powder. This is blown from a lorry running along the south side of a cotton number and is carried by the wind into the edges of the cotton areas. Thus large numbers of flea beetles are killed, and their spread into the main part of the crop is prevented. Hand-dusters can also be used by the tenants.

Flea beetles are not a major pest of cotton, but they can do severe local damage, especially to early-sown cotton. The above method of control has been carried out with success for a number of years, and can be applied whenever necessary, but the power duster can only be used where the direction of the wind allows. Hand-dusters can be used anywhere.

Other Leaf-eating Insects

Occasionally, damage is caused locally by other insects which eat leaves; locusts and grasshoppers are the commonest minor pests of this kind. In some seasons these can be quite severe. Egyptian leafworm is found in the Gezira, but seldom does much damage.

No. 22

BLACKARM

Blackarm is a very serious disease of cotton. It is caused by a germ which infects the leaves, stems and bolls of the plant. If germs are present on the leaves, they enter the leaf when it has been moistened by rain or dew. Small angular greasy spots appear on

the leaf where the infection starts. These soon become black and spread, especially if the weather is moist. If infection takes place near the veins, it spreads rapidly along them and gives the characteristic appearance of blackened veins. Severely attacked leaves always fall off, so that badly infected plants may lose nearly all their leaves except a small bunch of growing leaves at the top. Cotton stems become infected by the infection passing into them from leaves or buds. When this happens, it may kill all the tissues round the stem. If this happens, water and food cannot pass higher up the stem, and so the whole of the top of the plant dies. The same may happen with secondary branches and flower stems.

Both the defoliation and the damage to stems and branches cause a loss in yield, and badly infected plants often carry only one or two bolls at the top of the plant. The lint is sometimes stained. The poor yields of the years from 1929 to 1933 were in part due to blackarm. Sometimes as much as three-quarters of the potential yield was lost, and the yields in the worst blackarm years were between 1 and 2 kantars per feddan. The scheme at that time lost money, and the Sudan Plantations Syndicate almost went out of business. Anyone who remembers this must realise the great potential danger of this disease, and must appreciate the need to maintain control measures at their highest level of efficiency.

The extreme importance of the blackarm problem was recognised by the S.P.S. and the Research Division, and it became the main research problem in the years about 1930. During these years our scientists spent long hours by day studying the disease in the field and worked long into the night, often behind locked doors, to find out all about the disease and how to control it. Fortunately, their efforts were successful, and it is this success which has made the present years of prosperity possible.

The disease had been recognised very early in the days of the scheme, and the S.P.S. had undertaken control measures almost from the start. Thus, something was already known of the disease when concerted research started. Before finding methods of control, it was essential to find out as much as possible about how the disease is spread, what conditions favour its spread, etc., etc. This was done, and the working out of new and improved methods of control followed. The following is a brief summary of the information discovered about blackarm and methods adopted to control it.

Infected plants produce infected seed, and plants grown from them show the disease soon after germination. Most of the infection is present on the outside of the seed, so that disinfection of the seed coat kills large numbers of germs. This disinfection is done on all cotton seed sown, a poisonous powder called 'Abavit B' being used for the purpose. Another important measure to minimise seed infection is the use of seed from the Gash cotton crop. Because there is usually no rain during the cotton-growing season, there is in most years no blackarm in the Gash. The seed thus seldom carries the infection. A small amount of selected seed is sent every year from the Barakat Seed Farm to the Gash. It is grown there, and the seed from the Gash crop is sent back for the Gezira Scheme.

Blackarm infection is spread from the debris of fallen leaves, bolls and infected stems. These are blown about by the wind from one plot to another. The infection remains alive for a long time in dead twigs and bolls, and is carried over from one season to the next in them. Infection is also carried over by infected seeds which have fallen on the old cotton plot. These germinate and produce infected volunteer plants. It is for these reasons that all cotton debris has to be swept up and burned. Burning of cotton stalks had always been done in the Gezira, but after the bad blackarm years this was done more thoroughly and especial stress laid on the sweeping up of debris. We saw in an earlier article how very important the clean up was.

In rainy weather the germs are splashed from infected plants to healthy ones, and in this way the disease can spread very rapidly through the field. This is why blackarm is much worse in wet seasons. Thus an important method of control is to sow cotton after the heaviest rains are over. Originally, cotton was sown in July as soon as canal water was available, but now it is not sown till August 15th.

The changing of rotation from the original six-course rotation to the present eight-course rotation was done partly to control blackarm. The eight-course rotation with a fallow after cotton allows of a better clean up. It also means that cotton crops are farther away from each other and from the previous season's cotton land. This reduces the chance of infection. Finally, the gaps of two and four years between cotton crops mean that there is little likelihood of any blackarm-infected debris surviving in the plot itself.

Some varieties of cotton are resistant to blackarm disease, and if these are attacked they do not lose as much of their crop as do susceptible varieties. Until 1934, Sakel or other strains of cotton from Egypt were grown throughout the Gezira. All of these were severely attacked by blackarm. About 1927, Lambert selected plants from the Sakel crop which suffered less damage from the disease than Sakel and produced better yields when the infection was heavy. This was the beginning of the present variety X1730. It was multiplied up, and in the 1934/35 season it was grown over a large part of the Southern Gezira as blackarm tends to be worse there. This variety has been of immense value in the struggle against blackarm.

Some types of cotton are much more resistant to blackarm than X1730, and, even if grown in a heavily infected area, show little sign of the disease. Unfortunately, none of these resistant types has good quality lint, and therefore cannot be used as a substitute for Sakel or X1730.

However, it is possible to 'breed' cotton, and Dr. Knight at Shambat has crossed these blackarm-resistant types with Sakel and X1730 and by a process known as 'back-crossing' has brought up the quality of the lint of the original 'cross'. New varieties therefore now exist that are very resistant to blackarm and have lint of the quality of Sakel and X1730. These varieties are being multiplied up and tried in different parts of the Gezira. They have to be very thoroughly proved before acceptance, but it is almost certain that some time in the future they will be available for the whole Gezira. This will make a great difference in the problems of blackarm control.

This has been a particularly long note because blackarm is one of the most important matters in the Gezira Scheme.

No. 23

JASSIDS

Jassid is the worst insect pest of cotton in the Gezira, and can do severe damage in some seasons. Jassids are small insects which are usually found on the underside of cotton leaves. They suck juice out of the leaves and thus deprive the leaves of water and certain kinds of food. This causes the leaves to have dry, brown and yellow edges, and sometimes to die and fall off. Thus, not only does the insect take nutrients away from the plant, but it reduces the

efficiency of the leaf, and both growth of the plant and yield of cotton are reduced.

Jassids breed and live on other plants, often outside the Scheme, during the summer, and come on to cotton after it is planted. They multiply quickly on cotton, and by October or November there is often a large population which does much damage. Gubbein is the main alternative host plant within the scheme, and hoeing out gubbein helps to control jassids.

Jassids are usually much less severe in seasons of high rainfall, and it was found at the Research Farm that the splash of muddy water made by rain killed many jassids. If the rains fall before sowing cotton, the jassids are killed on alternate hosts; if soon after cotton sowing, they are killed on the cotton itself. It is thus possible to decide early in the season whether jassids are likely to be severe or not.

It was found that jassids were killed by the insecticide called D.D.T., and they are now controlled on a large scale by spraying this insecticide on the cotton. Spraying by tractor and by aeroplane is now so familiar that no description is necessary. The spray is put on as finely as possible so that the whole cotton leaf is covered and all jassids killed. D.D.T. will kill jassids for two or three weeks after it is sprayed on. In the tractor sprayers, some jets face upwards so that the lower sides of the leaves are sprayed. When a helicopter is used, the wind made by the propellors blows the leaves about so that the spray reaches all parts of them. Aircraft have the advantage over tractor sprayers that they can be used when the field is wet.

If jassids are severe, spraying may increase the yield of cotton by between 1 and 2 kantars per feddan. This happened in 1949, which was a very dry season; while in 1950, which was a wet one, increases were much smaller.

The Cotton Breeding Section at the Research Farm is breeding new varieties of cotton which are resistant to jassids. Jassids cannot suck leaves which have a thick enough covering of hair, and the cotton breeders have therefore crossed Sakel and X1730, which have smooth leaves, with cottons which have hairy leaves. They have succeeded in doing this, but experiments are still being done to ensure that the jassid-resistant strains are as good as Sakel and X1730 in quality of lint, yield and other factors.

No. 24

TERMITES AND COTTON STEMBORER

Termites

Termites are the well-known insects which live in the soil and eat plant and animal debris, and sometimes the roots of living plants, as well as wood in houses.

They sometimes eat right through the roots of cotton seedlings and cause them to die. When termites attack older plants, they often eat out large parts in the middle of the root. This interferes with the passage of water to the leaves and causes them to wilt. Where the damage is severe, the plants die. Termites can often be found outside or inside the roots of wilted and dead plants.

If they attack the roots at a lower level and less severely, only the end of the main root is killed, and side roots develop to replace it. In this case the plant recovers, but its root system is less efficient and because of this there is a slight loss in yield.

Termites occur everywhere in the soil, but they gather together on old dura roots, dung and any kind of dead plant and animal material. Thus, termite damage is worst in places where there has been a lot of dung or other debris, the cotton roots being attacked when the termites have eaten up all the debris.

Termites are not bad enough to necessitate special control measures, but they can be partly controlled by applying sawdust soaked in poison to the soil.*

Cotton Stemborer

The cotton stemborer is the larva of a beetle which bores into the cotton stem and eats out the middle of the stem. It has much the same effect on the plant as some types of termite damage. It prevents water reaching the leaves and causes wilting. If stemborer is the cause of the damage, it can be found by splitting the stem, when either the insect or the eaten-out stem will be found.

Stemborer is not a serious pest in the Gezira, only attacking a few plants each season. It is kept under control by the burning of cotton stalks. If these were not burned, the pupal stage of the insect would remain alive inside the cotton stem till the next cotton

* Also by application of insecticides to the soil, e.g., Gammexane (B.H.C.).

season, and then the adult beetles would emerge and lay eggs on the new cotton crop.

No. 25

THRIPS

Thrips are very small insects which are just large enough to be seen if one looks for them carefully on the leaf. Thrips tear small holes in the surface of the leaf, then suck the juice exuding from these holes. Leaves damaged by thrips have a silvery appearance with tiny black spots, and thrips damage can always be recognised by this. They often cause a dry type of 'asal' on the affected leaves. When severe, the leaves may dry up completely and fall off. The damage and shedding of leaves slows down growth and reduces yield. Thrips generally attack the cotton about October and do most damage to small plants, and resown cotton is most severely attacked. Older plants escape damage because the thrips have much more plant material to spread over. Thrips are liable to be very severe in patches and can cause great loss. Fortunately, this occurs only in some seasons and in fairly small areas.

Thrips feed on a number of weeds, garden plants and trees, and keep alive on these during the dead season. They breed up rapidly on the new weeds during the rains, and when these dry up in October they attack the cotton. They also attack other crops such as lubia. They tend to be heavier in the south end of the Gezira than the north, because rains are heavier there and there is more vegetation to maintain a large thrips population.

The adult thrips lay their eggs on the underside of cotton leaves. The larvæ hatch out and suck the cotton leaves until they are fully grown. They then fall off the leaves and form pupæ in the loose surface soil where conditions are cool and moist. After only a few days, adults emerge from the pupæ and start a new and larger infestation.

Thrips can be reduced by heavy frequent watering, as this drowns the pupæ resting in the surface soil. Thrips on the cotton plant can be killed by D.D.T. and can be controlled by spraying in the same way as for jassids. Thrips attack occurs very suddenly and increases rapidly, so that spraying should be done as soon as the thrips appear. This is, of course, not practicable on a large scale.

so that spraying for thrips cannot be organised in the same way as jassid spraying.

No. 26

WHITEFLY — APHIDS — ASAL

Whitefly

Whiteflies are small white insects which can often be seen in great numbers on cotton and lubia crops. The immature insects have no wings and their skins can be seen as white scales on the underside of cotton leaves. The adult has wings, and flies about actively if the cotton is disturbed.

Whiteflies suck juice out of the leaves and in this way reduce plant vigour. They leave a deposit of asal on the leaves which makes them very sticky. The severity of the damage they cause depends on the density of the whitefly population. When whiteflies are very numerous, they cause leaf-shedding and even wilting and death of the plant. This only happens occasionally, and in most seasons the damage is not apparent.* Whiteflies multiply up as the crop grows, and usually reach their greatest density in November. Cotton near lubia is often more severely infested, especially after the lubia is cut.

In addition to the direct damage they do, whiteflies play a very important part in spreading leaf curl disease. When a whitefly feeds on the juice of a cotton plant infected with leaf curl, the leaf curl infection remains alive inside the whitefly and is transferred to the next cotton plant which the whitefly sucks. In this way leaf curl infection is spread through the crop. No other insect carries leaf curl and there is no other natural means of spreading the disease. Because of this, whitefly is a very important and serious pest.

Whitefly is not killed by D.D.T., otherwise spraying for jassids would at the same time control whitefly. You can see for yourselves that whiteflies are just as numerous after jassid spraying as before. Certain 'systemic' insecticides which enter into the plant juice kill whitefly, and experiments with these are being carried out at present.

Aphids

Aphids are small green insects which suck the juice out of cotton leaves. They produce a great deal of asal, and cotton infested by them is often wet and sticky. They are usually found in thick,

* In recent years, whitefly damage has been very severe and research on this pest has been greatly increased.

sheltered parts of the crop where there is shade and a humid atmosphere. They cause loss by reducing the vigour of the plant, and can do serious damage if present in large numbers. They are often eaten by other insects, and are seldom serious enough in the Gezira to cause great damage.

Asal

Asal is usually associated with whiteflies and aphids. This sugary juice is excreted by these insects. They suck large amounts of plant juice and remove from it the foods they require. They excrete the rest of the juice containing foods such as sugar which they do not require. Thrips also produce a slightly sticky excreta. Asal in itself is not good for the cotton plant. A black fungus often grows on the asal, and this is also bad for the cotton plant.

The cotton plant itself sometimes exudes some of its own juice from spots on the underside of the leaf, but this never makes the leaf sticky all over like the asal of whiteflies and aphids.

No. 27

INSECTICIDES — SEED DISINFECTANTS — WEED-KILLERS

A number of chemicals are used to control pests and diseases in the Gezira, and many more are being tried at present. Their use has been mentioned frequently in previous articles. Though the Gezira Board is responsible for their application, tenants will be interested to know a little about them.

Insecticides

Insecticides are chemicals which are poisonous to insects and are used to kill them. Some of these insecticides are also poisonous to animals and human beings. None of those at present in use in the Gezira harms humans or animals.* Special precautions are always taken when poisonous chemicals are used. It is essential that insecticides used to spray a crop are not poisonous to plants or do not damage them in any way.

Different kinds of insecticides are required to kill different kinds of insects, and there is nowadays a very wide range of them. The kind of insecticide to use depends to some extent on the feeding habits of the insect. If the insect eats leaves or other exposed parts of the plant, the poison can be spread over the plant and the insect will eat it along with the leaf. Insecticides eaten in this way are called

* This is no longer the case.

stomach poisons. When insects suck plant juices they cannot be killed in this way because the insecticide does not penetrate inside the plant. They can be controlled by insecticides which kill them if applied only to their skin or by clogging up their breathing pores. These insecticides are called *contact poisons.* The two insecticides commonly used in the Gezira—D.D.T. for jassids, and Gammexane for flea beetles—can both be used as stomach and contact poisons.

A third type of insecticide, called a *systemic* insecticide, enters inside the plant when it is sprayed on it and gets into the juice and all parts of the plant. Systemic insecticides are very useful for killing sucking insects and insects which feed inside the plant. They have another advantage in that they remain active for some time after spraying, and one application can thus kill insects during the whole period of infestation. They are often poisonous to humans and animals.

Application of Insecticides.—Insecticides can be applied either as *sprays* or *dusts.* The D.D.T. used to kill jassids is applied as a spray. When sprays are used, the chemical is mixed with water and spread over the plant as a very fine mist. To do this it has to be forced through a special kind of jet at high pressure. The fine mist is necessary to make the insecticide spread over all the crop.

The Gammexane used to control flea beetles is used as a dust. In this case the insecticide is ground into a very fine powder and diluted with some other powdered material such as fine earth. It is then blown on to the crop, and, being in the form of a very fine dust, spreads all over it.

Poison Baits.—Poison baits are made by soaking some kind of insect food in a poisonous insecticide and then spreading it where the insect will eat it. Poison baits are used for termites and locusts. In the former case, sawdust soaked in poison is used, and in the latter, bran soaked in poison.

Seed Disinfectants

Some plant diseases such as blackarm of cotton and smut on dura are carried on the seed, and if the germs of these diseases are killed on the seed the spread of the disease can be prevented. Liquids and dusts can both be used. If a liquid is used, the seed is soaked in it. If a dust is used, the seed is shaken up with it in a revolving drum so that the dust covers every part of the seed. The dust used

for disinfecting cotton seed against blackarm is poisonous to animals and humans.

Insect pests attacking seeds can sometimes be controlled by dusts, but if they are inside the seed *fumigation* is necessary. Fumigation is done by placing the seed in an airtight container full of poisonous gas which penetrates into the seed. Fumigation is carried out to kill weevils (soos) in seeds which are being sent from one place to another so that the weevils are not introduced into a new region.

Weed-killers

Plants can be killed by chemicals in the same way as insects can. Some chemicals kill all kinds of plants, but others recently discovered kill only some kinds of plants. Unfortunately, cotton is killed by most kinds of weed-killers, so that if weed-killers are used for weeds in cotton the cotton crop is also damaged. They can be used for fallow weeds if applied a full season before cotton, but the residue left in the soil may affect cotton if it is applied later. Even very small amounts of these weed-killers carried in the wind affect cotton, and it is considered wise not to apply them anywhere near a cotton crop.

Weed-killers can be applied as sprays or dusts in exactly the same way as insecticides.

No. 28

BOLLWORMS

Bollworms are insects which attack the flower buds, and young or old bolls. There are four kinds of bollworm in the Sudan—pink bollworm, Egyptian bollworm, American bollworm and Sudan bollworm. The first and second are the only ones which do serious damage in the Gezira. The third, though present, does little damage; and Sudan bollworm does not occur there. Pink bollworm is potentially the most dangerous, and is dealt with fully in the next article.

The damage is done by the larval stage of the insects. The adult insects are different kinds of moths. In all cases the moths lay eggs on the cotton plant, and when the larvæ hatch out they enter the buds, flowers or bolls. The larva eats into the bud or boll and feeds inside it. This may cause the bud or boll to fall off, and so cause a direct reduction in the yield. If older bolls are attacked they are not always shed, but their growth is interfered with and the lint is

damaged. The result is that the boll produces immature and dirty lint of poor quality. It also produces damaged seed.

Egyptian Bollworm

The Egyptian bollworm is sometimes called the spiny bollworm, and the larva can be distinguished by its strong hairs or spines. After feeding, the larva comes out of the boll, leaving a hole which is larger than that of pink bollworm but smaller than the other two. It does more damage to buds than bolls. It forms a pupa which remains on the plant, in cotton debris, or on the ground. The adult emerges from this and starts the cycle again.

Egyptian bollworm also attacks bamia and hambok. Thus hambok should be destroyed. The main control is the dead period during which no cotton or bamia can be grown. Egyptian bollworm does not have a resting stage, so that the clean up is less effective than in the case of pink bollworm.

American Bollworm*

The young larvæ of American bollworm first feed on the leaves and then come into flower buds or bolls, eating out the inside. The full-grown larva is larger than the Egyptian bollworm larva, without spines, and is coloured brownish-green with striped markings. When the larva is fully grown it comes out of the boll, leaving a larger hole than either pink or Egyptian bollworm. It forms a pupa which lies in the soil.

The American bollworm attacks many crop plants and weeds, and it is probably of more importance in the Gezira as a pest of lubia than a pest of cotton. The annual dead period helps to control it.

The Sudan Bollworm

Fortunately, conditions in the Gezira do not suit this pest. It does very serious damage to cotton in other parts of the Sudan.

No. 29

PINK BOLLWORM

The adult pink bollworm moth and the larva which eats the cotton boll are both smaller than those of any other bollworm. The eggs are laid on the cotton plant, and as soon as the larva hatches out it enters a flower bud or boll. The hole made by the young larva

* This has done more damage in recent years.

closes up after it enters, so that bolls may look quite healthy though they contain the bollworm. The mature bollworm is yellowish in colour, with reddish markings. In the earlier part of the season the larva comes out, leaving a small round hole in the boll. It forms a pupa among cotton debris or on the soil. An adult moth soon emerges from this and again starts the cycle on the cotton crop.

The pink bollworm eats into the seeds in older bolls, and at the end of the cotton season the larva remains inside the seed and rests there either as a larva or pupa till the seed is sown in the following year. Thus the seed carries over the infestation from one season to the next, and infested seed is one of the main sources of crop infestation. It was found that the resting pink bollworm larvæ and pupæ were killed by the heat of direct sunshine, and this fact has been most important in the control of the pest.

It was found that most of the moths emerged from cotton seed in August. As there are no flowers or bolls on the cotton plant in the Gezira till October, the moths are unable to breed on cotton and no larvæ would be present to infest buds and bolls in October. Despite this, cotton was sometimes quite heavily infested in October, especially near the river, and research workers found that bamia, which is an alternative host for pink bollworm, was the source of infection. If bamia is sown in the rainy season it flowers in August, and the moths go to bamia instead of cotton to lay their eggs. The next generation then goes to the cotton plant, which by that time has buds and bolls for the bollworm to feed on.

All this information about the life history of pink bollworm was discovered by research, some carried out in the Sudan and some elsewhere. These discoveries indicate the measures which would be effective in controlling pink bollworm and explain why the Government found it necessary to make regulations which the people of the Gezira, and especially those living along the river, find irksome.

The measures in force for controlling pink bollworm are as follows:—

First.—The dead season during which no cotton or bamia are grown prevents the continued multiplication of the pest. For the reasons explained above, bamia is not allowed in the Gezira or near it (i.e., along the river) until September 15th.

Second.—The cotton debris is cleaned up and burned, thus

destroying damaged bolls containing bollworms which may not have been picked. The clean up also exposes the soil to the sun, which kills any bollworms which may be lying on the soil.

Third.—No unginned cotton seed is allowed in houses or ginneries or anywhere after the end of June.

Fourth.—All seed for sowing is heated to a temperature which kills the bollworm but not the seed. This could be done by sunning the seed, but in order to make it reliable it is done in a special seed-heating machine.

It is only because of these control measures that pink bollworm is not a serious pest in the Gezira. If they were not carried out, pink bollworm might ruin the cotton crop.

No. 30

LEAFCURL

Leafcurl is a disease which affects the leaves and young bolls of the cotton plant. It appears on the young leaves on top of the plant, especially if they are growing vigorously. The leaves become thickened and wrinkled, and their appearance cannot be mistaken by one who knows the disease. Leafcurl reduces the formation of new flowers and bolls and also interferes with the nutrition of those already present. If leafcurl attacks early in the season, it causes a large reduction in the crop. Because of the control measures at present in force, it does not usually appear before November and does not become widespread till the very end of the season. In the Gezira leafcurl attacks Sakel but not X1730.

Leafcurl is due to an infection which is spread by whiteflies. If a whitefly feeds on an infected plant it becomes infective and will then give the disease to any healthy plant it feeds on. No other insect can do this, and so leafcurl spreads more rapidly when whiteflies are numerous. When a plant is infected the infection passes to all parts of the plant—leaves, roots and stems—even though they do not show symptoms. Thus, if the roots of infected plants are left in the soil at the end of the season, they may sprout and produce infected shoots. These infected ratoons are the main source of infection in the early part of the season. Bamia and certain other plants related to cotton also suffer from leafcurl and are a source of infection to the cotton crop.

Leafcurl is found only in Nigeria and the Sudan, and practically all the research done on this disease has been carried out by the Research Division at Medani or Shambat. The discoveries made by Sudan research workers indicated methods of control.

Pulling out of cotton stalks is the most important control measure. Before the importance of ratoon cotton was realised, cotton stalks were chopped off and ratooning took place frequently. It was thus necessary to pull out cotton by the root, and it is in order to control leafcurl that pulling has to be carried out. Even though cotton is pulled up some roots are still left, and the ratoons which they produce must be destroyed as soon as they are seen. In the present Gezira rotation there is always a fallow after cotton to prevent ratooning and to make the ratoons easier to see. You will often see ratoons infected with leafcurl, thus showing how important their destruction is. The growing of certain garden plants which carry the disease is entirely forbidden, and the ban on bamia during the dead season and early rains is partly for control of leafcurl. The clean-up of ratoons and other infected plants can never be absolutely complete, so that there will always be a source of infection in the Gezira.

One of the most important things done to control leafcurl was the introduction of X1730 cotton variety. Leafcurl does not damage this variety in the Gezira, so that it can produce full yields. However, X1730 plants do occasionally get the disease and may sometimes carry it, so that they have to be pulled up in the same way as Sakel. Recently, the Plant Breeding Section has been selecting plants of Sakel resistant to leafcurl, and is now producing a leafcurl-resistant Sakel. This will be a great boon to the Gezira.

Before completing this article, it is perhaps as well to stress again that leafcurl is one of the greatest dangers to the Gezira cotton crop. A bad infection can ruin the crop, as it did with the help of blackarm in 1929 and 1930. The infection is always present in the Gezira, and any relaxation in pulling cotton, and especially in destroying ratoons, might cause widespread damage and disastrous yields.

No. 31

ROOTS — WILTING AND WILT DISEASE

The importance of good root development has been stressed in a number of previous articles. It has been pointed out that roots

do not grow well in Gezira clay, partly because of its stiffness and partly because air and water cannot move through it rapidly enough. Generally speaking, poor root growth results in poor development of stems, leaves and flowers, but does not cause damage or death to the plant unless irrigation water is insufficient. If roots are damaged, however, they cannot supply water and food required by the rest of the plant, and growth is checked or the plant may die. As we saw earlier, excessive salt in the soil and waterlogging both prevent the root from absorbing useful salts.

'Wilting' is the drooping of leaves when the plant is not getting enough water. Slight wilting is often seen in the hottest part of the day or just before watering, but this disappears as soon as the day becomes cooler or watering takes place, and no harm is done. Wilting which persists is usually a sign of root damage. As we saw earlier, this may be caused by termites. In some seasons numbers of wilted plants are found scattered through crop which shows no signs of termite or other damage. These plants are said to suffer from 'wilt' disease.

A great deal of research has been done at the Research Farm to find out the cause of this wilt disease, but the exact cause has not yet been discovered. The small roots of wilted plants were usually found to be rotten. This rotting was thought to be due to the poor conditions in Gezira soils which have been mentioned above, and possibly to poisonous substances in the soil. Wilt disease varies in severity. Sometimes plants recover without any permanent damage; sometimes leaves dry up and fall off, thus reducing crop yield; and sometimes the plants die completely. The severity of the disease depends partly on the extent of root damage and partly on the atmospheric conditions. If the weather is hot, wilt tends to be worse. Wilt is probably also encouraged by insects such as whiteflies sucking the plant juices and thus drying it out. Plants recover from wilt by producing new roots, and anything that encourages this helps the plant.

No. 32

THE YIELD OF COTTON

We have now discussed the most important factors affecting the growth of cotton and hence the yield. You will have seen that there are many factors affecting the crop either directly or indirectly, and

in order to interpret good or bad yields it is necessary to find out how much influence each factor has had.

Often the reasons for good or bad yields are fairly obvious, but this is not always so, and a series of ' observation plots ' at the Gezira Research Farm and in the north, south and west Gezira were started in order to study the effect of each factor on yield. Near these plots, rainfall, temperatures and other weather factors are measured, and the soil conditions studied throughout the year. In addition to taking cotton yields, a large number of plant characteristics are measured—the height, number of fruiting branches, number of flowers, number of leaves shed, number of bolls shed, etc., etc. The number of plants affected by the most important diseases and pests are counted, and notes are made of the incidence of others which cannot be measured or counted. These observations are carried out on both Sakel and X1730 and on manured and unmanured cotton, so that they represent most Gezira conditions.

The observations made in these plots showed the direct relationship between yield and certain factors. For instance, poor yield was related to poor growth (measured by the height and weight of the whole plant), to heavy boll-shedding, to poor boll development (measured by the weight of seed cotton per single boll) and to heavy leaf-shedding. It was actually possible to estimate the loss in yield from some of these, and estimates were worked out for the loss per boll shed, or per leaf shed, above a certain number.

Next it was possible to find out how these factors in the plant itself were related to outside influence, and how the different varieties were affected. Poor growth and sometimes leaf- and boll-shedding were usually caused by poor soil nitrogen, which in turn varied with the season and, of course, with the amount of manure applied. Leaf-shedding was often caused by pests and diseases, particularly blackarm, wilt, thrips and sometimes jassids. Poor development of bolls in turn was due to leaf-shedding and to leafcurl, as well as to the factors causing poor growth. Flower bud and boll-shedding was due to shortage of nitrogen within the plant, shortage of water, pests and diseases, in particular bollworms. The worst yields were always associated with the joint effect of leafcurl and heavy leaf-shedding. This is what occurred in the Gezira as a whole in 1929 and 1930, when the leaf-shedding was caused by blackarm, and leafcurl was very severe.

The next stage in the relationship between cotton yields and the

environment cannot usually be shown in observation plots because the cotton plant is not directly affected. For instance, seasons of high July-August rains reduce jassids and thus increase yield; and high rains in the season before cotton work through fallow weeds, which in turn reduce available nitrogen, which causes poor growth and thus results in poor yield. These relationships have been found out from other observations, from experiments and from statistical calculations.

No. 33

RESEARCH METHODS

We have seen in the last article how much information can be obtained by carrying out observations and measurements on the cotton crop itself and the factors closely affecting it. The same method of observation and, if possible, measurement is used for the study of many other problems. For instance, when an insect pest is being studied, its 'life history' and its relationship with the weather, soil, weeds, etc., as well as with the cotton plant, is worked out in this way. Soil is studied by measuring in the laboratory the amount of nitrogen and other plant foods in it, and then finding how crops grow on it. Weather is measured by rain gauges and various other instruments. In obtaining measurements of anything (e.g., a cotton plant), it is essential to be sure that the plant measured represents the whole crop, or the special crop being studied. This is done by taking a large number of measurements instead of one. The average of these measurements then represents an average of whatever is being studied. All these measurements provide information which can be related by statistical calculations to measurements of cotton growth and yield.

There is one other important method of studying agricultural problems in addition to the important methods just mentioned. This is the use of experiments. Experiments can be carried out in laboratories or in the field, depending on what one wishes to find out. The principle is the same in both cases. A known treatment is given to the plant, soil, pest, or whatever it is, and its effect is measured. To find out the effect of various treatments on the growth and yield of cotton, 'field' experiments are carried out. Field experiments are an important part of the research work at the Gezira Research Farm, and are also conducted on a much larger scale by the Gezira Board. Visitors to the Research Farm see many of these field experiments, and, though the results obtained by them are explained, there is

hardly ever time to explain how they are carried out.

Two things are essential in a proper field experiment: one is 'replication' and the other 'randomisation'. Let us consider an experiment in which we wish to test out the effect of nitrate of ammonia on cotton yield. A rough experiment could be done by dividing a 10 feddan hosha into two equal parts and treating one with nitrate and leaving the other untreated. However, the soil might be poorer in the nitrated half, or goats might get into the crop and eat it, or some other accident might happen. This would perhaps cause lower yields from the nitrated half and give a completely false result. In order to get over this difficulty, several small plots are treated with nitrate and the same number left untreated. This is 'replication'. The small treated and untreated plots must be mixed up with each other so that if there is a bad patch of soil or other irregularity in the hosha, both the nitrated and untreated plots sample it. The best way to do this is to put treated and untreated plots always side by side. If several 'treatments' (e.g., nitrate applied before sowing, at sowing, after sowing, and no nitrate) are being tried, one plot of each should be put together in one 'block' of the hosha and these 'blocks' should be replicated several times. Within the block each treatment (occurring once only) should be allocated 'at random' to one of the small plots; that is to say, its place within the block is chosen by chance (e.g., by throwing a dice). By randomising the treatment in this way, it is possible to make use of the mathematical laws of chance, and this in turn indicates the probability that any differences of yields between treatments are really due to the treatments and not to chance differences. When yields are obtained, the yields for the replicates of each treatment are averaged, but at the same time a statistical calculation is carried out which shows whether the differences between these averages are 'significant' or not—that is, whether they are really due to the treatment or to chance.

The above procedure may seem complicated, but it is comparatively simple when the technique has been mastered, and it is well worth the trouble, because the results obtained by such field experiments are thoroughly reliable.

A very large number of field experiments have been carried out at the Research Farm and have provided information on manuring, watering, spacing, thinning and many other things. Field experiments are very important in trying out new varieties of cotton, and can

often show and prove both differences in yield and quality between new and old varieties. These results have been found to apply over most of the Gezira, which in itself is a measure of their reliability and value.

No. 34

QUALITY AND GRADE OF COTTON

Quality

The market value of cotton depends on the quality, and the profits obtained by tenants depend on the good quality of Gezira cotton as well as its good yield. There are big differences in the quality of different types of cotton. American and Indian cottons are in all respects poorer in quality than the Egyptian cottons grown in Egypt and the Sudan. The quality of these Egyptian cottons is very high, and prices paid for them are always higher than for American cotton. The quality of Sakel is a little higher than that of X1730. The quality, like the yield, of cotton varies from place to place and from season to season, but it always retains the characteristics of its own type of cotton.

The main characteristics of cotton lint which determine its quality are its length, its strength and its fineness. Egyptian cottons have long, strong and fine fibres. They are much finer and silkier than American cottons, and the yarn spun from them and cloth woven from them are finer than from American cottons. Short and immature fibre in lint reduces quality. Cotton spinners and weavers, above all, need lint of uniform quality, and the lint of Sudan cottons is frequently tested to see that its quality does not alter much.

Grade

Gezira cotton is classified into six grades, with some half grades, according to its quality. Each tenant's cotton is graded separately, so that those producing good grades can get the benefit of better prices. The cotton grader judges the length, strength and fineness of the fibre and looks for dirt, weak fibres and anything else likely to lower the grade. The grades given to the seed cotton are checked after ginning. Cotton buyers know that Sudan grading is carefully done and are confident of getting the kind of cotton they want if they go by the grade marks. This is most important for the tenant and the Gezira Board, because buyers are prepared to pay higher prices for what they can depend on.

Generally, the grade of cotton in any one place or season depends on a variety of factors which the tenant cannot control. It is well known that the late-picked crop is of poorer grade than the early picks. This is because the plant has begun to exhaust its stores of food before the season is finished. Anything that increases the late crop tends to reduce grade, and it is well known that fertilisers do this. However, the increase in crop more than compensates for loss in grade. The bolls at the top of the plant, being late, are usually poorer than those at the bottom. A large amount of good grade can thus be expected from crops which are sown early and in which resowing has not been heavy. Bollworm damage and anything else which causes damage or premature opening or malnutrition of bolls reduces grade.

Grade is often reduced by mixing good and bad cotton. For instance, if cotton from immature bolls is mixed in Grade 1 cotton, the grader has to reduce the grade to nearer the poor grade of the immature cotton. This is a common reason for poor grade. Of course, pickers in the field cannot be expected to distinguish between good and bad cottons, even if they had time to do so. However, the tenant can send a few experienced pickers ahead of the others to pick all damaged and badly opened bolls, thus avoiding some mixing. Pickings of good and bad cotton would then be kept in separate sacks and the tenant could expect most of his cotton to be high grade, but with a little of very low grade, instead of all his cotton being medium to low grade.

Dirt, bits of leaf, stained cotton, etc., all reduce grade, and if possible should not be picked with the cotton, or at least taken out of it after picking.

No. 35

PLANT BREEDING

There is one important means of improving the yield and quality of cotton which we have not yet discussed, and that is by improving the ability of the plant itself to do this. If plants of one variety of cotton are grown in exactly the same conditions, they will all grow and yield in the same way, but other varieties can be found or bred which will grow and yield in a different way. In this way cotton varieties can be found which are particularly suitable for special purposes.

Egyptian cottons such as Sakel are of good quality and yield well, but they are susceptible to many pests and diseases. Thus the main varieties to be searched for were those resistant to pests and diseases. It was by searching for resistant plants that 1530 (now X1730) was found. It was resistant to leaf curl and partly resistant to blackarm, and was of yield and quality similar to Sakel. Varieties resistant to blackarm and to jassids have been found but their yield and quality is much poorer than that of Sakel or X1730. Plant breeders therefore have crossed these resistant varieties with Sakel and X1730 to bring the resistance to them. In recent years this has been the main work of the Research Farm Cotton Breeding Section and, as will be shown below, the plant breeders have achieved great success.

To cross cotton varieties the 'pollen' (or male part) of one variety is put on the 'stigma' (the female part) of the flower, and the seeds produced contain the characteristics of both parents. When the seed is sown a plant will grow which has characteristics from both parents, but which will not breed true to itself, as some of the characteristics in the next generation may come from one original parent and some from the other. After crossing, therefore, the plant breeder has two important tasks, first he must retain all the good characteristics, and second he must ensure that plants always breed true for these characteristics. The best way to understand how this is done is to study two examples.

*The introduction of X*1730: When blackarm was severe in the Gezira, Lambert inspected large numbers of plants and found some plants which appeared to be resistant to it. He sowed seed of these and found that one strain was very resistant. These plants, being derived from Sakel, were not much different from it in yield and quality, and the resistance to blackarm was mainly due to extra vigour. This strain was also found to be resistant to leafcurl. No crossing had been done in this case, and quality yield and disease resistance were maintained by multiplying up seed only from the plants which gave the best of these. This is how X1730 was developed. It has proved of great value to the Gezira, and Lambert, who started it, deserves the gratitude of the Government, the Gezira Board, and every tenant on the scheme.

Breeding for Blackarm Resistance: Certain American and other cottons of poor quality were found to be much more resistant to blackarm than Sakel or X1730, and it was decided to introduce this resistance into those cottons. The first step is to cross the X1730 (or

Sakel) with the resistant type. The cross thus contains resistance and non-resistance to blackarm and good yield and bad yield and good quality and bad quality. The cross is allowed to fertilise itself and the plants of the second generation tested for all these qualities—this is because the qualities get mixed in the first generation and segregate out in the second. In the case of blackarm, resistance is tested for simply by spraying the seedlings with blackarm infection from a badly infected previous crop. Seed was kept only from the plants resistant to blackarm and with better quality and yield. However, the quality and yield may never be as good as in the original X1730 if selection only is done, and 'backcrossing' is carried out in addition to selection. Each time a resistant progeny has been selected this is crossed with ordinary X1730. The quality is improved by each cross and the progeny is tested for resistance after each cross. In this way after about seven crossings the variety contains resistance to blackarm and is of the same quality as the original X1730. This is a slow but sure way of introducing resistance to disease into our cotton without altering the quality.

The plant breeders of the Sudan Government and Empire Cotton Growing Corporation who have been lent to the Sudan have in this way produced varieties which are resistant to blackarm and to jassids. Leafcurl resistance has been increased by the methods used in the selection of X1730.

These new disease-resistant varieties have been mentioned elsewhere. It takes many years to fix the type and to complete the trials needed to ensure good yield and, in particular, uniform good quality. After all this is done the seed has to be multiplied up. Some of the blackarm-resistant varieties are at this stage and whole blocks in the Gezira have been sown with them. Their final introduction into the scheme will be a most important advance.

No. 36

CONCLUSION

In this series of articles we have tried to show the reason for carrying out the various operations which have to be carried out on the cotton crop and why some of these are so very important. It is hoped that tenants and others working in the scheme will understand what goes on and find greater interest in their tenancy and their day-to-day labour in it. We have also mentioned some of the

work done by the Research Farm and the considerable contribution it has made to the Gezira Scheme during the 33 years of its existence. Tenants who have read these articles and who visit the Research Farm will realise that it is not something remote from their everyday affairs.

At the beginning of this series we stressed the importance of experience and research in the development of good agriculture practices. Experience and research are of little value if the tenant and the management do not use them, and it was suggested that the Gezira Scheme had benefited from both the experience and research, and from its careful and efficient application. There is an interesting comparison which gives some indication of what research and experience and their applications to the scheme have meant. In 1950/51 the rainfall conditions were very favourable to the cotton crop and a record yield of 6.7 kantars per feddan was obtained. Yet in 1929/30 the rainfall conditions were more favourable than in 1950/51 but only 2.3 kantars per feddan were obtained. The difference between these two yields is a measure of the progress of the Gezira Scheme.

No two cotton seasons are the same and the relative importance of cotton-growing problems is always changing. In reading these notes, this, and the fact that research is always advancing, should be remembered. New facts about the cotton crop and its pests and diseases are always being found out. Many of these are of little practical importance, but it is certain that by the time these notes are read some new advances worthy of record will have taken place.

GLOSSARY

atrun - - salt deposit, rising to surface of soils with irrigation.

bamia - - *Hibiscus esculentus* L.

dura - - great millet: *Sorghum vulgare* Pers.

feddan - - measure of land = 1.038 acres.

gubbein - *Solanum dubium* Fresen.

hambok - *Abutilon figarianum* Webb.

hosha - - tenant's 40-feddan holding = 10 feddans of cotton annually.

kadunka - small digging hoe.

kharif - - rainy season.

lubia - - *Dolichos lablab.*

malod - - long or short-handled weeding hoe.

molokhia - *Corchorus fascicularis* Lam., *trilocularis* L., *olitorius* L.

nazz - - seepage.

rihan - - *Ocimum basilicum* L.

sureib - - *Phyllanthus niruri* L., *maderaspatensis* L.

tebr - - *Ipomoea cordofana* Choisy.

PRINTED BY KENT PAPER COMPANY, LTD., ASHFORD, KENT, ENGLAND.

وزارة الزراعه السودانيه
حكومة السودان

البلتين
نمره ١٥

مذكرات عن زراعة القطن من قسم الابحاث الزراعية

المؤلف
هـ. فيرقسن

لجنة النشر الزراعيه
الخرطوم ١٩٥٤

الثمن ١٢ قرشا