SOME STUDIES ON CULTIVATION PRACTICES, FOOD CROPS AND THE MAINTENANCE OF FERTILITY AT THE COTTON STATION, NYASALAND.

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THE cotton industry in Nyasaland is one of African peasant growers, and the work at the Cotton Experiment Station is primarily concerned with cotton problems. But cotton is not grown as a mono-culture, and the chief native food crops of the area are included in the rotation. There is also the universal problem, especially important in Africa, of maintaining and improving soil fertility. This article is not directly concerned with cotton problems, and gives a summary of general investigations that have been undertaken since the Cotton Station was opened in 1930.

SITUATION, ECOLOGY AND SOILS

The Cotton Station is situated at Chitala, some 14 miles inland from Domira Bay, on the plain bordering Lake Nyasa. It lies on about latitude 13° S. and at an elevation estimated at 1,985 feet above sea level. Its lands are close to the main fault system on the western side of the Rift Valley, and immediately to the west of them are the foot-hills, and farther back the main escarpment which forms the dominant feature of the landscape.

The soils of the Station can be roughly classified into two series: one a reddish brown soil on areas with good natural drainage, the other a black soil which occurs where drainage is not so good. An extensive study has been made at Rothamsted of large samples from the two series, and it appears that the general mechanical composition of the two soils is similar, and that the black coloration is due to some peculiar difference in the state of the iron compounds. The black soils show calcium accumulation in the form of nodular concretions which are lacking in the reddish-brown soils, the latter being somewhat more acid. The contrast between the two soils becomes more evident as one moves towards or away from the foot-hills, the red soils predominating and becoming redder towards the hills, and the black soils predominating on lower levels nearer to the lake.

The average rainfall for the past seventeen years is 33 inches, nearly the whole of which falls in the four months from December to March. Within this period distribution is normally good, and heavy falls of over 3 inches per day occur only once or twice each season. Variation in the total rainfall has not been large, ranging from 27 to 36 inches, with the exception of one year when the total reached 46 inches. The distribution is important in determining high or low yields, but there is no known record of shortage of rain causing a complete crop failure. The mean maximum temperature in December at the beginning of the planting season is about 90° F. falling to 85° F. in May, when the rains are over. During the same period the mean minima fall from 70° F. to 60° F. Extremes recorded to date are 101° F. maximum in November and 42° F., minimum in July.

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The Station lands have a very mild slope and it has been possible to make all the fields rectangular and standardize their dimensions, which is a great advantage in experimental work. Erosion has been satisfactorily controlled by ridge cultivation and by a few shallow drains to prevent surface wash. In fact, the problem on quite a large area of the heavier lands is to provide surface drainage. In a few places the general slope of about 1 in 150 is exceeded and contour bunds have been made and contour ridge planting has been adopted. The first fields opened still give as good yields as they did seventeen years ago, which may be regarded as proof of the the general efficacy of these mild anti-erosion measures for this particular site.

The lake shore plain lies in a tsetse-fly belt and no animal-drawn cultivation has been possible except for a brief and abortive experiment in keeping work oxen free from trypanosomiasis by regular injections. No tractor-drawn implements have yet been used and the whole of the cultivation to date has been by hand, except for a little ploughing in the two years with the oxen. In fact, it may be said that the cultivation practices on the Station are no more than could be done by an energetic African peasant.

In the account which follows all results quoted are based on statistical experiments.

CULTIVATION PRACTICES

The main experiment, begun in 1938–39, was a factorial one comparing ridge and flat cultivation, early and late preparation of fields, and three levels of digging. This experiment was carried out on a black soil field in good heart for four consecutive years through the normal rotation, and similarly for three years on a brown soil field which had been cultivated by Africans and was in a low state of fertility. Results are therefore available for seven occasions. The fields used formed part of the main Station rotational plan and were cropped in cotton, groundnuts, cotton and maize, in that order. There were also several later experiments concerned with digging only, and others on the frequency and timing of post-planting cultivations on cotton. Where ridge is mentioned in this account, a low ridge some 9 inches in height and 18 inches wide at the base is understood. Such a ridge settles during the season and is seldom more than 6 inches in height at the end of the rains.

Ridge and Flat Cultivation.—Three of the seven occasions were cotton crops, and in each case there was a significant increase in yield from the ridged plots. Out of two maize crops and two groundnut crops, one of each gave a higher yield from the ridged plots, once with maize there was a lower yield, and there was no difference on the other occasion with ground nuts. The yields of the ridged plots were 15 to 20 per cent. higher than the flat plots. The germination was higher on the ridged plots, but when the yields were corrected for final stand at harvest there was still a significant advantage for the ridged plots, showing that the advantage was not due to the greater number of plants. Six weeks after planting samples taken from the cotton crop showed that the ridged plots gave plants with a greater average weight and a higher moisture content, but no difference in height. Fourteen weeks after planting the plants from the ridged plots averaged 5 cm. taller than plants from the flat plots.

Ridge planting is justified if for no other reason than erosion control, and is doubly worth while as higher yields are obtained. It is suggested that the reason for the advantage is that nitrogen is not leached away so quickly from a ridge, as most of the rain will sink into the ground in the furrow. There is no direct evidence of this, but the higher moisture content of the young plants is suggestive.

Time of Preparation of Fields.—The local African cultivator usually delays the cleaning up and preparation of old fields until the very end of the dry season, and seldom completes the work until after the rains have begun. Although it is known that in this area the highest yields are obtained from planting as soon as possible after the rains begin, traditional African

methods are often sound, and it was thought worth while to include this factor in the main cultivation experiment. The usual reason advanced for this habit of late preparation is that it entails less work ; a field cleaned early may grow a second crop of weeds and tree-root suckers, and after rain has fallen the soil is easier to work, though few do more than burn weeds and trash in heaps. One possible reason for late clearing might be that bare fields are exposed to the very hot sun of the latter part of the dry season, and the humus content of the surface layers might be destroyed. The amount of ground cover on the " late " plots and the time of " early " preparation varied with the previous crop. On land emerging from rest there was dense cover, and preparation of " early " plots (digging and ridging as needed for the different treatments) was completed by the first half of May. After a cotton crop the cover was of medium intensity and preparation was completed in July. After groundnuts there was practicially no cover and preparation was completed in April. As maize was the last crop in each field, there was no trial of the effect of maize trash cover. The " late " plots were left undisturbed till the latest date by which the preparation could be completed before the rains, usually about the middle of November. In all cases the trash from the previous crop was burnt on the plots in random heaps and the ash incorporated with the soil.

The results from all experiments showed a small but regular increase in yield from the "early" plots. The increase was usually less than 10 per cent. and was most marked in the case of the maize crops following a cotton crop. There was no difference between the treatments in germination, weight or height of the cotton plants. It was concluded, again without direct evidence, that the slight advantage for " early " cleaning was due to greater accumulation of nitrates in the soil. The advantage was slight, and fields can be prepared at whatever time best suits the available labour, so long as preparation is completed before the rains start.

Digging.—In the main experiment there were three levels of digging : full digging over the whole area, strip digging about 10 inches wide along the planting row, and no digging at all. The digging with a native-type hoe averaged about 4 inches in depth. No yield differences were found until the last year of cultivation in each field, which in both cases was a maize crop. In the black soil field with a very fair mean yield of 2,500 lb. grain per acre the full digging gave a 15 per cent., increase over no digging. In the worn-out soil of the brown soil field with the very low average yield of 700 lb. per acre, the increase was as much as 40 per cent. for the full digging. The strip digging gave an intermediate yield which was not significantly better than no digging.

There were five subsequent experiments concerned with digging. Cotton was planted with three treatments : no digging, normal digging to one hoe depth, and deep digging by trenching. The results were highly significant, no digging and normal digging giving increased yields of 19 per cent. and 13 per cent. over deep digging. The residual effect was tested the following year with maize, and the order of yields was the opposite of that with cotton. There was a progressive increase in yield from no digging, normal digging to deep digging, and the difference only just fell short of significance. Three more experiments with maize and one with groundnuts failed to show any differences.

Maize, therefore, was the only crop which showed any positive response to digging, but the size of the increase was not large enough to pay for the cost of the work involved. From the native point of view increases in yield of the order found can be obtained with less effort by hoeing a slightly larger garden. It was concluded that digging of the land before planting was not necessary except for the first crop after a resting period ; it must be done then to provide a good seed-bed. In all subsequent crops an adequate seed-bed is provided by making up the planting ridges. These conclusions would have to be modified if there were any real pressure on the land.

Early Cleaning of Cotton.—It does not take a profound knowledge of agriculture to realize that young cotton will not thrive when competing with a thick growth of weeds as big as, or bigger than, the cotton plants themselves. Nevertheless every year a large number of cotton gardens can be found with etiolated cotton plants drowned in a sea of weeds. This lack of attention is partly due to lack of interest in the cotton crop, and partly to preoccupation with food crops. But there are some Africans who maintain that the practice is advantageous, the cotton plant being made to grow tall and then quickly making fruiting branches when the grass is removed. The first contention is true, the second is not. Although the results of this experiment were a foregone conclusion, it was thought worth while to find out just how much the crop is decreased by late cleaning.

The figures are so striking that they are quoted in full. One series of plots was cleaned before thinning, and another at the same time as thinning six weeks after planting. The plots were then divided and half had one and half two subsequent cleanings. The yields are expressed as percentages of the normal station practice.

	One cleaning after thinning per cent.	Two cleanings after thinning per cent.	Mean per cent.
Cleaned before thinning	84	100	92
Cleaned at thinning	26	40	33
Mean	55	70	—

A large percentage of the cotton gardens in the central areas of Nyasaland are not cleaned till thinning, and for many this is the only cultivation given. These figures show that the yield is only a quarter to a half of what it might be. The aggregate loss of crop, for want of a few days' work in the early stages of the plants' life, must be very large.

FOOD CROPS

Maize Spacing.—Different varieties of maize have been tried over a number of years. All yellow varieties have been discarded, partly for low yield and partly because the labourers prefer to eat a white maize. Potchefstroom Pearl was grown for some years and was eventually replaced with a selection from the local mixture grown in the vicinity of the Station. This is a hard white type and, though it yielded slightly less than Potchefstroom Pearl, has much better keeping qualities and so is to be preferred. Four spacing experiments were made on this local selection and all led to the same general conclusions. A large number of spacings and numbers of plants per hole were tried, nearly all of them with a fixed inter-row distance of 3 feet. It was found that 2 and 3 feet inter-row spacing was better than 4 or 5 feet, no matter how many plants per hole were left. The 3 feet spacing was slightly better than 2 feet; two plants per hole gave the maximum yield for both 2 and 3 feet spacing, one plant per hole being a good deal worse and three plants slightly lower in yield. All maize on the Station is now planted 3 feet by 3 feet, which is rather wider than is often thought to give maximum yields; less labour per acre is required when planting at 3 feet than at 2 feet. Three seeds per hole are planted and no thinning or supplying is subsequently attempted. This is a labour-saving method which gives very satisfactory yields.

Groundnuts.—These are an important crop on the lake shore, as they are the only leguminous food crop which can be relied on to give a good yield. A large number of varieties have been tried, both bunch and runner types. There is some variation in yield, the best averaging rather more than 1,000 lb. of shelled nuts to the acre, and the worst about 800 lb. Apart from yield considerations it is important to choose a variety which is easy to harvest.

The cost of growing a short ton, excluding all overhead charges, has been about £4.10*s*. Rather more than half of this total represents the cost of stripping the nuts from the plant and shelling with hand labour. With a small seeded runner type from Senegal this part of the cost is at least doubled. Two types have been retained for bulk plantings; an early bunch variety from Gambia and a semi-bunch variety, Mwitunde, imported from Tanganyika. The latter matures a little later and so labour requirements are more evenly spread out during the harvesting period. It is well known that for high yields and control of rosette disease it is essential to plant early and to space close together. The standard spacing adopted is to plant in two lines on either side of ridges spaced 3 feet apart; the inter row distance on each side of the ridge is 1 foot. This spacing was tried against ridges 1 foot 6 inches apart with seed planted 1 foot apart on top of the ridge, giving the same plant population, but a more even spacing; and also with 1 foot 6 inch ridges with a double row 1 foot apart, giving double the standard plant density. There was no advantage in the closer ridges with the same population but when the plant density was doubled there was an increase of 210 lb. per acre in a year with the exceptionally high average yield of 1,720 lb. shelled nuts to the acre. In a year of more normal yields it is unlikely that the difference would be so great; and as the closer spacing requires about 40 lb. more seed to the acre and much more work in preparation, planting and harvesting, it is not justified. It is an advantage to sow two seeds per hole; if unshelled nuts are planted the germination is slightly delayed and is not quite so good but the final yield is not affected. An experiment was tried with after planting cultivation contrasting clean weeding with hand pulling of the largest weeds only, and really dirty cultivation with no weeding. The last treatment led to a decrease in yields, but there was no difference between the first two. The time of harvest is important with an early-maturing bunch variety which may sprout in the ground; the optimum time will depend to a certain extent on the season and the amount of moisture in the ground at harvest time. In one experiment with Gambia bunch the highest yield was obtained 105 days after planting; a week later the yield had dropped 6 per cent.; a week sooner or two later it had fallen off by 12 per cent.; and three weeks later the loss was 15 per cent.

Another point of interest with groundnuts is that if two crops are planted in consecutive years, the yield of the second crop is reduced. This was first noticed on a European estate where large areas of groundnuts were being planted by tenant farmers. The first-year yields were good, but they fell off greatly the second year. This reduction of yield might have been due to a variety of causes, but no satisfactory explanation could be advanced until a number of the tenants said that they had always found a second crop to be poor; they had not mentioned this before planting because they assumed that Europeans knew better. About the same time a large reduction in the yield of groundnuts was found when one crop succeeded another after one intervening crop. The yields are taken from a rotation experiment and are given in the Table below:

Rotation 1.

1st year	..	Cotton: 160 lb. lint
2nd year	..	Cotton: 226 lb. lint
3rd year	..	Maize
4th year	..	Groundnuts: 737 lb. nuts

Rotation 2.

1st year	..	Cotton: 156 lb. lint
2nd year	..	Groundnuts: 776 lb. nuts
3rd year	..	Sorghum
4th year	..	Groundnuts: 374 lb. nuts

It will be noticed that though in the first year the yield of cotton from the two sets of plots was identical, in the fourth the yield was reduced to half when groundnuts succeeded groundnuts. As no reason for this result could be found, a further experiment was laid down. In the final test year of this experiment groundnuts planted in two consecutive years were contrasted with groundnuts with one, two and three other crops intervening. Different intervening crops were tested in the various treatments. The yields are given in the Table below :—

	Shelled nuts per acre lb.
Groundnuts following groundnuts	814
With one intervening crop	915
Mean of plots with two intervening crops	1,054
Mean of plots with three intervening crops	1,035
Significant difference	218

There was no difference between plots in the incidence of rosette or wilt disease, the amount of these diseases being negligible in all cases. It is not usual to plant groundnuts in consecutive years, as it has been found that maize gives an increased yield when following groundnuts. There should be at least two intervening years before the crop is planted again under the conditions which obtain at the Cotton Station.

MAINTENANCE OF FERTILITY

When the Cotton Station was first opened the rotation adopted was three years crop followed by two years rest under pigeon pea. Maize was always the last crop in the rotation and the pigeon pea was sown from four to six weeks after planting the maize. There were signs that this amount of rest would not maintain fertility indefinitely, but there were difficulties in the way of extending the period under pigeon pea. After the first year termites caused a big loss in the pigeon pea, and by the third year there were very few plants left. Also a wilt disease attacked the plants in patches, leaving a very poor stand. About that time Martin drew attention to the beneficial effect of grass on soil structure in Uganda. Elephant grass is not found on the main lake-shore plain, but only alongside the streams which run down from the hills during the rainy season. Every year the dried tops are burnt by bush fires, but the grass is not killed and planting material can always be obtained at the beginning of the wet season, and it has been found that these plantings grow well under field conditions.

A rotation experiment was planned in 1936 to test the suitability of using elephant grass to restore fertility. Various rotations were employed and the main comparisons were between no rest, one year's rest with pigeon pea, two years' rest under either pigeon pea or elephant grass, and three years' rest under elephant grass. Cotton was used in the first test year and maize for the second year. With the cotton crop the last three treatments were all equal and all better than one year or no rest. With the succeeding maize crop the results were rather different. Three years' rest was better than two years, and elephant grass was better than pigeon pea. It was therefore concluded that three years' rest under elephant grass was the minimum required and futher experiments are in progress to find out if four or five years give still better results.

It was thought that the lack of a leguminous crop in the resting period might slow up the restoration of fertility. If very worn-out land is abandoned to bush there is often a very heavy, almost dominant growth of Buffalo Bean (Stizolobium spp.) which becomes less common in later years. It has also been noticed that elephant grass planted on badly run-down soil grows less luxuriantly when planted alone than when mixed with pigeon pea. Accordingly an experiment was planned contrasting elephant grass alone and mixed with velvet bean. No

difference was found in yield when cotton was planted subsequently. The point cannot be said to have been proved, as it was impossible to prevent the growth of buffalo bean among the elephant grass. The seeds of this plant must be capable of lying dormant for at least five years, as they grow up freely even after five years' clean cropping.

The planting and subsequent clearing of elephant grass involves an amount of labour which does not appeal to the African cultivator, so trials are going on to try to find a simpler method of resting the land. Various rest crops have been tried, including pigeon pea, allowed to degenerate into weeds, chance weeds and the local long term sorghum treated as perennial. So far the results have been inconclusive, as no differences have been demonstrated.

Experiments have been made on different spacings and times of planting of the elephant grass, and results show that a wide range of both seem to give equally good results. Spacings have been tried from 3 feet by 3 feet up to 8 feet by 3 feet, and the resulting cover has always been excellent. This is a good deal wider than is reported as being necessary in Uganda to establish a good cover. The local variety of elephant grass is stoloniferous, and after the first year, when growth in Nyasaland appears to be slower than in Uganda, the spread is rapid and all other grasses are largely suppressed. The planting material used is main stems cut up into lengths of about 2 feet 6 inches, pieces bearing roots being preferred. These have been planted from January to early March, not far from the end of the rains, and in all cases a good stand has been obtained. For the time being the standard Station practice is to plant pigeon pea among the maize about the middle of January, when the maize is four to six weeks old. Elephant grass is planted later whenever labour is available, generally during a wet spell when hoeing is impossible. In the first year the elephant grass makes little growth and the pigeon pea gives a crop about September. During the second year the elephant grass makes rapid growth and a second crop can be taken from the pigeon pea if wanted. After that a good deal of the latter dies out with termite attack and is more or less swamped by the vigorous growth of the elephant grass. The year before the land is to be cleared the grass is fired at the end of the dry season, and a fierce fire and a clean burn is the normal result. If this burning is omitted clearing is more troublesome the following year. A strong re-growth is made during the rains and this is cut down in March or April, burnt as soon as dry and the land then dug. Some roots continue to grow during the dry season and these are dug up at intervals. The grass can be burnt at the end of the dry season and the land immediately prepared for planting. But if this is done it is impossible to kill more than a percentage of the roots and a lot of labour is necessary in frequent cleanings of the subsequent crop.

MIXED CROPPING

Mixed or inter-cropping has been tried at various times without success. The very short growing season necessitates the planting of all crops at the break of the rains to get maximum yields, and young plants growing together compete strongly for the available nitrogen. The common haricot bean, which grows well among maize at higher elevations, does not thrive in the hotter climate of the lake shore. If groundnuts are planted among the maize the yield of the latter is not affected, but with a good growth of maize the yield from the groundnuts is so small as to be hardly worth the bother of planting. Similarly groundnuts give a very low yield if planted among rows of cotton, and cleaning the fields is more difficult. If cotton and maize are planted in alternate rows the cotton is so suppressed that the yield is negligible. There is little doubt that for maximum returns crops must be planted in pure stand in this area. Further experiments are being made with planting cotton among wide-spaced maize, not with the idea of increasing cash returns per acre, but to encourage new people to plant cotton among maize because they will obtain a food supply at the same time as they are earning some cash.

ROTATIONS AND FERTILIZERS

There has only been one experiment with different rotations; the only positive result was that maize yields more when planted after groundnuts than after cotton. In one year the increase was 40 per cent. and another year only 10 per cent. The rotation finally adopted is cotton, maize, cotton, groundnuts and maize, the last being interplanted with rest crops. This rotation is not designed to be suitable for peasant cultivators, but has been adapted to meet the needs of the Station; the chief needs are an adequate acreage of cotton for experimental purposes, and the provision of food crops for the labour force; at the same time the fertility of the soil must be maintained and if possible improved.

This rotation of five years' cropping followed by four years' rest under a mixture of elephant grass and pigeon pea is one which should maintain a good soil structure indefinitely. It also appears that there are enough plant nutrients in the soil to give continuous yields.. Experiments on the use of compost have shown that yield increases are only obtained with uneconomically large dressings. Artificial fertilizers, owing to their high cost and the low value of the crops grown on the Station, have not been considered important. One experiment with artificials was made, but no increases in cotton yield were found, nor were there any residual effects on maize the following year. New fertilizer experiments are being planned, and only the future can prove if the above cropping scheme will maintain yields at their present level. It is hoped, however, that neither artificials nor compost will be needed for a long time to come.