FAO SOILS BULLETIN 14

improving soil fertility in africa

FOOD AND AGRICULTURE ORGANIZATION
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INTRODUCTION

The main purpose of the Conference was to discuss developments and requirements in the field of soil fertility, fertilizer use and soil development in Africa and to provide fresh ideas and lines of action for future work.

There were 58 participants at the Conference from most of the African countries and from various countries and organizations from outside Africa.

The technical part of the Agenda included the following items:-

1. Soils and Plants
2. Responses of Crops to Fertilizers on Farmers' Fields and Research Stations
3. Fertilizer Economics
4. FAO's Standard Guide to Soil Fertility Investigations
5. Fertilizer Materials
6. Fertilizer Supply, Fertilizer Use Development Programmes and Policies
7. Stabilization of Soils and Agriculture in Areas of Shifting Cultivation
8. Planning of Soil Fertility and Fertilizer Use Development Programmes

A large number of papers were presented on these items. From the papers and the discussions, the following conclusions were drawn:-

> Although it was recognized that research and experimentation work should continue to form the basis for the rational use of fertilizers, under African conditions, the Conference felt that more emphasis should be placed on applied research, demonstration and extension work in close contact with the farmers. It has become very clear that the lack of adequate distribution facilities for fertilizers and other inputs is the main bottleneck at present for their introduction into practical agriculture on a large scale. In this connection, the problems of fertilizer price policy, including the establishment of long-term fertilizer development plans and the setting up of input units in the Ministries of Agriculture was stressed. The need to take action in transforming shifting cultivation into more stable and more productive forms of land use was strongly emphasized.

The papers included in this Soil Bulletin are the ones presented at the Conference which appear to be of immediate interest.

THE FERTILITY STATUS OF ETHIOPIAN SOILS

Dr. H.F. Birch* and Ato Desta Hamito**

INTRODUCTION

As recently as 1966 information on the fertility of Ethiopian soils was somewhat sparse and scattered. They were frequently described as fertile but this was not supported by yields of teff, wheat and barley which in our opinion, were low. These important cereals are extensively grown on the Central Highlands and the average yields for three years were approximately 800 kg/ha (teff), 950 kg/ha (wheat) and 1 200 kg/ha (barley).

Reports of field trials carried out before 1966 were few. Such results as were available indicated responses to nitrogen and phosphorus, especially the latter, at widely spread sites but no attempt had been made to systematize the information.

In 1959 Murphy published a valuable report on the fertility status of some Ethiopian soils. Altogether about 2 200 soils widely distributed throughout Ethiopia were collected and comprehensively analysed. According to Murphy 79 percent of the soils were medium to high in total nitrogen, 60.5 percent medium high in available phosphorus and over 90 percent high in available potassium. For the Central Highlands his figures show adequate amounts of nitrogen and potassium and low amounts of available phosphate.

From the foregoing information it appeared that phosphate deficiencies were widespread and, to a lesser extent, nitgoren deficiencies. The latter were suspected from the extensive erosion found throughout much of the country. It was decided to focus attention on the NP status of the soils starting with the important cereal-growing soils of the Central Highlands.

Approach to the Problem

The area under consideration is about 400 000 sq km (arable and pasture). With limited laboratory facilities and only two staff members, we had to be selective in our methods to get the maximum information as readily as possible. Fortunately the Central Highland soils consist predominantly of two groups only, namely vertisols and ferrisols both derived from basalt. Result from studies of these two groups could therefore be extrapolated to cover a very large proportion of the Central Highlands.

Samples of these two groups were taken from widely spaced sites for soil analyses and pot experiments. Soil analyses revealed that common features of both groups were medium total N contents, low available phosphate contents and high clay contents. Nitrification studies showed that at field capacity the soils produced moderate amounts of nitrate - N (about 20 kg/ha/week). Under saturated conditions such as occur for long periods during the growing season no nitrification occurred. When ammonium nitrate at the rate of 48 kg/ha each of NH_4-N and NO_3-N was added to saturated soil clods straight from the field 100 percent of the ammonium nitrate was denitrified after 12 days with the vertisol and 22 percent with the ferrisol. Pot experiments showed responses to N, slightly bigger ones to P and marked responses to NP together.

From this work and the similarity of the red soils to each other and the black soils to each other as regards chemical and physical characteristics it was concluded that practically the whole of the Central Highland (or Plateau) area was deficient in N and P and likely to

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show marked responses to N plus P. Recognition of the high clay contents of both groups was important as the water logged conditions associated with such soils bring about anaerobic conditions which adversely affect nitrification and the ability of plants to take up nutrients. Such conditions occur for a considerable proportion of the growing period and adversely affect yields as shown by the dramatic increase in yields when soil drainage is practised.

Finally in these studies it was found that soil drying enhanced soil nitrification and aggregation. These benefits are transient and limited to the early period of the rains but are important in these clay soils as they help early sown plants to get off to a good start.

Confirmation from FFHC Trials

In the three seasons between 1967 and 1970 the FAO Fertilizer Team with the Ministry of Agriculture Extension Service laid down 2 600 field trials in 12 of the 14 provinces. From these trials reliable results were obtained from 1 600. The trials were 5 - treatment trials (C. N. P., NP and NPK) mainly with teff, wheat and barley, but also with sorghum, maize and other crops. The results of the trials were kindly made available to us for statistical analysis. Complete reports of each year's trials and statistical analyses are available. A brief summary is given in relation to the preliminary work already described.

Over the three seasons there were 672 trials with teff, 490 with wheat and 173 with barley. The total trials for each crop revealed significant responses to N, P, NP and NPK. Responses to P were almost invariably greater than to N but not significantly so. Responses to NP were always significantly greater than to N or P but did not differ signifcantly from NPK.

In the 1969/70 season there were 43 places where the number of trials at each was sufficient for statistical analyses. Of these 45 percent showed significant responses to N, 56 percent to P and 93 percent to NP and NPK. With NP (responses to which are almost invariably significant) average profits in Eth.$/ha were 179 (teff), 137 (wheat) and 95 (barley). There were 31 places with teff trials, 8 with wheat and 4 with barley so the average profits for the latter two are only indicative (One U.S. $ = 2.5 Eth. $).

The outstanding fact to emerge from the trials is the very extensive area over which NP responses, usually profitable, occur. The results not only confirm the widespread N and P deficiencies forecasted in our studies but also show that these are much more extensive than expected and that profits from NP are frequently high. Since these extensive and profitable returns result from fertilizers alone (i.e. in the absence of improved cultural practices, use of high yielding varieties, etc.) widespread and rapid benefits from NP can be virtually guaranteed. Combined with improved cultural practices, drainage, high-yielding varieties, etc., the benefits will be greater still. In brief the outlook for fertilizer use in Ethiopia is extremely promising. The emphasis in future soil fertility studies at the Institute will be on soil phosphate especially in those areas where outstanding P - responses occur.

Yields and Soil Characteristics

These were confined to yield-clay relationships in view of what has already been said about the adverse effect of the clay soils on yields. Further there was insufficient time and inadequate facilities for nitrogen and phosphate tests on so many soils (over 300).

The clay-yield relationships proved to be very interesting. With teff very significant inverse relationships were found between yields (without and with fertilizers) and the percentage clay in the soil. The inverse relationship was particularly significant with the phosphated plots. With wheat similar inverse relationships were found but the only significant one was with the phosphated plots. The equations are given below:

Teff	Yield (with P)	= 16.1 q/ha	– 0.13% clay ($P<0.001$)
Wheat	Yield (with P)	= 16.8 q/ha	– 0.14% clay ($P<0.001$)

The regressions of the above yields on percentage sand were positive and significant, but less significant than with clay.

It cannot be said yet whether the significant inverse equations with teff are directly due to clay or whether high clay contents are associated with other conditions adverse to teff e.g. high rainfall. It is highly probable however that clay has a direct effect on applied phosphate, significantly reducing its effectiveness through fixation by absorption or through chemical interaction. The yield (with P) – clay relationships are note-worthy as phosphate, singly and in combination is of prime importance to Ethiopian soils. It is evident that phosphatic fertilizers will be most effective on sandy soils. This has been convincingly demonstrated in the FFHC trials where outstanding and very profitable phosphate responses have occurred on sandy soils where in some places the soils were abandoned as no longer worth cultivating. Special attention will be paid to such P – responsive places as regards their extent, the optimal dressings required and soil tests.

APPENDIX

THE FERTILITY STATUS OF ETHIOPIAN SOILS

(Desta Hamito and H.F. Birch)

REGRESSION OF YIELDS Y (q/ha) ON % CLAY (RED AND BLACK SOILS)

TEFF		WHEAT	
RED SOIL	BLACK SOIL	RED SOIL	BLACK SOIL
(70 obs)	(146 obs)	(25 obs)	(83 obs)
Average % clay 34.9 (4.6 – 57.8)	Average % clay 47.9 (10.6 – 74.0)	Average % clay 30.5 (10.6 – 57.8)	Average % clay 42.5 (6.4 – 70.6)
Y = –0.023X + 7.2	Y = –0.009X + 7.8	Y = 0.083X + 8.3	Y = –0.06X + 11.1
Y-N = –0.052X + 11.0	Y+N = –0.033X + 11.9	Y+N = 0.091X + 6.2	Y+N = –0.07X + 13.7
Y+P = –0.055X + 12.1	Y+P = –0.068X + 13.5^{+++}	Y+P = 0.026X + 9.8	Y+P = –0.12X + 16.1^{+++}
Y+NP = –0.057X + 12.8	Y+NP = –0.066X + 16.7^{+}	Y+NP = 0.193X + 6.3^{+}	Y+NP = –0.11X + 18.9^{+}
Y+NPK = –0.075X + 15.0	Y+NPK = –0.041X + 16.4	Y+NPK = 0.142X + 8.6	Y+NPK = –0.13X + 20.9^{++}

+ P = 0.05, ++ P = 0.02 +++ P = 0.01

THE FAO FERTILIZER PROGRAMME IN ETHIOPIA

by

Ato Girma Belaineh*, R. Ryan and D. Sap**

Summary

The FAO Fertilizer Programme was very successful in creating a fast growing demand for fertilizers among small scale farmers. In order to satisfy this demand Pilot Credit Schemes were initiated in 3 places during the 1968/69 season. Participating farmers have found extremely profitable responses to application of chemical fertilizers on important crops as teff and wheat. The expansion of the Pilot Credit Schemes which is presented in the following table was limited by the funds available.

Year	Number of areas	Number of ha fertilized***
1968	3	126
1969	9	573
1970	29	2 650

Besides the Pilot Credit Schemes, fertilizers were sold on cash either through the extension agents or directly from the Fertilizer Programme Main Office. The number of ha involved in this Cash Scheme increased from 27 ha in 1967 to 3 358 ha in 1970. The total number of ha fertilized with fertilizers distributed through the Fertilizer Programme will amount to 6 000 ha in 1970. In addition many commercial farmers purchased large quantities from the private fertilizer companies after they were convinced of the profitability of fertilizer use by seeing the Fertilizer Programme fertilizer demonstrations.

Fertilizer consumption in Ethiopia increased from 3 000 metric tons in 1967 to 11 000 m.t. in 1970. The increase of fertilizer consumption was hampered to a great extent by the lack of an efficient fertilizer distribution system. The follow-up of the FAO Fertilizer Programme by the Ethiopian Government will be decisive for the further expansion of the fertilizer consumption.

1. Background

During centuries of continuous farming with little attention being paid to proper soil management, the majority of Ethiopian soils had reached a state of near complete depletion of basic plant nutrients resulting in poor average yields of important crops in most parts of the country. Besides, little was known about specific nutrient deficiencies of the soils.

The FAO Fertilizer Programme in Ethiopia started its activities in 1967, following a request from the Imperial Ethiopian Government, Ministry of Agriculture. The Fertilizer Programme has been attached to the Extension Department in the Ministry of Agriculture. 100 extension agents and 50 assistants are working part-time for the Programme which is, however, by far their most important occupation. These field level workers are supervised by 11 provincial extension supervisors.

As the use of fertilizers was unknown to Ethiopian farmers, the first objective of the Fertilizer Programme was to demonstrate the use of fertilizers on the farmers

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*** Maximum 2 ha per farmer during his first year of participation and maximum 5 ha per farmer during the following years.

own fields. Besides, it was necessary to conduct trials to find out which fertilizer treatments would be most profitable in order to formulate sound recommendations. For typical Ethiopian crops like teff* and noog** there was even no knowledge available in other countries which fertilizer treatments could be tried out.

2. The Fertilizer Demonstration Programme

The demonstration programme consists of the following main activities:

- conducting of a large number of fertilizer demonstrations;
- training of the field level workers on how to carry out the field demonstrations properly;
- demonstration of the combined use of fertilizers and improved varieties.

The development of the fertilizer demonstration programme is presented in the following table :

Year	No. of dems. planned	No. of crops	Harvest data recovered
1967	522	5	296
1968	987	15	626
1969	1,145	15	656
1970	1,230	19	-***

Each extension agent lays down about 10 fertilizer demonstrations but the final number is subject to his own decision. Before the current agricultural season (1970/71), the extension agents were asked to conduct at least 6 demonstrations on the same crop (preferably the main crop of the area) in order to allow a more reliable statistical analysis of the results.

3. Fertilizer Kinds Used

Although the Ethiopian fertilizer market is very limited, a large number of fertilizer kinds are imported and sold by the private fertilizer companies. The latter sold about 7,800 metric tons of fertilizer in 1969 divided among 25 different fertilizer kinds.

From the beginning the Fertilizer Programme stuck to a limited number of high grade fertilizers, namely urea (46% N), triple superphosphate (46% P_2O_5), and sulphate of potash (50% K_2O). Before the current agricultural season it was decided to switch over to Diammoniumphosphate (18% N + 48% P_2O_5) because:

- DAP is the cheapest source of plant nutrients on the fertilizer market;
- transport and storage costs are minimized due to the high nutrient content;
- fertilizer treatments based on the use of full bags of DAP and urea, e.g. 18-48-0 (100 kg of DAP) and 41-48-0 (100 kg of DAP + 50 kg of urea), have proved to be very profitable when applied on Ethiopian soils.

As most of the Ethiopian soils contain a sufficient amount of available potash, a combined use of N and P_2O_5 will be the most profitable fertilizer treatment in most areas. Certain deficiencies, e.g. sulphur, may appear after a long period of using the same treatment. As the use of sulphate of potash did not show significant responses in most areas, it may be accepted that no sulphur deficiency has to be corrected for the time being.

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* Teff: Eragrostis abyssinica L., is the most important grain crop used for the preparation of typical Ethiopian food called "enjera".

** Noog: Guizotia abyssinica Cass., is the country's principal oil crop.

*** Unknown at time of writing.

4. Demonstration designs

During the first 3-year period of the Fertilizer Programme the demonstration design was mainly aimed at determining which major plant nutrients were lacking in Ethiopian soils to an extent that would make the application of the relevant fertilizers a profitable practice. A demonstration plot (2000 sq.m) consisted of 5 sub-plots (400 sq. m each) with the following applications of N, P_2O_5, and K_2O in the forms of urea, triple superphosphate, and sulphate of potash respectively:

Plot	Small grains, oil seeds	Legumes	Maize, sorghum cotton	Potatoes
a	40- 0- 0	20-0-0	60-0-0	40-46-0
b	0 -46- 0	0-46-0	0-69-0	40-46-37.5
c	0 - 0- 0	0-0-0	0-0-0	0-0-0
d	40-46- 0	20-46-0	60-69-0	80-92-0
e	40-46-37.5	20-46-37.5	60-69-37.5	80-92-75

As the best responses were found to phosphate followed by nitrogen - with a very high interaction of these nutrients - and profitable responses to potash were only found in a limited number of areas, the second phase of the Fertilizer Programme would be aimed at determining the most profitable combinations of N and P_2O_5. Therefore, a new demonstration design was introduced for the current season and will be adopted through another 3-year period. The new design was based on the nutrient content of full 50 kg bags per ha of the fertilizer kinds providing the necessary plant nutrients at the lowest cost per kg. Whenever potash is applied a split-plot design will be used, so that K_2O is applied on only half of each sub-plot. The new design is presented in the following table :

Plot	Small grains, oil seeds, legumes	Sorghum	Cotton, onions, pepper, potatoes	Maize (3 sub-plots)
a	18-48-(50)	18-48-(50)	18-48-50	41-48-50
b	41-48-(50)	41-48-(50)	41-48-50	0-0-0
c	0-0-0	0-0-0	0-0-0	73-72-50
d	27-72-(50)	50-72-(50)	50-72-50	
e	50-72-(50)	73-72-(50)	73-72-50	

5. Demonstration Results

Fertilizer prices paid by Ethiopian farmers are approximately twice as high as those paid by most European farmers for comparative amounts of plant nutrients. In spite of such high prices, caused by the abnormally high transport costs, profits which can be derived from proper fertilization of major Ethiopian crops under most common conditions are very attractive and encouraging for further investigations and fertilizer promotion.

There are, however, big variations in fertilizer responses, even within relatively limited geographical areas. They are partly due to variations in climatic conditions, altitudes, and soil types, and partly to the extension agents' ability to get the demonstrations in the ground at the optimum planting time, a factor of considerable importance in obtaining maximum yields. Because of these different reasons, only average yields to various fertilizer treatments are shown in the following table which concerns demonstrations on wheat during 3 years:

Year	No. of observations	Check	Wheat grain quintals*/ha N	P	NP	NPK
1967/68	181	9.9	12.9	14.0	18.0	18.6
1968/69	155	9.0	12.1	12.9	16.8	17.4
1969/70	154	9.2	12.2	13.2	16.4	17.4

The demonstration results for wheat, teff, and barley were very similar during the first three years of fertilizer trials. This proves that the amount and distribution of rainfall is fairly reliable which facilitates recommendation of profitable fertilizer treatments.

Economic calculations based on crop prices at harvest time - Eth.$30/100 kg of teff, Eth.$20/100 kg of wheat, Eth.$15/100 kg of barley (1) - and on a fertilizer cost of $55/ha (including transport over 200 km) are presented in the following table.

Economics of Fertilizer Use

Year	Yield increase in the NP sub-plot quintals/ha	Net return (2) E.$	Value/Cost ratio (3)
TEFF			
1967	6.34	135.20	3.5
1968	8.12	188.60	4.4
1969	7. 3	164.00	4.0
WHEAT			
1967	8.14	107.80	3.0
1968	7.75	100.00	2.8
1969	7. 2	89.00	2.6
BARLEY			
1967	6.96	49.40	1.9
1968	9.53	87.95	2.6
1969	9. 7	90.50	2.6

Although the number of observations on other crops was too limited to be used for statistical analyses, the available field demonstration results show mostly excellent responses to fertilization.

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* One quintal = 100 kg
(1) Eth.$ = U.S.$0.40
(2) Net return : Value of yield increase - Fertilizer cost.
(3) Value/Cost ratio: Value of yield increase divided by the fertilizer cost (output/input ratio).

6. Special Results

(a) Split and non-split nitrogen applications

During the 1969/70 season in a number of fertilizer demonstrations with teff (69 observations), local wheat (26 observations), and Kenya wheat (25 observations) the sub-plots were split. To one half of the plot all nitrogen was applied at sowing time, and to the other half one third of the nitrogen was applied at sowing time and the balance 4 weeks later.

Statistical analysis showed that the differences in yield between split and non-split application of nitrogen were non-significant. There was little difference between the effects of split and non-split applications regardless of the soil types and yield levels.

(b) Comparison of local and Kenya hybrid maize yields

The average results of 22 fertilizer demonstrations conducted during the 1969/70 season where local and Kenya hybrid maize (1) were compared are presented in the following table:

	Check	N	P	NP	NPK
Difference between local and Kenya hybrid in 100 kg.	12.9	11.0	14.0	17.4	16.3

With and without fertilizers, the Kenya hybrid maize significantly outyields the local varieties by about 14 quintals per ha average. The results also prove the profitability of the combined use of fertilizers and improved varieties.

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(1) The Kenya hybrids used were the H613B above 2000 m and the H632B below 2000 m.

FERTILIZER USE ON MAIZE IN KENYA

by

A.Y. Allan*

Maize is well-known as a crop which is very responsive to fertilizers, and huge and ever-increasing amounts of plant foods are applied to it in such countries as U.S.A., Yugoslavia and Mexico. Kenya has about 2½ million acres of maize, of which over 95% is grown by small-scale farmers for their own food requirements. The other 5% is grown by large-scale farmers, commercially. In the small-scale areas, most of the maize does not receive fertilizers, although increasing numbers of small growers are beginning to use them. In the large-scale areas the use of fertilizers on maize has increased greatly since 1964-65, and some farmers are now using 100 Kg. P_2O_5 and 160 Kg. N per hectare on commercial fields, and even more on seed crops. Although the large-scale growers could, and undoubtedly will, use more fertilizer in future, it is obvious that the greatest scope for expansion is in the small-scale areas.

What are the problems connected with using more fertilizers on maize in the small-scale areas?

Fertilizers have to be bought and paid for with cash, therefore the small farmers have to be able to make money out of using them. Fertilizers applied to a food crop may produce bigger crops, but if the amount surplus to family needs cannot be sold, then the cash to pay for the fertilizer has to come from other sources. Fortunately, in Kenya, maize which is surplus to domestic requirements can be sold for cash, and in fact the Government, under the new Cereals Policy, is actively encouraging small farmers to produce more and more maize so that a larger proportion of the total crop enters the money economy. Therefore favourable economic conditions exist in this country for a great expansion in both maize production and fertilizer consumption in these areas.

Once the small-scale grower starts moving into the cash economy with regard to maize, then he begins to think about costs, returns, and the difference between these, i.e. profit or loss.

Information on costs and returns

Once farmers become interested in profits, costs and returns, then consciously or unconsciously they begin to seek for more and more information on these subjects. Relevant information comes from the farmers' own experiences and those of neighbours, from demonstrations and field trials, and from other sources. In this paper I propose to describe some of the information on fertilizers which has been obtained from the maize agronomy research programme which was started at Kitale in 1963.

The three main lines followed in the fertilizer part of the programme were:-

a) to find out the relative importances of fertilizers and other factors affecting yields, at different levels of these various factors.

b) to determine the fertilizer responses under conditions when other factors were not limiting yields, i.e. the conditions were favourable for obtaining good fertilizer responses.

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c) to determine what factors affect fertilizer responses, i.e. the interactions between fertilizers and other factors.

A. The relative importances of fertilizers and other factors

In order to find out the relative importances of six of the main agronomic factors which affect yields, a series of large multifactorial trials was started in 1966 and continued in 1967. These trials, which were of a 2^6 design, provided a great amount of useful information, but only the most important conclusions can and need be mentioned here.

1. The average yield level in these trials was around 15 bags per acre (33 q/ha), which is 2½ times the estimated Kenya national average yield.

2. At these average yield levels of 15 bags/acre, N. and P. fertilizers were relatively much less important than the other factors investigated, namely time of planting, plant population, genotype of maize and standard of weeding.

3. When these other factors were at their lower levels, fertilizers had even less effect on yields.

4. When these other factors were at their higher levels, then significant responses to N and P were obtained, and fertilizers became relatively much more important.

From these trials it was easy to deduce that the low national average yields would not be improved merely by using more fertilizers. Before fertilizers can have much effect it will be necessary to greatly improve the simple basic cultural practices. (There is, of course, every incentive to adopt the improved cultural practices and fertilizer use simultaneously.)

B. Determining fertilizer responses under good cultural conditions.

In 1968 and 1969 over 100 fertilizer trials were laid down in the Trans Nzoia and Uasin Gishu districts of Western Kenya, and smaller numbers have been conducted by other members of the maize research team at Embu and Kakamega. The objects of these trials were firstly to obtain the physical yield responses to the fertilizers, and secondly to use these physical responses in conjunction with fertilizer costs and maize prices, to work out fertilizer recommendations for various sets of conditions.

Outline of these fertilizer trials

Potash and phosphate were applied in the planting holes at rates which ranged from 0 - 150 Kg/ha of K_2O and 0 - 140 Kg/ha of P_2O_5. N was applied as a topdressing at rates from 0 - 280 Kg/ha of N. The K was applied as sulphate of potash, the P as single superphosphate, while the N was applied as CAN in 1968, and as ASN in 1969. The statistical design was a modified 3 x 3 x 3 factorial in the form of a central composite with 18 treatment combinations, from which the linear, quadratic, and linear x linear responses can be derived.

Results of these trials

To illustrate the type of information which has been obtained from these trials, the results from 2 different areas of the Trans Nzoia will be presented here. In both areas no significant yield responses to K were obtained, and K did not affect lodging. Hence K will not be discussed further here. In the first area, which consists of the heavy dark clays on Mount Elgon and at Endebess, there were very good N responses, but no P effects. In the second area, on the red sandy clays of the Trans Nzoia, there were good responses to both N and P.

1. The N response curves obtained on the clay soils of Mt.Elgon and Endebess for 1968 and 1969 are shown in Figure 1, along with the curve for both years combined. Using this combined response curve, and a maize price of 25/- per 200 lb bag (27/56 per quintal), it is seen that the application of N is profitable up to 167 Kg/ha when N is 2/- per Kg. The fertilizer recommendations for these soils can be taken directly from Figure 1 geometrically, or can be worked out algebraically from the equation for the curve and the relevant N cost and maize price. In Table 1 the recommendations for 3 different N prices with varying amounts of available fertilizer money have been worked out, and the profitabilities of these are indicated. In these trials, under good cultural conditions, the maize yielded 44 q/ha without N, but by using 167 Kg/ha N, yields could be increased by 29 q/ha, i.e. almost 66%.

2. On the sandy clay soils of the Trans Nzoia district, derived from acidic gneisses of the Basement Complex, there were good responses to both N and P, with some interaction between these fertilizers. Hence both fertilizers should be considered together. In Figure 2 the P and N responses are shown simultaneously on an isoquant diagram, from which it can be seen that a given yield can be obtained by using various different combinations of N and P. However, for a specific price of N and P there is one combination of the two which is cheaper than any other, and it will obviously be the most profitable combination. The diagonal line in Figure 2 and in Figure 3 shows the combinations of N and P which are cheapest when N costs 1/80 and P_2O_5 costs 1/30 per Kg., and the maize price is 25/- per bag (27/56 per Q). Table 2 gives details of the N and P combinations which should be used with different amounts of fertilizer money available, and the profitabilities of these rates. On these soils the yields were increased from 38 q/ha without fertiliser to 71 q/ha by using 158 Kg. N and 102 Kg. P_2O_5 per ha.

Putting these recommendations into practice

As soon as these recommendations were worked out, they were handed over to the local extension team, and they are being put into practice by most of the farmers in the relevant areas. In the economic survey of 109 growers carried out in those areas in 1967-68, the average amount of money spent on fertilizers for maize was 101/- per acre; the best individual grower, who averaged 27.4 bags per acre over 300 acres, spent 98/- per acre on maize fertilizers. Since then, the rates being used have gone up on most farms.

Another important plant nutrient - Sulphur

K is usually regarded as the third of the three most important plant foods, but as already stated, no significant K responses were found in these NPK trials in these areas. However, another nutrient which may be in short supply in the soil under certain conditions in Sulphur, and some research has been done on this problem.

Sulphur deficiency must have been affecting maize in various parts of Kenya for many years, but to the best of my knowledge, the first case which was positively diagnosed, treated and cured occurred in my own garden in Kitale in April 1968. After this discovery sulphur deficiency was diagnosed in several fields in Trans Nzoia and Uasin Gishu in 1968 and has been seen again since then, although most farmers in the area are now "sulphur-conscious".

To investigate causes and effects of sulphur deficiency 9 Sulphur trials were laid down in 1969 and are being repeated this year. The aim of the trials was to study the effects of S on yields; S was applied in ordinary commercial fertilizers. The compositions of the fertilizers used are shown in Table 3, and the details of the amounts and combinations applied, and the times of application are shown in Table 4. The yields from each treatment in every trial are shown in Table 5 and these results are condensed in Table 6 to show the effects of S more clearly. In some of the trials S had no effect, but in others, particularly at Kiminini and Hulme, the S had a very large effect on yield. The

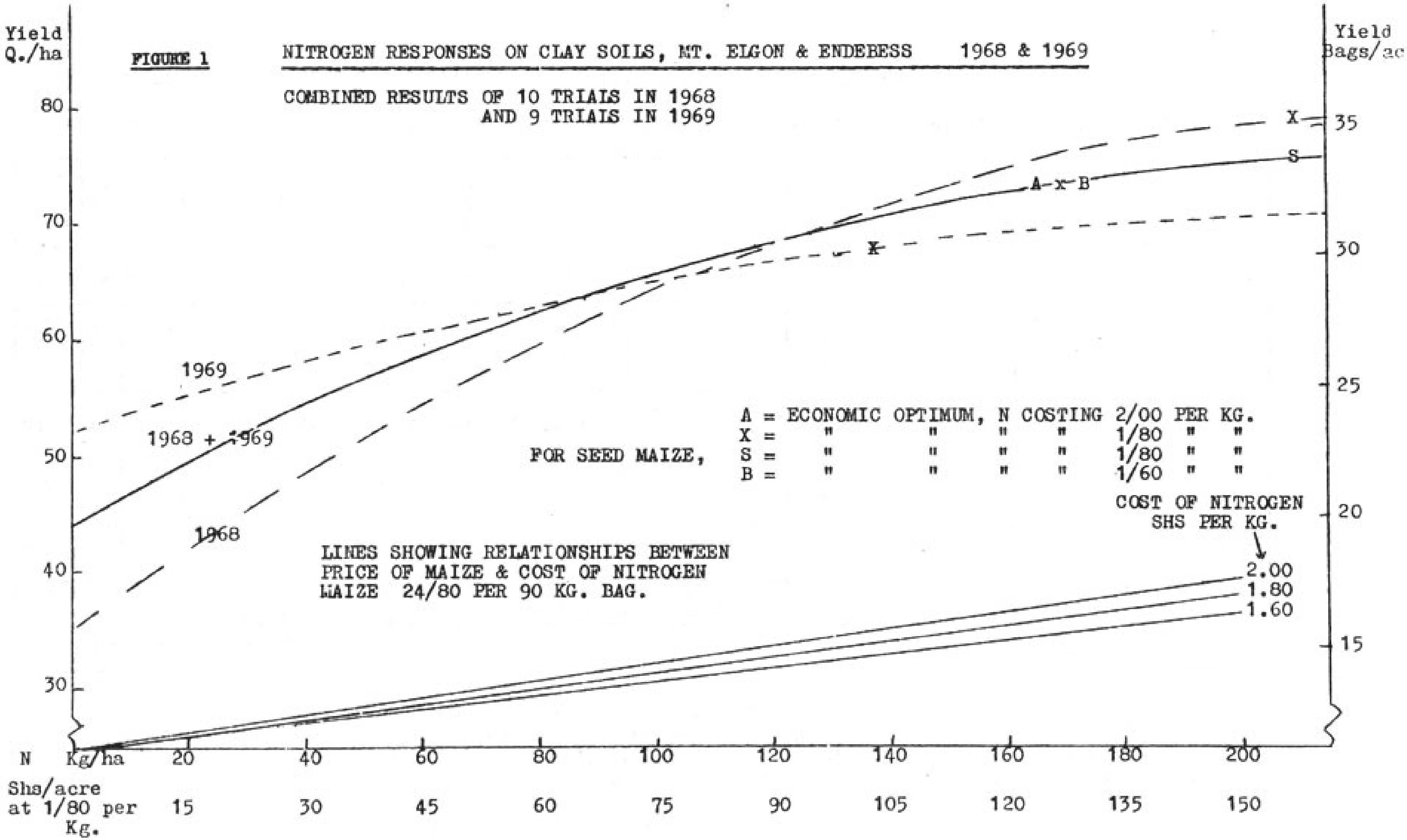

Yield Q./ha
FIGURE 1
NITROGEN RESPONSES ON CLAY SOILS, MT. ELGON & ENDEBESS 1968 & 1969
Yield Bags/ac
COMBINED RESULTS OF 10 TRIALS IN 1968 AND 9 TRIALS IN 1969
80
70
60
50
40
30
35
30
25
20
15
X
S
A-x-B
X
1969
1968 + 1969
1968
A = ECONOMIC OPTIMUM, N COSTING 2/00 PER KG.
X = " " " " 1/80 " "
FOR SEED MAIZE, S = " " " " 1/80 " "
B = " " " " 1/60 " "
COST OF NITROGEN SHS PER KG.
LINES SHOWING RELATIONSHIPS BETWEEN PRICE OF MAIZE & COST OF NITROGEN MAIZE 24/80 PER 90 KG. BAG.
2.00
1.80
1.60
N Kg/ha
20
40
60
80
100
120
140
160
180
200
Shs/acre at 1/80 per Kg.
15
30
45
60
75
90
105
120
135
150

Table 1. FERTILIZER RECOMMENDATIONS FOR CLAY SOILS, ON OR NEAR MT.ELGON, TRANS NZOIA DISTRICT, W.KENYA WHEN N COSTS 1/60, 1/80 or 2/- per KG.

N.B. There were no significant phosphate responses on these soils and therefore it is recommended that phosphate be applied at rates adequate to replace the phosphate removed in the crop. Suggested rates are 20 Kg/ha P_2O_5 where the expected yield is below 40 q/ha, and up to 40 Kg/ha P_2O_5 at higher yield levels. Phosphate costs are not included in the following table; the phosphate cost is regarded as an "overhead" cost here.

a) N costs 1/60 per Kg. (72 cents per lb.)

Money available for Nitrogen Shs.		Kgs. N per ha recommended	Predicted yield increase q/ha	Increase in gross return - Shillings		Increased profit from nitrogen usage - Shs.		% Profit from nitrogen usage
Per acre	Per ha			Per acre	Per ha	Per acre	Per ha	
50	124	78	17	190	470	140	346	280
100	247	155	27	302	747	202	500	202
E.O. 116	286	179	29	325	802	209	516	180

b) Nitrogen costs 1/80 per Kg. (82 cents per lb.)

50	124	69	15	168	415	118	291	236
100	247	138	26	291	719	191	472	191
E.O. 126	311	173	29	325	802	199	491	158

c) Nitrogen costs 2/- per Kg. (91 cents per lb.)

50	124	62	14	157	387	107	263	214
100	247	124	24	269	664	169	417	169
E.O. 135	334	167	28	313	774	178	440	132

E.O. = Economic optimum, at which maximum total profit is obtained, and beyond which profits decrease.

Maize price is 27/56 per Quintal (100 Kgs.) = 24/80 per 90 Kg. bag = 25/- per 200 lb. bag.

Figure 2. ISOQUANTS FOR N AND P RESPONSES - 35 TRIALS ON SANDY CLAYS, TRANS NZOIA. 1968 - 69

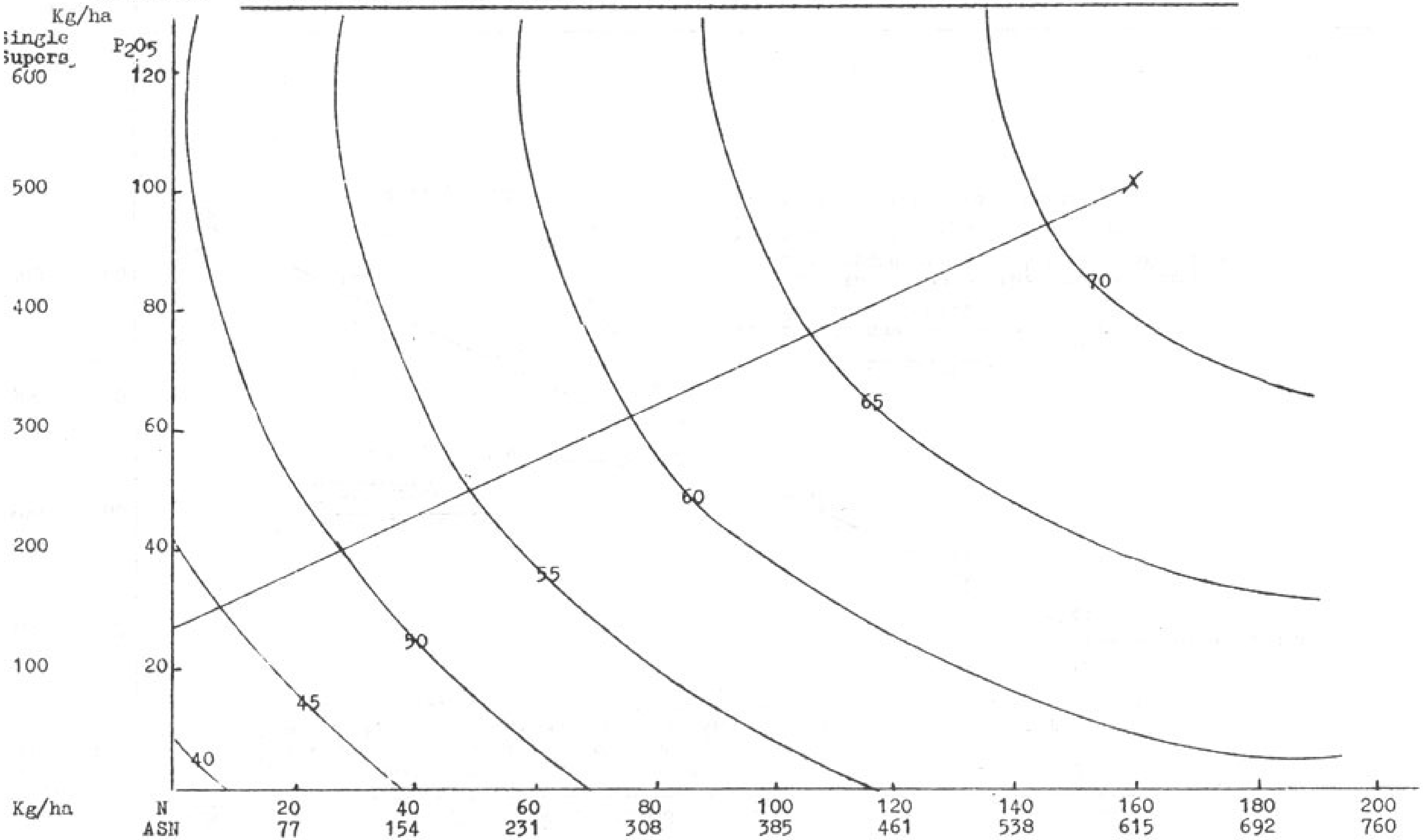


FIGURE 3 . FERTILIZER RECOMMENDATIONS FOR SANDY CLAYS, TRANS NZOIA, W. KENYA

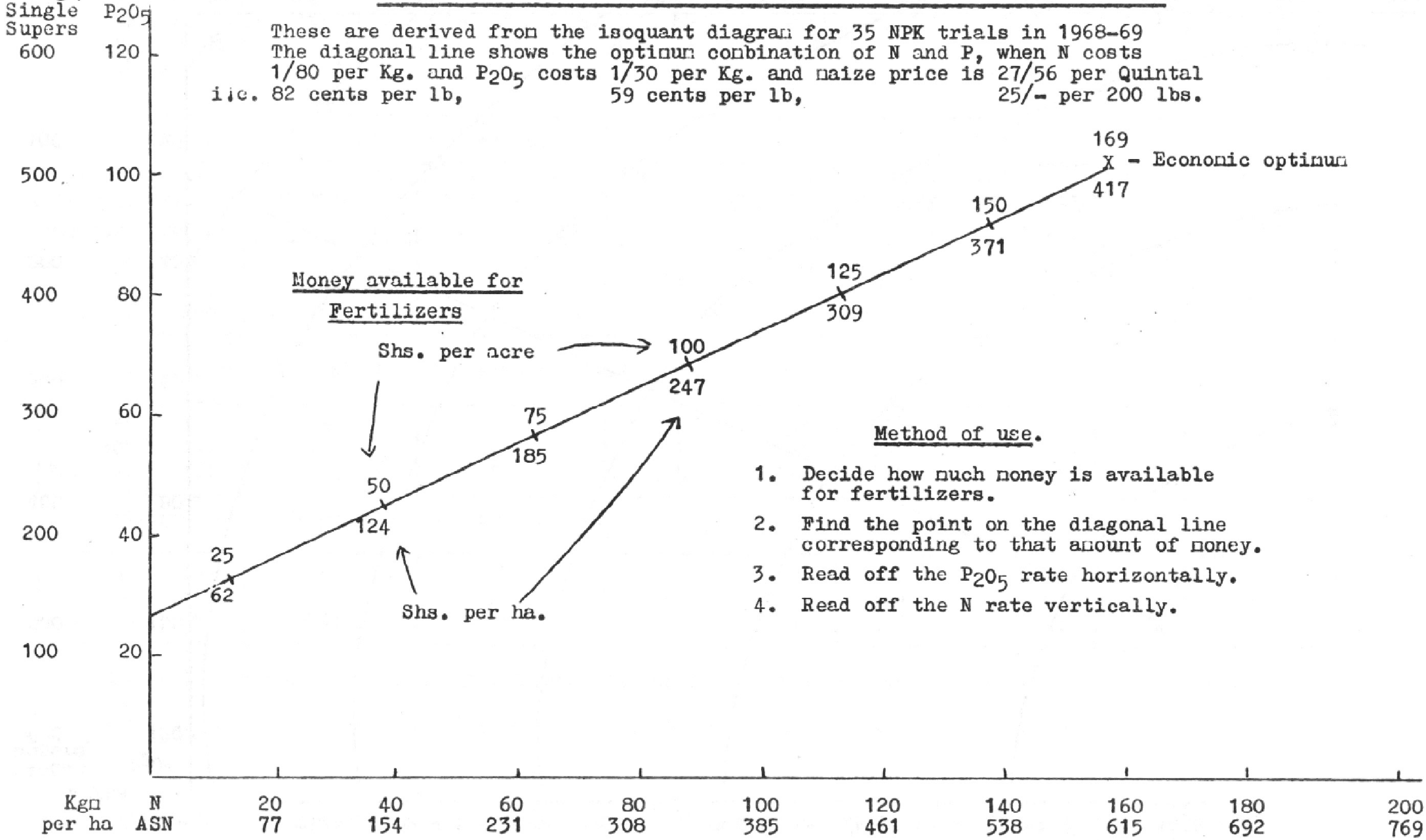


Table 2. FERTILIZER RECOMMENDATIONS FOR SANDY CLAYS, TRANS NZOIA, W. KENYA

These are derived from the results of 35 NPK trials in 1968-69
The economic results are based on the following:-

N costs 1/80 per Kg; P_2O_5 costs 1/30 per Kg; maize price is 27/56 per Quintal
i.e. 82 cents per lb; 59 cents per lb; 25/- per 200 lbs.

Money available for fertilizers Shgs.		Fertilizers recommended Kgms. per ha.		Predicted yield increase q/ha	Increase in gross return - Shgs.		Increased profit from fertilizers Shgs.		% Profit from use of fertilizers
Per acre	Per ha	N	P_2O_5		Per acre	Per ha	Per acre	Per ha	
25	62	13	34	8	89	221	64	159	256
50	124	38	45	14	156	387	106	263	212
75	185	63	57	19	213	526	138	341	184
100	247	88	69	24	269	664	169	417	169
125	309	113	81	28	313	774	188	465	150
150	371	138	93	31	347	857	197	486	131
169	417	158	102	33	370	913	201	496	119

biggest effects occurred on grassland which had been ploughed late, so that there was not enough time before maize planting for the organic matter to rot down much. Such conditions pertained at Kiminini, Hulme and Long. When N and P fertilizers without S were used at these sites, acute S deficiency symptoms were seen on the growing plants, and at harvest the grain was a dull, creamy-white colour and was smaller in size with a higher proportion of rotten pips.

Farmers can easily avoid sulphur deficiency by:-

a) ploughing grassland early, well before planting, and

b) applying at least 25 Kg/ha of S in their other fertilisers, preferably at planting.

C. Factors which affect fertilizer responses

In the previous section, the responses to fertilizers obtained under good cultural conditions were described. However, farmers very often fail to provide the optimum cultural conditions for their crops, and therefore it is important to have information on how sub-optimal conditions affect fertilizer responses. In other words, a knowledge of the importance and the magnitude of the interactions between fertilizers and other factors affecting yields is essential for efficient fertilizer use. In our experimental programme, several of the most important interactions have been studied, and some examples of these will be described.

1. Time of planting

It is fairly well known that late planting reduces maize yields drastically, but it may be less well known that late planting also reduces fertilizer responses, particularly responses to N. This effect is shown in Table 7, from which it is quite easy to see that there are some conditions under which farmers should definitely not use N!

2. Plant Population

As the fertility level and nutrient supplying power of the soil is raised by the application of fertilizers, the population level must also be raised to take full advantage of the higher fertility. Figure 4 shows the yield isoquants for N and P responses in a trial where there were 2 populations, the first being half the recommended number of plants, and the second being correct. The figure clearly shows that about 50% more increase in yield was obtained from the same amounts of fertilizer when the population was correct. The extra cost of obtaining the correct population is only a few shillings, and some extra care and attention at planting; the extra return is very considerable.

3. Improved types of maize

The breeding programme has very successfully produced hybrids with much higher yield potentials than the former farmers' varieties. Not only do they have a higher yield potential, but they can also utilise fertilizers more efficiently. For example, in 5 District Husbandry Trials in 1967, it was found that 80 Kg. N/ha increased the yields of a local variety by 8.3 q/ha whereas the same amount of N increased the yields of hybrid 613B by 10.1 q/ha

4. Complex interactions

As well as the simple interactions described above, there are complex interactions between fertilizers and the other factors affecting yields. In the same 5 District

Table 3. Nitrogen, phosphate and sulphur contents of fertilizers used

Code	Fertilizer	% N	% P_2O_5	% S
D.S.	Double superphosphate	-	40	*
S.S.	Single superphosphate	-	20	12
D.A.P.	Diammonium phosphate	18	48	*
U.	Urea	46	-	-
C.A.N.	Calcium ammonium nitrate	26	-	-
A.S.N.	Ammonium sulphate nitrate	26	-	12

Note:- * = very small, negligible amount of sulphur

Table 4. **Rates and Combinations of N, P, and S per Hectare**

Treatment Code No.	Kgms. of pure Nutrient applied per ha.					Kgms. per ha. of fertilizer					
	Seedbed S	Topdressed S	Total S	P_2O_5	N	At planting			Topdressed		
						DS	SS	DAP	U	CAN	ASN
01	0	0	0	0.0	0.0	0	0	0	0	0	0
02	0	0	0	70.7	141.4	177	0	0	307	0	0
03	0	0	0	70.7	141.4	177	0	0	0	544	0
04	0	0	0	70.7	141.4	0	0	147	251	0	0
05	0	0	0	70.7	141.4	0	0	147	0	442	0
06	42	0	42	70.7	141.4	0	354	0	307	0	0
07	42	0	42	70.7	141.4	0	354	0	0	544	0
08	0	42	42	70.7	141.4	177	0	0	0	190	354
09	0	42	42	70.7	141.4	0	0	147	0	88	354
10	21	21	42	70.7	141.4	89	177	0	0	367	177
11	42	42	84	70.7	141.4	0	354	0	0	190	354

Notes

D.S. = Double superphosphate
S.S. = Single superphosphate
D.A.P. = Diammonium phosphate
U. = Urea

Table 5. SULPHUR TRIALS - TRANS NZOIA 1969

Yields - Q/Ha. (2.24 q/ha = 1 bag of 200 lbs/acre)

All treatments, except control, received 70 kg. P_2O_5 + 141 kg. N per ha. (1.12 kg/ha = 1 lb/acre)
Treatments 2 - 5 received no Sulphur
Treatments 6 - 10 received 42 kg. Sulphur/ha
Treatment 11 received 84 kg. Sulphur/ha

SULPHUR TREATMENT	TYPES OF FERTILIZER	LOCATIONS									
		STRONG	SABWANI	RUSSELL	LONG	HULME	LEYS	DAVIDSON	KIMININI	COX	AVERAGE
1. Control	0	81.2	18.0	37.2	45.8	27.4	33.7	27.4	20.9	38.6	36.7
2. No S	DS+U	78.8	79.0	40.0	63.3	41.9	58.4	41.8	38.2	60.6	55.8
3. " "	DS+CAN	79.3	88.4	34.5	66.3	36.6	63.2	28.0	35.0	49.1	53.4
4. " "	DAP+U	87.8	74.7	40.1	56.5	35.9	63.3	40.8	30.3	60.9	54.5
5. " "	DAP+CAN	89.8	78.8	41.6	57.3	34.1	59.8	31.0	23.2	51.4	51.9
6. S in	SS+U	80.0	76.7	42.2	66.7	55.0	62.1	42.8	58.8	64.2	60.9
7. Seedbed	SS+CAN	83.9	78.3	34.6	55.9	48.0	63.5	46.4	54.3	48.8	57.1
8. S top-	DS+CAN+ASN	79.3	77.2	38.2	72.2	57.7	68.8	40.2	63.4	57.4	61.6
9. dressed	DAP+CAN+ASN	86.7	76.8	38.9	66.6	49.3	66.4	52.8	52.4	49.9	60.0
10. S in bed & top-dr.	DS+SS+CAN+ASN	86.6	85.7	42.4	76.3	51.9	59.7	49.0	63.8	39.2	61.6
11. Double S	SS+CAN+ASN	83.9	87.0	40.6	68.3	52.0	74.6	51.0	57.0	55.4	63.3
Averages		83.4	74.6	39.1	63.2	44.5	61.2	41.0	45.2	52.3	56.1
L.S.D. 5%		6.7	12.2	11.4	24.0	13.9	13.0	19.2	14.8	17.0	5.5
C.V.%		4.0	8.2	14.6	19.0	15.6	10.6	23.4	16.4	16.3	14.9
F		-	xxx	-	-	x	xx	-	xx	-	xxx

Table 6.

SULPHUR TRIALS - TRANS NZOIA 1969

YIELDS IN QUINTALS/HECTARE

TREATMENT	LOCATIONS									OVERALL MEANS
	STRONG	SABWANI	RUSSELL	NAI FARM	HULME	LEYS	DAVIDSON	KIMININI	COX	
1. NO FERTILIZER	81.2	18.0	37.2	45.8	27.4	33.7	27.4	20.9	38.6	36.7
2. NO SULPHUR 70 kg. P_2O_5 + 141 kg. N/ha	83.9	80.2	39.1	60.9	37.1	61.2	35.4	31.7	55.5	53.9
3. 42 KG SULPHUR + 70 kg P_2O_5 + 141 kg. N/ha	83.3	78.9	39.3	67.5	52.4	64.1	46.2	58.5	51.9	60.8
4. 84 KG SULPHUR + 70 kg P_2O_5 + 141 kg. N/ha	83.9	87.0	40.6	68.3	52.0	74.6	51.0	57.0	55.4	63.3
SIGNIFICANCE	-	xxx	-	-	x	xx	-	xx	-	xxx

Notes. A Treatment 1 is averaged over 2 plots at each location
2 " " " 8 " " " "
3 " " " 10 " " " "
4 " " " 2 " " " "

Therefore the comparisons between 2 & 3 are most accurate.

B The most severe S deficiency symptoms were seen at Kiminini, Nai Farm & Hulme.

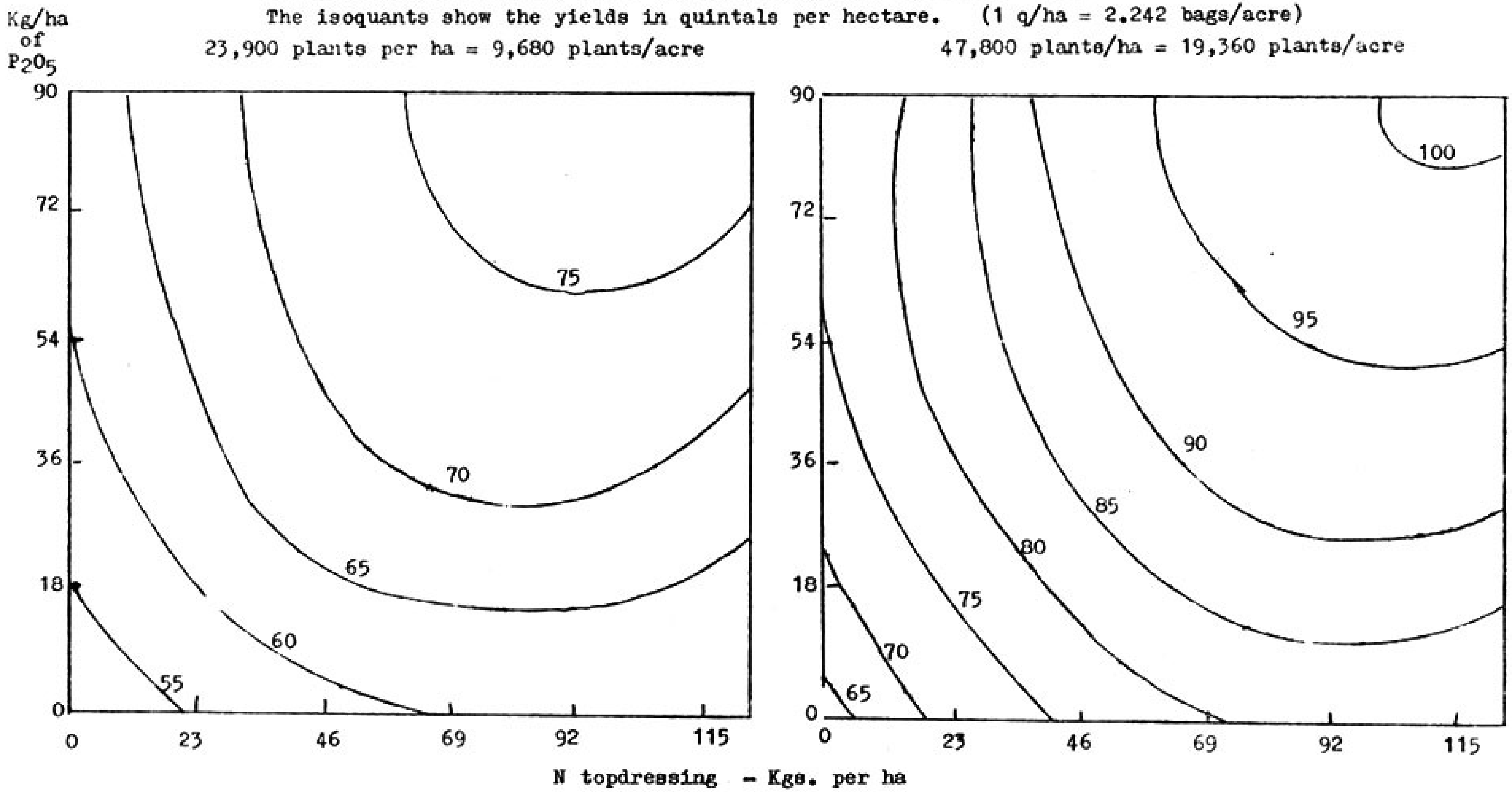
Table 7. Time of Planting Effect

Year	No. of Trials	Time of Planting	Yield increase from 160 Kg/ha N topdressing Q/ha	Return (shs) from N N costs 1/80 per Kg Maize price 27/56 per Q	
				Per acre	per ha
1965	2	Start of rains	15.7	+ 59	+ 145
		3 weeks later	8.3	- 24	- 59
		6 weeks later	-	- 116	- 288
		9 weeks later	-	- 116	- 288
1966	4	Start of rains	24.4	+ 156	+ 384
		3 weeks later	13.3	+ 32	+ 79
		6 weeks later	0.9	- 107	- 263
		9 weeks later	1.3	- 102	- 252
1967	2	Start of rains	33.6	+ 258	+ 638
		4 weeks later	22.4	+ 133	+ 329
1968	2	Start of rains	26.2	+ 176	+ 434
		3 weeks later	17.0	+ 73	+ 181
		6 weeks later	5.6	- 54	- 134
		9 weeks later	2.0	- 94	- 233
1968	4	Start of rains	31.8	+ 238	+ 588
		3 weeks later	15.5	+ 56	+ 139
		6 weeks later	4.5	- 66	- 164

Figure No. 4. The Effect of different plant populations on responses to N and P fertilizers

DISTRICT CULTURAL TRIAL, FIELD 16, N.A.R.S., KITALE, KENYA. 1966

The isoquants show the yields in quintals per hectare. (1 q/ha = 2.242 bags/acre)



Husbandry Trials in 1967, there is a good example of such interactions, as shown in the table below.

Complex Interactions between fertilizers and other factors - Q/ha

	Without fertilizers	With fertilizers	Differences
BH + LF	20.9	26.0	5.1
GH + Hy	74.7	90.8	16.1
Differences	53.8	64.8	

<u>Notes.</u> GH = Early planting + good population + clean weeding.

BH = Planting 4 weeks late + low population + poor weeding.

LF = Local farmers' maize.

Hy = Hybrid 613B.

Fertilizers = 56 Kg. P_2O_5+ 80 Kg. N per ha.

In these trials the response to the fertilizers was three times greater when it was used under good cultural conditions along with hybrid seed.

Conclusion

There are many reasons for believing that the next few years will see a major revolution in maize growing in the small-scale farming areas of Kenya, and that fertilizers will play a very important part in this development. Small-scale farmers have planted 50% more hybrid seed in 1970 than they did in 1969 - the acreage in small farming areas is now 250,000 acres. Enough hybrid seed is being produced this year to plant 400 - 500,000 acres in 1971, and again the greater part of that will go to the small-scale areas. As they see the high yields which can be obtained by combining fertilizers, hybrid seed and good cultural practices, these small farmers will buy more and more fertilizers to go along with these other inputs.

We on the research side can give very good varietal recommendations and good advice on many of the cultural aspects such as plant populations, time of planting, weeding and insect control. However, we are able to give detailed and accurate fertilizer recommendations for only a few of the main maize growing areas. It is imperative therefore that efforts are made to expand the maize fertilizer research work into those areas which are not adequately covered at present.

RESPONSE OF CROPS TO FERTILIZERS ON FARMERS FIELDS AND RESEARCH STATIONS

by

S.N. Muturi*

Of the major farming enterprises in Kenya, investigations into fertilizer use have been carried out for a number of years. Those related to pyrethrum, wheat, pastures and pineapples are reviewed in this paper. It is our experience in Kenya that the maximum benefits from fertilizer application can only be obtained if the other conditions such as the genotype, cultural husbandry and the weather are at their optimum.

PYRETHRUM

Pyrethrum, (Chrysanthemum cinerariaefolium Vis.) is a daisy-like perennial producing a quantity of white flowers. The commercial values of the crop lies in the insecticidal properties of the pyrethrins contained in the achenes.

The first experiments in Kenya included phosphates, lime and mulch. Owing to the shortage of superphosphate during the second world war, the little superphosphate that was available was mixed with Uganda Rock Phosphate at a ratio of 1:4½. Results were rather disappointing and it became evident that only water soluble phosphate were beneficial to the crop.

Later trials showed that phosphorus was almost a necessity especially since superphosphates were more available at the end of the second world war. Trials at Kinangop, Kipkabus, Ainabkoi and Londiani lasting two seasons showed significant yield increase to triple superphosphate (Table 1).

Table 1. Effect of superphosphate on pyrethrum flower yield at 4 locations

Fertilizer	Yield (Kg/ha.)
Control	649
330 Kg/ha Triple Supers.	890

Various types of fertilizers were later tried to find out whether basic fertilizers of slower action such as basic slag produced a more pronounced lasting effect than superphosphates. There was no prolonged effect of basic fertilizers over the phosphates (Table 2).

In Kenya and other countries where pyrethrum has been grown at one time or another (England, France, Japan and India) response to phosphate is only obtained in the first year. This is generally attributed to phosphate fixation by the soil.

* Ministry of Agriculture, Nairobi.

Table 2. Effect of various phosphatic fertilizers on pyrethrum flower yield (Kg/ha.)

Marindas	(3 seasons)
Control	2120
220 Kg Triple Supers	3106
495 Kg Basic slag	3024
495 Kg Kenaf	2860
Ol Joro Orok	(3 seasons)
Control	789
220 Kg. Triple Supers	1460
550 Kg. Basic slag	1114

Further studies were undertaken to determine the effect of increasing the amount of phosphate. Application was based on the quantity of P_2O_5, a linear comparison of 0, 165, 330 and 495 Kg/ha triple superphosphate.

Table 3. Effect of increasing amounts of triple superphosphate on pyrethrum flower yields (Kg/ha)

Rate of Triple Supers	Rate of P_2O_5	Yield
KINANGOP	(2 Seasons)	
0	0	711
165	67	810
330	134	1012
495	201	1124
MARINDAS	(2 Seasons)	
0	0	1161
165	67	1529
330	134	1546
495	201	1476

The soil at Kinangop was poor, grey-orangey in colour, a transition from forest soil to Vlei. In this case, a heavy dose of 495 Kg. triple supers proved superior. At Marindas, however, with a good loamy soil a dosage of 165 Kg triple supers proved adequate.

It is therefore advisable, unless soil conditions demand more, to restrict the dose to 165-220 Kg triple supers (67-95 Kg P_2O_5) per ha. On deep, well drained soils deficient in P about 20-30% increase in flower yield could be expected. If the planting material used has high yield potential, and the standard of husbandry is high, then economic returns are feasible.

Other Elements

Potash: At the rates of 55 and 165 Kg/ha Muriate of potash repeated every season, K produced no response at Marindas for 3 years. At Molo and T/Falls there were decreases in yield (not significant) through K applications, though the soils showed deficiency in K.

Nitrogen: Pyrethrum has never responded to N applications over numerous trials carried out to date. In some cases decreases (not significant) have been recorded. The tendency is that too much N causes too much vegetativeness and too little flower production.

Calcium: Response has only been obtained at high doses (1000 Kg/ha) lime on heavily leached soils.

Minor elements: No response has ever been obtained to Mo, Zn, Mg or Cu even in soils showing severe deficiencies in these elements.

WHEAT

An extensive fertilizer programme on wheat was carried out by Holme and Sherwood between 1950 and 1954. They found that generally there was far greater response to phosphate than to nitrogen fertilizer. A summary of their work is published in "The Fertilizer requirement of the Kenya Highlands, Colonial Research Study No.12, H.M.S.O. London".

In 1967 investigations were started on the influence of N, P, K and lime on yield at 30 locations evenly distributed over the wheat growing areas. The trial sites covered varied rainfall patterns, altitudes and soil types. The levels of fertilizer used ranged as follows (Kg/ha).

N : 0-80, P_2O_5 : 0-125, K_2O : 0-80 and $CaCo_3$: 0-1000.

In 1968 the trial was modified to 3^2 NxP factorial within the range N : 0-40 and P_2O_5 : 0-80 Kg/ha. This trial was planted at 28 locations.

In 1969 the basic 3^2 NxP factorial trial was retained but a tenth treatment which included N, P and K at 40,80,80 Kg/ha respectively was added. The trial was planted at 19 locations. During the course of the trial information was collected on cropping history, soil type, altitude and rainfall. Soil samples were also collected and analysed at the National Agricultural Laboratories at Nairobi.

From these trials the following conclusions can be drawn:

Potash:

Although past experience of effect of potash has not been encouraging, potash was included in these trials to obtain a comprehensive foundation for future experimentation. None of the 1967 trials showed a response to application of potash alone. Nonetheless there were five sites, all from young forest soils under heavy rainfall regime, where potash significantly increased yields. The increase was at high levels of K_2O (80 Kg/ha) and also at high levels of N and P.

Lime:

The effect of lime has been a subject of investigation by many workers in the past. Their results generally suggested that beneficial effects may only be realised after repeated heavy dressings. In the 1967 trials, rates of 1000 Kg/ha agricultural lime did not produce any significant effect on either soil pH or grain yield. Future trials will therefore be conducted on long term basis, on areas where response is most likely.

Phosphate:

As expected, phosphate has proved to be the only effective plant nutrient in wheat. Significant yield increases due to the application of phosphate were obtained on nearly half the number of sites for three years. Highest effect of phosphate was common on fields where wheat was planted on the first, second or third year after grass. Response tended to fall off the more the land was repeatedly cultivated. With good management standards economic yields could be obtained to phosphate dressings of up to 80-100 Kg/ha P_2O_5 with 100 Kg/ha more or less as the upper turning point. On land which is continuously cropped, a maintenance of 40-60 Kg/ha is recommended.

In all cases attempts were made to correlate soil test data with response to P. Soil data has been of little value in this aspect except in extreme cases where it is possible to predict response based on soil status. No other factor seemed to correlate with response to P better than the cropping history during the 3 year trial period.

Nitrogen:

Response to N was also very closely correlated with the cropping history than any other factor. In land which is ploughed in time after grass there is adequate supply of nitrogen resulting from mineralisation of organic matter. Such effect may last into the second year of cropping. In cases where land is hastily prepared, a starter dose of 10-20 Kg/ha is worth while.

Generally, there was economic response to N on land which had been continuously cropped for three or more years.

Trials on top-dressing with N have not been very encouraging. Trials involving top-dressing in the form of broadcasting and foliar sprays at the time of herbicide application have not resulted in yield increases and in some cases there have been depression of yield.

Minor Elements

A limited amount of work has been done on the question of minor elements. So far rewarding results have been realised on aspects of copper deficiency. In the early fifties it was realised that although Njoro soils were deficient in phosphate, the use of P aggravated the deficiency of some other nutrient, the degree of severity increasing with the amount of P applied. The deficient nutrient was later found to be copper.

During 1968 and 1969 trials were laid on farmers fields in the Cu-defficient areas to determine the most effective methods and the optimum rates of copper application.

It was generally found that there was no significant response to Copper in fields which had been cropped to wheat with copper application in the previous 2 years. However, significant response was obtained in fields planted to wheat in the first year after grass. In one particular site in the Menengai area, the application of Copper increased yields ten-fold.

The current recommendation is to apply 1 Kg/ha 50% Copper oxychloride as seed-dressing, followed by 1 Kg/ha foliar spray at the time of herbicide application. As copper deficiency symptoms can occur at any time during the life-cycle of the crop, the first application as seed-dressing ensures that the crop has adequate amounts of copper to last up to the time the second dose is applied together with the herbicide.

Generally, it is obvious by the standards of other tropical or sub-tropical countries which have had experience with wheat, that the sort of response obtained with wheat in Kenya is extraordinarily low. It is probable that when higher yielding varieties are introduced, greater responses will be obtained.

PASTURES

The pasture research project in Kenya aims at, among other things, ways of obtaining leys with high dry-matter yields of high nutritive value. A fertilizer programme to find out whether fertilizer application can raise the two traits is currently under way and some of the findings for the medium and high altitudes are summarised here.

Phosphate:

Phosphate is recognised as one of the most limiting soil nutrients in pasture plants of Kenya. It is needed for the establishment of grasses in most areas and improves their nutritive value and yields. The optimum rates depend on the locality, soil reaction and rainfall following application. Generally, the lower the pH, the greater the response to P_2O_5. Responses are therefore greater at higher altitudes than at medium altitudes.

For high altitudes a basal dressing of 130-195 Kg/ha P_2O_5 followed by 65 Kg/ha annual top-dressing is recommended. For medium altitudes, the optimum rate does not exceed 60 Kg/ha P_2O_5 per annum.

Nitrogen:

Added nitrogenous fertilizer leads to a greater response to phosphatic fertilizer by pasture plants. Sown grass as well as natural grasslands in the medium and high altitudes respond to nitrogen in terms of dry matter yield. Nitrogen application, however, does not appreciately increase the crude protein content (C.P.). The table below indicates response to nitrogen obtained at Kitale with Nandi Setaria for 8 cuts in the 1968/69 season.

Treatment	D.M. Kg/ha	N Kg/ha	% C.P.
0 Kg N/ha	6302	110.6	11.0
99 "	8754	160.6	11.5
197 "	10577	198.8	11.8
296	13597	260.9	12.0

Owing to the high price of nitrogenous fertilizers, more interest is increasingly being focused on the role of legumes. The table below shows the effect of various

Setaria/legume mixtures at Kitale during the 1968/69 season.

Setaria mixed with	D.M. Kg/ha	N Kg/ha	% C.P.
Setaria alone	6302	110.6	11.0
Kenya white clover	10904	287.0	16.5
Desmodium uncinatum	11502	349.4	19.0
D. intortum	14708	465.4	19.8

It is evident from the above table that legumes increase both the yield and quality of the herbage. The presence of the legumes also resulted in build up of the soil fertility that benefitted the subsequent crop.

Other Elements:

No responses have been found for potash except for Pennisetum purpurem (Napier grass) receiving high rates of N. Only transitory responses to lime and Molybdenum have been found for lucerne (Medicago sativa) at high altitudes.

PINEAPPLES

Pineapples (Ananas comosus L.)have assumed great economic importance in Kenya as a canned crop. Canned pineapples are grown between the altitudes of 1370 and 1740 metres. Below this range the fruit becomes too sweet and above this altitude the fruit becomes too acid, both aspects being unsuitable for canning. The cycle from planting to replanting lasts for about four years.

Investigations into fertilizer use in pineapples have been carried out for sometime and the major findings are summarised below:

Nitrogen:

The pineapple needs large amounts of nitrogen to increase fruit weight, size and weight and its use has become standard practice with most large scale growers. It has been shown that almost two tons of Sulphate of Ammonia per hectare are needed during the first 3 years of the cycle. The optimum rate for this fertilizer is about 460 Kg/ha N for the plant crop followed by 120 Kg/ha N for the ratoons. There is no difference whether N is applied in the form of Sulphate of Ammonia, Ammonium Sulphate Nitrate or Calcium Ammonium Nitrate.

Studies on the use of foliar sprays of nitrogen in the form of Urea showed that it was as efficient as soil applied Sulphate of ammonia. Urea concentrations higher than 5% are harmful when applied during the dry season. Present recommendations for urea are monthly applications of 86 Kg/ha in a convenient volume of water but the solution must be below 5%. This should be done for 10 months beginning from the 4th month after planting. The ratoon should receive 8 monthly applications at the rate of 50 Kg/ha. Foliar sprays can conveniently be applied with pesticides.

Phosphate and Potassium:

In trials conducted in Kenya there has seldom been any response to either P or K, although most Kenya soils where these trials have been carried out have shown severe deficiencies in both elements. No interaction between N, P and K have been deserved.

Minor Elements:

Minor elements, especially iron and zinc, have been found to be necessary for pineapples in Kenya. Iron applied in chelated form and in combination with N gave significant increase in yield and individual fruit weight. Iron and Magnesium sprays did not produce significant increase in yield but Mg sprays significantly increased the mean fruit weight. Copper has been found to have a depressing effect on yield.

THE FAO FERTILIZER PROGRAMME IN KENYA

by

A.J. Okalo* and K. Zschernitz**

Summary

The FAO Fertilizer Programme started working in Kenya in September 1968. Since then 500 demonstrations have been laid out in the planting season 1969 and 1200 demonstrations in 1970. Results of planting season 1969 were summarized and they are contained in this report. Inspite of drought conditions in most parts of Kenya in 1969 very good fertilizer response was reported, especially from maize and groundnut demonstrations. NPK trials conducted on groundnut, beans and soya beans gave first information on the fertilization of this crop. They have been repeated in 1970 to confirm the information obtained in 1969.

To improve the distribution of fertilizers and seed a Pilot Scheme for Fertilizer and Seed Distribution was started in Vihiga Division of Kakamega District. This is one of the most densely populated divisions in Kenya. Farms are very small so that the highest yield has to be obtained from the small acreage. Good cultivation methods, seeds and fertilizers can increase maize yields from 6 to 8 bags per acre to 25-30 bags. The scheme became operational in January 1970.

a. INTRODUCTION

The Republic of Kenya joined the FAO Fertilizer Programme in 1968 with the aim to increase agricultural production in the small scale farming areas. Demonstrations carried out in the Fertilizer Programme on farmers' fields are a package of good crop husbandry methods, improved seeds, insecticides and two different fertilizer treatments. By including all these factors in one demonstration the effect on the farming population is very high. In small scale farming areas average maize yields are still between 5-6 bags of 200 lb per acre. Maximum yield in some of the demonstrations carried out under the FAO Programme gave more than 30 bags per acre. That shows the wide range of improvement that is possible in Kenya's agriculture. Many small scale farmers in Kenya have accepted already modern methods of farming. But in some areas inputs like fertilizers, improved seed and insecticides are not easy to buy. Depots of the large fertilizer firms can be found only in the bigger towns and market places. The distribution of inputs has to be improved in many districts of Kenya if the production targets in agriculture are to be reached.

Under the FAO Fertilizer Programme Pilot Schemes of Fertilizer Distribution have been initiated to improve the supply of fertilizer. Another problem which has to be solved is the availability of production credits to small scale farmers. Up to now all efforts in this direction have failed for several reasons. In phase three of the Fertilizer Programme credit schemes for small scale farmers will be started.

b. ACTIVITIES OF THE FERTILIZER PROGRAMME IN KENYA

The FAO Soil Fertility Expert arrived in Kenya in September 1968. After getting familiarized with the different parts of the country the expert started operations at the beginning of October 1968. The official opening of the programme took place at a seminar held at the Kitale National Research Station. Forty-six district agricultural officers and assistant agricultural officers participated in the opening seminar.

Before and during the seminar treatments were fixed for the demonstrations on different crops. Crops included were maize, groundnuts, potatoes, beans, soya beans and sorghum. The treatments for them were as follows:

Maize:	Plot 1	Plot 2	Plot 3
1. Western Kenya			
	control	0-60-0	60-60-0
2. Central and Eastern Kenya			
	control	0-40-0	40-40-0
3. Katumani maize for dry areas			
	control	0-40-0	

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	Plot 1	Plot 2	Plot 3
Potatoes :	control	60-60-0	60-60-60
Groundnuts, beans and soya beans :	control	0-40-0	0-40-40
Sorghum :	control	0-40-0	40-40-0

For maize different treatments were used according to the recommendations of the Kitale Research Station. For potatoes recommendations of the Horticultural Research Station at Thika were followed. Little information was available on the fertilization of legumes. Treatments used were based on experience gained in other countries. For sorghum the recommendation of the Serere Research Station in Uganda was followed.

As there were almost no recommendations available on legumes, it was decided by the seminar to carry out some exact trials on these crops. Results can be seen in part d. of this paper.

The total number of demonstrations to be laid out during the planting season 1969 was fixed at 500, 300 on maize, 100 on groundnuts, 50 on potatoes and 50 on beans, soya beans and sorghum. The results of this demonstration can be seen in part c. of this paper. For the planting season 1970, 1220 demonstrations were laid out in Kenya. Results of these demonstrations are still outstanding when this paper was compiled. According to crops there are 700 maize plots, 220 groundnut plots, 200 potato plots, 50 bean plots, 30 sorghum plots and 20 soya bean plots. These demonstrations are carried out in 6 provinces including the Coast province. There are no demonstrations in the arid North Eastern province.

At the beginning of each planting season training courses for the field staff are conducted in each of the 24 districts. Besides discussions of the work carried out during the last planting season, plans are made for the new planting season, and plots are practically laid out on the ground so that each instructor in the field knows what he has to do. Besides this instruction books and recording sheets are explained and handed out to field staff.

With the planting season 1970 the Fertilizer Programme entered its second phase. According to the plan of operations a Pilot Scheme for Fertilizer Distribution was started in Vihiga Division of Kakamega district, Western province. Details of the scheme can be seen in part e. of this paper. The pilot scheme is operational since the beginning of 1970. First maize fields planted with 20-20-0 compound fertilizer gave very high yield.

c. FERTILIZER DEMONSTRATIONS

Planting Season 1969 Long Rains - Average Yield Data

Below, results are summarized of fertilizer demonstrations carried out during the planting season long rains 1969. Average yield data have been calculated for each district and the various crops on which demonstrations have been laid out. The yields are given in lbs/acre as most of the recordings were done in the British system. Out of 500 demonstrations planned 417 reports were received at the Ministry of Agriculture Headquarters in Nairobi. 336 reports had results that could be used for calculations. In this respect it has to be recalled that 1969 was an extremely dry year in Kenya. Especially potato and bean plots in Central and Eastern province suffered from drought and many of them failed completely. Maize plots in Central, Eastern and parts of Rift Valley province gave low yields because of lack of rain. Western Kenya was somewhat more fortunate as there was more rain in most parts of Nyanza and Western province. This is reflected in higher yields of the demonstration plots.

Prices for Produce :

Generally the prices for produce paid by the Maize and Produce Board were used to calculate the value of yield increases over control. As it appears from the recording sheets, these prices are very much on the conservative side. In many districts prices between 30 - 40 K. shs. per bag of maize were reported. The same can be said of other crops. Prices used for calculations are as follows :

Crop	K. shs. per unit	lb/bag	cents/lb
Maize	25	200	12.5
Groundnuts :			
a) Homa Bay	125	180	69.4
b) Uganda Bunch	75	180	41.6
Beans	50	200	25.0
Soya Beans	60	200	30.0
Sorghum (white)	18	180	10.0
Potatoes	15	180	8.3

Prices for Fertilizers and Treatments :

For fertilizers prices were used as reported by the field staff in the recording sheets for each district. Remote places usually have higher prices because of higher transport costs. Treatments are given in lb/acre of pure nutrients. For example, 0-40-0 means 40 lbs per acre of P_2O_5 which is the equivalent of 100 lbs of double super or 200 lbs of single super. Fertilizers used were double superphosphate 40 - 42 % P_2O_5. Sulphate of ammonia 20 - 21 % N and muriate of potash 60 % K_2O.

Calculations of the Economics of Fertilizer Use :

By using the above listed prices of produce and fertilizers the value of increase over control and the cost of fertilizer was calculated. Dividing the value of increase by the cost of fertilizer gives the value/cost ratio. A fertilizer treatment is usually considered as economic if the value/cost ratio is 2 or higher. That means, in simple words, for each shilling the farmer spends on fertilizer he will get back two at harvest time. He will double his money invested in fertilizers within 4 - 6 months according to the length of the vegetation period of various crops. If the value/cost ratio is below 2, yield increases are usually too low to give a good economic return or produce prices are too low and fertilizer cost too high. In more developed countries where enough capital is available lower value/cost ratios are usually accepted. The same is true in countries with food shortages. There a lower value/cost ratio can be expected, if the increase over control is big enough.

In some cases results were affected by drought so the increase over control was too low to be economic. In the case of Katumani maize plots, certainly the NP plot was missing. An NP plot was added in 1970 to Katumani maize demonstrations.

Discussion of results

Western Province :

Maize. Kakamega district returned the biggest number of valid results from all districts in Kenya. Yields in general and increase over control was very satisfactory. Value/cost ratios of 2.8 per plot 2 and 2.6 for plot 3 are very good. Bungoma had slightly lower yields and an economic value/cost ratio was only reached in plot 3. In Busia district, due to more severe drought conditions, yields were lower, but the value/cost ratios were good, because of a good increase over control.

Soya Beans. In Kakamega district yields of soya beans were highest but the economic return was not as good as in Bungoma and Busia because of small differences between the treatments. Both in Bungoma and Busia yields were lower but economic returns on fertilizers better.

Groundnuts. Very good economic returns were obtained, as elsewhere in Kenya, from groundnuts. If the PK treatment is better than P alone must be confirmed in a second year's results and in the results of the exact trials.

Sorghum. Demonstrations in Busia showed no economic return to fertilizers, however the percentage increase of yield was quite good.

Nyanza Province :

Maize. Kisii district obtained the overall highest yield from plot No 3 in Kenya. This is due to the good management of the plots and the high rainfall in this district. The economic return was also remarkable in plot No 3 with NP fertilizer. Homa Bay got better yields than Kisumu and Siaya but the value/cost ratio was not good because of high fertilizer cost in this remote area. Siaya district, in spite of low yields due to drought, and Striga weed, still got a reasonable value/cost ratio. Kisumu district had extremely low yields and very little increase over control because of drought and Striga weed in the Kano plains. Hopefully demonstrations will be better in 1970.

Groundnuts. In all districts of the province groundnut plots gave extremely good economic returns on fertilizers. That is due to high prices of the produce and good increases over control. The fertilization of groundnuts should be very much more promoted by the Extension staff than has been done up to now.

Rift Valley Province :

Maize. Because of the vast area of the province and the climatic and soil differences, results in this province show a considerable amount of variation. That is especially true for the results of maize plots. Very high yields were obtained in Kericho and Nandi districts showing very good value/cost ratios. Good management of the plots in addition to reasonable rainfall caused this excellent result. Fairly good yields were obtained in West Polot, Keiyo Marakwet and Baringo but the economic return was rather erratic in these districts. In most places of this area rainfall was very low in 1969. The economic return could have been by far better, if local prices would have been used. Prices of up to Shs. 40/- per bag were reported by the field staff.

Narok district had rather high yields because of irrigation in some of the plots.

Kajiado had a good economic return on plot No 3. In Eldoret, where plots had been laid out by Dutch Volunteers, most of the demonstrations were destroyed by drought. The few plots that gave results showed a good return on the P plots and 12-31-0 plots.

Potatoes. Very few results were obtained from potato plots in Keiyo-Marakwet, but for those that got through the drought gave reasonable yields and a good economic return in plot No 3 with NPK fertilizer.

Central Province :

Maize. As could be expected, average maize yields were lower in Central Province as in Western Kenya, but in all districts the NP treatment in plot No 3 was by far superior to the P treatment in plot 2. That confirms observations recorded during the growing period. Good differences in growth were carried through to the harvest. This was somewhat contrary to former research findings. However, the reason can be found in the complete exhaustion of some of the soils in Central Province.

Beans. Most bean plots failed due to drought in Central Province. Those recorded in Fort Hall district showed low yields but a good economic return.

Potatoes. The same as has been said for bean plots is true for the potato plots. Most were lost because of drought. A few plots recorded showed low yields and low economic returns.

Eastern Province :

Maize. With the exception of Embu district no economic returns were obtained from Katumani maize plots in Eastern Province. Katumani yields were low in Machakos and Kitui districts, because of drought. The lower parts of Embu district however recorded reasonable yields on Katumani plots, mainly because of somewhat higher rainfall. Hybrid maize in Embu and Meru district showed good economic returns and fairly high yields. Plots were especially well managed in Meru district.

Beans and Sorghum. Many plots of these two crops were lost in East Province. From the few plots recorded none showed an economic return and yields were low.

Potatoes. Plots in Meru district showed fairly good yields and a very good economic return to fertilizers.

Nairobi District :

Demonstration plots on all three crops, maize, beans, potatoes, gave good yields and very good economic returns. That is mainly due to the good attention the plots got in this district and the interest the field staff showed in their work. The good results were obtained in an extremely dry year and should be an incentive to intensify the fertilizer work in Nairobi District even more.

FAO Fertilizer Programme, Kenya

Planting Season 1969 Long Rains

Fertilizer Demonstrations, Yields and Economy

District	Crops & Number of Demonstrations	Treatments	Yields and Increases lbs/acre	Profit K. Sh.	V/C ratio
		A. Western Province			
1. Kakamega District	Maize (40)	0 0 0	3440		
		0 60 0	1021	83	2.8
		60 60 0	1841	143	2.6
	Soya Beans (7)	0 0 0	1338		
		0 40 0	23	-23	0.2
		0 40 40	82	-25	0.5
	Groundnut (4)	0 0 0	514		
		0 40 0	180	45	2.5
		0 40 40	403	118	3.4
2. Bungoma District	Maize (14)	0 0 0	3649		
		0 60 0	644	36	1.8
		60 60 0	1447	91	2.0
	Groundnut (5)	0 0 0	888		
		0 40 0	131	61	3.0
		0 40 40	416	239	5.8
	Soyabeans (7)	0 0 0	716		
		0 40 0	312	64	3.1
		0 40 40	432	80	2.6
3. Busia District	Maize (14)	0 0 0	2688		
		0 60 0	867	63	2.4
		60 60 0	1786	133	2.5
	Groundnut (5)	0 0 0	927		
		0 40 0	393	133	5.4
		0 40 40	349	95	2.9
	Soyabeans (7)	0 0 0	578		
		0 40 0	528	128	5.3
		0 40 40	346	54	2.1
	Sorghum (5)	0 0 0	1503		
		0 40 0	490	19	1.6
		40 40 0	1059	46	1.8

District	Crops & Number of Demonstrations	Treatments	Yields and Increases lbs/acre	Profit K. Sh.	V/C ratio
		B. Nyanza Province			
1. Kisii District	Maize (10)	0 0 0	4297		
		0 60 0	1043	76	2.4
		60 60 0	2418	203	3.1
	Groundnut (8)	0 0 0	789		
		0 40 0	292	167	5.6
		0 40 40	545	318	6.3
2. Kisumu District	Maize (6)	0 0 0	2335		
		0 60 0	40	-40	0.1
		60 60 0	773	7	1.1
	Groundnut (7)	0 0 0	1119		
		0 40 0	337	204	7.8
		0 40 40	371	207	5.1
3. Siaya District	Maize (8)	0 0 0	1516		
		0 60 0	1050	86	2.9
		60 60 0	1575	107	2.2
	Groundnut (7)	0 0 0	670		
		0 40 0	292	173	6.8
		0 40 40	342	187	4.7
4. Homa Bay District	Maize (7)	0 0 0	3352		
		0 60 0	474	5	1.1
		60 60 0	1227	54	1.5
		C. Rift Valley Province			
1. Kericho District	Maize (16)	0 0 0	4029		
		0 60 0	1126	96	3.1
		60 60 0	1619	112	2.2
2. Nandi District	Maize (10)	0 0 0	4831		
		0 60 0	1340	123	3.7
		60 60 0	1714	124	2.4
3. Karyo Marakwet District	Maize (6)	0 0 0	4025		
		0 60 0	263	-12	0.7
		60 60 0	289	-54	0.4
	Potatoes (3)	0 0 0	8831		
		60 60 0	48	-86	0.0
		60 60 60	6008	379	4.2
4. West Pokot District	Maize (8)	0 0 0	2661		
		0 60 0	538	22	1.5
		60 60 0	2267	193	3.1
5. Baringo District	Maize (6)	0 0 0	2853		
		0 60 0	315	-6	0.9
		60 60 0	910	24	1.3
6. Narok District	Maize (3)	0 0 0	4081		
		0 60 0	634	34	1.8
		60 60 0	1148	54	1.6

District	Crops & Number of Demonstrations	Treatments	Yields and Increases lbs/acre	Profit K. Sh.	V/C ratio
7. Kajado District	Maize (3)	0 0 0	2835		
		0 40 0	245	1	1.0
		40 40 0	1330	106	2.8
8. Eldoret District	Maize (4)	0 0 0	2651		
		0 60 0	804	56	2.2
		12 31 0	1804	156	3.2
		10 30 0 + C.A.N.	1182	28	1.2
		D. Central Province			
1. Kiambu District	Maize (7)	0 0 0	3375		
		0 40 0	239	0	1.0
		40 40 0	920	55	1.9
2. Nyeri District	Maize (8)	0 0 0	4331		
		0 40 0	368	16	1.5
		40 40 0	1090	76	2.3
3. Fort Hall District	Maize (7)	0 0 0	3141		
		0 40 0	728	61	3.0
		40 40 0	1426	118	3.0
	Beans (4)	0 0 0	506		
		0 40 0	385	66	3.2
		0 40 40	503	76	2.5
4. Kirinyaga District	Maize (10)	0 0 0	2357		
		0 40 0	391	19	1.6
		40 40 0	1004	66	2.1
	Potatoes (3)	0 0 0	6986		
		60 60 0	2102	84	1.9
		60 60 60	2643	99	1.8
		E. Eastern Province			
1. Machakos District	Katumani Maize (8)	0 0 0	1773		
		0 40 0	320	10	1.3
	Beans (6)	0 0 0	819		
		0 40 0	2	-30	0.0
		0 40 40	52	-37	0.3
	Sorghum (8)	0 0 0	2199		
		0 40 0	331	3	1.1
		40 40 0	395	-20	0.7
2. Meru District	Maize (18)	0 0 0	2778		
		0 40 0	859	77	3.6
		40 40 0	895	52	1.9
	Potatoes (3)	0 0 0	7961		
		60 60 0	4852	313	4.5
		60 60 60	5970	376	4.1

District	Crops & Number of Demonstrations	Treatments	Yields and Increases lbs/acre	Profit K. Sh.	V/C ratio
3. Embu District	Katumani Maize (6)	0 0 0 0 40 0	2420 880	 30	 1.7
	Hybrid Maize (6)	0 0 0 0 40 0 40 40 0	2936 718 1648	 60 146	 3.0 3.4
	Sorghum (2)	0 0 0 0 40 0 40 40 0	313 215 855	 -8 26	 0.7 1.4
4. Kitui District	Katumani Maize (14)	0 0 0 0 40 0	2527 253	 2	 1.1
5. Nairobi District	Maize (8)	0 0 0 0 40 0 40 40 0	2743 932 1450	 87 121	 3.9 3.0
	Beans (3)	0 0 0 0 40 0 0 40 40	941 292 467	 43 67	 2.4 2.3
	Potatoes (2)	0 0 0 60 60 0 60 60 60	5940 3960 4950	 239 291	 3.7 3.4

d. RESULTS OF FERTILIZER TRIALS 1969

Treatments used in the FAO Fertilizer Demonstration Programme are normally based on research work carried out before the start of the programme. However if there is no information available some exact trials have to be executed within the Fertilizer Programme.

In Kenya there was very good research information available on the fertilisation of maize, some on potatoes and pasture but very little on the most important legumes such as soya beans, beans and groundnuts. These crops were all included in the Fertilizer Programme and it is the policy of the Ministry of Agriculture to produce more of these crops. To base the treatments used on a better foundation, trials on these crops were planned in the planting season 1969. To have them under complete control the trials were laid out in Farmers' Training Centres, where they could also be used as demonstrations for farmers attending courses.

The NPK fertilizer trials were carried out under different soil and climatic conditions in Machakos, Eastern Province, Bukura in Kakamega District, Western Province, and in Busia District also in Western Province. The soils were red loam, brown loam and tropical laterite soils in Busia. Rainfall and length of the rainy season are different on all three stations.

The layout of the trials followed all recommendations of the Fertilizer Programme used all over the world. Once a basic knowledge of crop responses has been established the trials can be differentiated to include for example different levels of the same nutrient. Actually trials planned for the planting season 1970 will have three levels of the three main nutrients.

Besides the trials on legumes, a maize trial using fertilizer and coffee pulp was carried out in Machakos F.T.C. The initiative for this trial came from the Coffee Officer Machakos District, who wanted to use the coffee pulp which was lying in huge quantities around the coffee factories. Furthermore two pasture trials were established at the Kambu F.T.C. in the Central Province. They are based on permanent pasture of Kikuyu and Star-grass where little information on fertilizer response is available. Another grassland trial was laid out on a ranch near Embakasi in cooperation with the Range Management Division of the Ministry of Agriculture. All the pasture trials have not been completed yet; they will be continued for at least three years to get the full effect of the fertilizers.

When reviewing the results of all the following trials, it should be noted that 1969 was an extremely dry year in Kenya. Relatively low yields and variation within the trials has to be attributed to the adverse weather conditions. In all the trials sulphate of ammonia, double superphosphate and muriate of potash 60 percent were used in various mixtures. All trials on legumes were laid out in the randomized block design with four replications. The other trials were latin squares 4 x 4.

Trials Long Rains 1969

Machakos F.T.C.

A) NPK Trial on Beans

Results of analysis :

Treatment	lb yield per plot	lb yield per acre	bags per acre (200 lbs)
1 Control	4.04	1192	5.96
2 N_{40}	4.53	1136	6.68
3 P_{40}	4.04	1192	5.96
4 K_{40}	3.81	1124	5.62
5 $N_{40}P_{40}$	4.70	1387 + (195)	6.93
6 $N_{40}K_{40}$	4.70	1387 + (195)	6.93
7 $P_{40}K_{40}$	4.20	1239	6.19
8 $N_{40}P_{40}K_{40}$	4.84	1428 + (236)	7.14

Least significant differences : 5 % - 184.1
1 % - 250.1
0.1 % - 338.1

Standard error : ± 88.5 lb per acre

Fertilizer was applied before planting in a furrow along the planting rows. Treatment No 5, 6, 8, were significantly better than the control plot at the 5 percent level. The best treatment of the trial was No 8 NPK at 40 lb/acre each. This treatment gave 236 lb/acre more than the control plot. During the vegetation period, the treatment No 8 looked the best and as the results show this has been carried through to the yield. Trial should be repeated to confirm the results in a second growing season.

B) Phosphate plus Coffee Pulp Trial

Treatment No	Average yield per plot lbs grain	Yield per acre lb grain	Bags/acre (200 lbs)
1 Control	15.9	3848	19.24
2 P_{40}	16.1	3896	19.48
3 P_{40} + one debbe of coffee pulp for six yards	16.5	3993	19.95
4 P_{40} + 2 debbe of coffee pulp for six yards	16.9	4090 ++ (242)	20.45

Least significant differences : 5 % - 73.5
1 % - 111.3
0.1 % - 178.0

Standard error : ± 30.9 lb per acre

The trial was badly damaged by birds and squirrels near harvest time. Therefore, to get any results at all, 50 stems of each plot were taken and the yield measured. As seen from the results the yields were rather high. But there was possibly no better maize plot in the whole Machakos area than the trial.

Treatment 4 was highly significant better than the control plot in spite of the drought conditions during part of the vegetation period. But the differences in general were rather small compared to the control plot, which might be due to the fertility of land on which the trial was carried out.

c) Fertilizer plus Coffeee Pulp Trial
Short rains 1969/70

Treatment No	Average yield per plot in lb	Yield per acre lb grain	Bags/acre (200) lb
1 Control	32	3485	17.4
2 P_{40}	37	4029	20.1
3 P_{40} + 1 debbe of coffee pulp per 6 yds	34	3703	18.5
4 $N_{40}P_{40}$ + 1 debbe of coffee pulp for 6 yds	39	4247++	21.2

Least significant differences : 5 % - 453
1 % - 686
0.1 % - 1103

Standard error : ± 185 lbs/acre

The trial was repeated in the short rains; this time 40 lbs N were included in the treatment No 4. During the vegetation period the plots of treatment No 4 were by far superior to all others. This was carried through to the yield. Treatment No 4 was highly significantly better than the control.

Trials Long Rains 1969

Bukura F.T.C.

A) NPK Trial on Beans

Results of analysis :

Treatment No	lb yield per plot	lb yield per acre	bags/acre (200 lb)
1 Control	8.31	906	4.5
2 N_{40}	8.63	941	4.7
3 P_{40}	9.19	1002	5.0
4 K_{40}	9.72	1059	5.2
5 $N_{40}P_{40}$	8.38	913	4.6
6 $N_{40}K_{40}$	10.13	1104	5.5
7 $P_{40}K_{40}$	10.13	1104	5.5
8 $N_{40}P_{40}K_{40}$	12.50	1363++	6.8

Standard error : ± 143 lbs per acre

Least significant differences : 5 % - 299.1
1 % - 406.9
0.1 % - 540.7

As in the Machakos trial plot No 8 the NPK treatment was significantly better at the 1 % level. The increase over control was 457 lbs which is 50.4 percent. During the whole vegetation period treatment No 8 was the best in all four replications. No other treatment was significantly better than the control.

B) NPK Trial on Groundnuts

Results of analysis :

Treatment	lb yield per plot	lb yield per acre	bags/acre (180 lbs)
1 Control	10.0	1090	6.1
2 N_{40}	11.1	1210	6.7
3 P_{40}	11.7	1275	7.1
4 K_{40}	11.7	1275	7.1
5 $N_{40}P_{40}$	10.5	1145	6.4
6 $N_{40}K_{40}$	13.0	1417	7.9
7 $P_{40}K_{40}$	14.9	1624 (534)	9.0
8 $N_{40}P_{40}K_{40}$	11.3	1232	6.8

Standard error : ± 274.7 lb/acre

Least significant differences : 5 % - 571.4
1 % - 777.4
0.1 % - 1049.3

The L.S.D. in this trial was very high due to uneven germination. No treatment was significantly better than the control. Treatment No 7 gave an average 534 lbs more than the control, which was almost significant at the 5 percent level. Treatment No 8 which looked good during the vegetation period was not very good at the harvest time.

C) NPK Trial on Soya Beans

Results of analysis

Treatment	lb yield per plot	lb yield per acre	bags/acre (200 lbs)
1 Control	9.5	1036	5.2
2 N_{40}	10.5	1145	5.7
3 P_{40}	11.0	1199	6.0
4 K_{40}	10.7	1166	5.8
5 $N_{40}P_{40}$	10.7	1166	5.8
6 $N_{40}K_{40}$	10.0	1090	5.5
7 $P_{40}K_{40}$	14.0	1526^{+}	7.6
8 $N_{40}P_{40}K_{40}$	12.0	1308	6.5

Standard error : ± 199.5 lb/acre

Least significant differences : 5 % - 415.0
1 % - 564.6
0.1 % - 762.1

During the whole vegetation period the soya beans looked well in this trial. As in the groundnut trial the PK treatment No 7 was the best. It was significantly better at the 5 percent level. Calculated per acre the PK plots gave 490 lbs more than the control. The NPK plot again did not carry through to the yield its good appearance during the vegetation period.

Trials Long Rains 1969

Busia F.T.C.

A) NPK Trials on Soya Beans

Results of analysis :

Treatment No	lb yield per plot	lb yield per acre	bags/acre (200 lbs)
1 Control	8.4	916	4.6
2 N_{40}	8.5	927	4.6
3 P_{40}	8.4	916	4.6
4 K_{40}	8.6	937	4.7
5 $N_{40}P_{40}$	11.5	1254	6.3
6 $N_{40}K_{40}$	8.8	959	4.8
7 $P_{40}K_{40}$	9.8	1068	5.3
8 $N_{40}P_{40}K_{40}$	10.1	1101	5.5

Standard error : ± 211.5 lb/acre

Least significant differences : 5 % - 439.9
1 % - 598.5
0.1 % - 807.9

The soya bean trial at Busia F.T.C. showed during the whole vegetation period great differences in growth, mainly due to lack of rain. This is reflected in the results of the analysis. Yields per acre were low. The best treatment was No 5 NP at 40 lb/acre each, giving 338 lbs over the control. No treatment was significantly better than the control.

B) NPK Trial on Groundnuts

Results of analysis :

Treatment	lb yield per plot	lb yield per acre	bags/acre (180 lbs)
1 Control	10.9	1188	6.6
2 N_{40}	11.2	1221	6.8
3 P_{40}	14.6	1591	8.8
4 K_{40}	10.9	1188	6.6
5 $N_{40}P_{40}$	12.0	1308	7.3
6 $N_{40}K_{40}$	10.5	1145	6.4
7 $P_{40}K_{40}$	15.6	1700+	9.4
8 $N_{40}P_{40}K_{40}$	15.3	1668	9.3

Standard error : ± 247.4 lbs/acre

Least significant differences : 5 % - 514.6
1 % - 700.1
0.1 % - 945.1

The groundnut trial in Buria District looked very well during the whole vegetation period and it gave good yields at harvest time. As in Bukura the PK treatment No 7 was the best. It gave 512 lb per acre more than the control, within 2 lb of being significant at the 5 percent level. The second best was the NPK treatment No 8 giving 480 lb per acre more than the control. Treatment No 8 always looked the best during the vegetation period.

Conclusion

If results of the first planting season of exact trials can be confirmed in 1970 under normal rainfall conditions, first conclusions could be drawn to make preliminary recommendations to farmers. A NPK treatment might be the best for beans. It is almost certain that the PK treatment will in the long run be the best treatment for groundnuts and soya beans. However, before any final decisions are made one should await the results of yet another planting season.

e. THE VIHIGA PILOT SCHEME ON FERTILIZER AND SEED DISTRIBUTION

1. Location: Vihiga Division, Kakamega District. This district was selected by the Rural Development Programme as one of the Pilot Scheme areas. Vihiga Division is one of the most densely populated areas in Kenya (1600 inhabitants per square mile). Farms are generally very small (2-5 acres) and soils are of a granitic type which is generally not very fertile. This all forces farmers in the division to get the highest possible yield from their small acreage. However, input factors to reach the necessary high yields per acre are difficult to get in many parts of the division. To overcome these problems, FAO, in cooperation with the Ministry of Agriculture, will initiate a pilot scheme of Fertilizer and Seed Distribution in the division.

2. Contribution by FAO : FAO has made available 100 tons of 20-20-0 compound fertilizer free of charge to the Kenya Government. This fertilizer is of a highly concentrated type suitable for maize production, vegetables and permanent treecrops. An FAO Expert, Mr. B. Jensen, has been posted to the division to organize the pilot scheme. He has been provided with a suitable duty car by FAO.

3. Contributions by the Ministry of Agriculture : The Ministry of Agriculture makes available, on a parttime basis, field staff stationed in the division to help organize the pilot scheme. Local authorities and elders will be asked to help in organizing meetings in the pilot area and popularize the pilot scheme. The Ministry of Agriculture will arrange the necessary contacts for this purpose. Special training courses in maize production for participants of the programme will be organized within the division or in a F.T.C. to make sure the fertilizer is used in the right way.

4. Details of organization of the scheme :

a) K.F.A. has agreed to take over the distribution of seed and fertilizer. Actually, the fertilizers are already in K.F.A. stores in Kisumu.

b) K.F.A. is appointing a transport firm to carry fertilizers from Kisumu to Vihiga Division and deliver it at prearranged centres.

c) Farmers will be organized by the field staff in groups to order fertilizers and seeds together, minimum one lorry load of 3-5 tons. This groups system will ensure that the farmers in the division pay a price for fertilizers comparable to the price paid by large scale farmers (13 tons lot price). Each group of farmers should select a leader who is responsible for setting up a list of participants, their demand of fertilizers and seeds and the payments they have made. No cash should be handled by the field staff of the Ministry of Agriculture.

d) Payments are made to the mobile bank vans touring the division. A copy of the receipt is sent to K.F.A. On receipt of the payment advice KFA delivers the fertilizer to the farmers. All proceeds of fertilizer are kept by K.F.A. in a special revolving fund to be used again for fertilizer purchases.

e) It is anticipated that each member of the group should have at least one acre of hybrid maize. Fertilizer is sold only in full 50 kg bags.

f) To ensure the full success of the Programme and high yields of maize, all modern methods of maize cultivation must be employed. Instructors of the Ministry of Agriculture will have a training course with each group of farmers. Mr. Jensen will also participate in these activities.

5. Timetable of scheme :

a) Beginning of operations second week of November. The scheme will be started with barazas in Chief Centres of every location in the division.

b) During November, December and beginning of January, subsequent meetings have to be organized with the groups to explain the details of the scheme to them.

c) Delivery of fertilizers can be started by the middle of January. If necessary payments can be made earlier when farmers have money available.

d) Demonstrations on modern methods of maize production will be conducted by the field staff starting at the beginning of February and carried through to March.

e) During the growing period of the maize, field days are organized by the field staff and the FAO Expert,

f) At harvest time, field days are organized and actual yields are measured and demonstrated to farmers.

RESPONSE OF CROPS TO FERTILIZER IN BOTSWANA, LESOTHO & SWAZILAND

by

J.J. Doyle*

Summary

In an FAO/SIDA Fertilizer Programme, response of crops to fertilizer was studied in a season in which yields were lower than normal due to drought.

On sandy soils in Botswana, where the rainfall average was 13 inches, phosphorus at 45 Kg P_2O_5/ha was the only treatment which produced economic returns for maize. Nitrogen, by stimulating vegetative growth, seemed to aggravate the moisture deficiency.

In Lesotho, on a wide range of soil textures, maize and sorghum gave a statistically significant response to all three major nutrients. With maize, all treatments which contained phosphorus gave satisfactory financial returns. With sorghum it appears as if phosphorus alone would have been the most profitable.

In Swaziland, on a wide range of soil textures, maize responded to all three nutrients, with evidence of a positive interaction between nitrogen and phosphorus. Response to potassium was considerably lower than to the other two nutrients.

Phosphorus and potassium gave rise to a substantial increase in the yield of cotton. Although nitrogen had much less effect, it seemed to have a positive effect on the responses to phosphorus and potassium.

It is felt that in all three countries the response pattern was affected by the drought. It is realised, however, that in order to obtain a basis for sound fertilizer recommendations, fertilizer studies must be conducted over a wide range of moisture availabilities, and that some pre-season measurement of moisture availability should be contemplated.

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* FAO Soil Fertility Expert

INTRODUCTION

In late 1969, a Programme of Fertilizer Trials and Demonstrations was initiated in Botswana, Lesotho and Swaziland. These Programmes, which will run for a five-year period, are sponsored by the Government of Sweden through the Swedish International Development Agency (SIDA).

BOTSWANA

In Botswana the soils represented in the Programme are for the most part very coarse, some 80 percent having a texture coarser than sandy loam.

Rainfall in the 1969 - 70 growing season was 13 inches, about two-thirds of the average 20 inches. This drought resulted not only in a drastic reduction from the number of demonstrations and trials originally planned, but also in the number yielding useful results. From a total of 25 trials and 100 demonstrations set out, only 4 trials with maize and 10 with sorghum provided results which might be considered useful in assessing response to fertilizer. The yield of maize and sorghum are presented in Tables 1 and 2 respectively.

Table 1. Response of Maize to Fertilizer at Baralong (Mean of 4 trials)

Fertilizer Treatment (Kg/ha)			Yield	Increase	B/C	Net Return
N	P_2O_5	K_2O	(Kg/ha)	(Kg/ha)		/ha
0	0	0	687	-		
45	0	0	1064	377	1.5	6.83
90	0	0	1120	433	0.9	- 3.63
0	45	0	1330	643	2.7	21.69
45	45	0	1372	685	1.4	10.47
90	45	0	1247	560	0.8	- 9.76
0	90	0	1443	756	1.6	14.81
45	90	0	1484	797	1.1	3.54
90	90	0	1191	504	0.5	- 25.74
45	45	45	1176	489	0.8	- 4.73
45	45	90	1260	573	0.9	- 4.88
90	90	90	1232	545	0.5	- 32.83

Table 2. Response of Sorghum to Fertilizer at Ngvaketse and Baralong

(Mean of 10 trials)

Fertilizer Treatment (Kg/ha) N	P	K	Yield (Kg/ha)	Increase (Kg/ha)	B/C	Net Return /ha
0	0	0	638	-		
45	0	0	762	94	0.5	- 7.29
90	0	0	683	45	0.1	- 24.00
0	45	0	1036	348	2.0	13.30
45	45	0	924	286	0.7	- 7.57
90	45	0	974	336	0.6	- 17.76
0	90	0	1098	460	1.2	4.42
45	90	0	1249	611	1.0	0.91
90	90	0	974	336	0.4	- 30.73
45	45	45	980	342	0.7	- 8.52
45	45	90	963	325	0.6	- 4.31
90	90	90	1098	460	0.5	- 31.85

It appears from the results as if phosphorus was the only nutrient giving rise to any substantial increase, and in fact phosphorus at 45 Kg P_2O_5 per hectare was the only treatment which provided an economic incentive.

There are however, several observations which should be made at this point.

1. There was a marked decrease in yield, due to nitrogen at many locations. This decrease is attributed to the stimulation of vegetative growth which increased the demand for moisture, which was already limiting due to drought.

2. Even the response to phosphorus would be expected to be much more marked under adequate moisture conditions.

3. The fact that an economic increase has been obtained even under these unfavourable conditions suggests that the potential increase due to fertilizer is quite promising.

4. There is ample evidence of deficiency of zinc and other trace elements in the soils of Botswana. In the past season however, trials set out for the purpose of studying these deficiencies failed because of the drought.

LESOTHO

In Lesotho 257 demonstrations were set out in an area covering 7 of the 9 Districts. Of these demonstrations 145 were with maize, 47 with sorghum and 65 with beans.

The texture of the soils on which the demonstrations were set out varies from sandy loam to clay loam; with a pH range of about 5.0 to 7.5.

The growing season started with a reasonably good supply of moisture which continued until about mid-season. At this point a drought occurred which resulted in failure of most of the demonstrations. Of the 257 demonstrations, useful results were obtained from only 29 with maize, and 15 with sorghum. The yields are presented for maize and sorghum in Tables 3 and 4 respectively.

Table 3. Response of Maize to Fertilizer in Lesotho (Mean of 29 demonstrations)

Fertilizer Treatment (Kg/ha)			Yield	Increase	B/C	Net Return
N	P_2O_5	K_2O	(Kg/ha)	(Kg/ha)		/ha
0	0	0	1031	-		
0	51	27	1490	459	2.1	15.02
45	0	27	1369	338	1.5	7.35
45	51	0	1650	619	1.8	16.85
45	51	27	1808	777	2.0	22.00

L.S.D. = 165 (P = 0.05) and 217 (P = 0.01)

From the data in Table 3 it is concluded that the maize crop responded to all three major nutrients, with phosphorus having the greatest effect, and potassium the least. The full NPK treatment gave the best results both from the standpoint of physical response and of return per hectare.

Of the 29 demonstrations with maize, 21 showed a response to nitrogen, 27 to phosphorus and 14 to potassium. All but one showed a response to fertilizer treatment generally.

There now remains the problem of determining with more accuracy the amounts of each element required for the major crops on all important soils.

Table 4. Response of Sorghum to Fertilizer in Lesotho (Mean of 15 demonstrations)

Fertilizer Treatment (Kg/ha)			Yield	Increase	B/C	Net Return
N	P	K	(Kg/ha)	(Kg/ha)		/ha
0	0	0	794	-		
0	51	27	1058	264	1.2	3.01
45	0	27	812	18	0.1	-12.36
45	51	0	1144	350	1.0	0.28
45	51	27	1351	557	1.4	10.31

L.S.D. = 178 (P = 0.05) and 234 (P = 0.01)

Statistically there was a highly significant response, over the Control, to all fertilizer treatments containing phosphorus. The full "NPK" yield is also significantly higher than for all other treatments, indicating a response to all three major nutrients. The economic returns however are not very attractive either from the standpoint of Benefit/Cost ratio or net return per hectare. In fact a close examination of the results leads to the conclusion that phosphorus alone might have been the most profitable treatment.

Of the 15 demonstrations with sorghum, 10 showed a response to nitrogen, 15 to phosphorus, and 11 to potassium. All 15 responded to fertilizer generally.

Since most of the original demonstrations failed because of lack of moisture, it is reasonable to assume that moisture was less than adequate for the fraction which survived. It is expected therefore that under conditions of adequate moisture the response pattern may have been considerably different.

SWAZILAND

In Swaziland a Programme of District Fertilizer Trials is conducted by the Research Branch of the Ministry of Agriculture.

This Programme is designed to study not only the response of crops to fertilizer, but also to study this response in relation to a number of environmental factors including rainfall, temperature, and some physical and chemical properties of the soil. The experimental design is a 4 x 4 x 3 factorial in a systematic arrangement.

In Swaziland as well as in Botswana and Lesotho many of the trials were lost because of drought.

The report presented here represents but a brief summary of the results obtained in 68 maize trials and 31 cotton trials. No attempt has been made to relate these results to environmental factors, as this entails an involved regression analysis requiring a computer.

Results for maize are presented in Figs. 1 to 9, and for cotton in Figs. 10 to 18.

1. Fig. 1 shows a marked response to nitrogen, corresponding to a quadratic curve. This response was greater where phosphorus was applied (Fig. 4).

2. The response to phosphorus (Fig. 2) levelled off at the first increment, suggesting that lower rates should have been applied. The response was enhanced when nitrogen was applied (Fig. 6).

3. Response to potassium (Fig. 3) was lower than to the other major elements. As with phosphorus the first increment probably should have been lower. Examination of Figs. 8 and 9 shows no noticeable interaction of potassium with nitrogen and phosphorus.

For <u>cotton</u> it is concluded that:

1. In general the response to nitrogen was not very important (Fig. 10). Application of phosphorus and potassium however, seemed to increase the need for this element (Figs. 13 and 14).

2. The response of cotton to phosphorus was quite marked and at the rates applied, fits a quadratic curve (Fig. 11). This response was higher where nitrogen was applied (Fig. 15).

3. The response to potassium (Fig. 12) was quite substantial, but levelled off at the first increment. Information on response to lower rates would be of interest. This response was higher where nitrogen was applied (Fig. 17) but did not seem to be affected by phosphorus (Fig. 18).

No attempt has been made in this report to study the economic returns, because:-

(1) Analysis of the whole project remains to be done, and

(2) Prices of fertilizer and produce were not known at the time of writing.

On the basis of the response curves however, some pertinent information is presented in Table 5.

Table 5. Increase in Yield (Kg) per Kg of applied nutrient

	N	P_2O_5	K_2O
Maize	11.0	7.0	5.0
Cotton (seed)	1.4	3.0	4.0

GENERAL OBSERVATIONS

It is clear that deficiency of moisture has limited yields in the trials and demonstrations conducted in all three countries, and there is no doubt that this deficiency has had its effect on the response pattern. The experimenter might dream of an ideal season in which there would be no limiting factors and a "true" response would be obtained. It must be accepted however, that in these countries moisture deficiency is a fact of life and that "ideal" years do not occur with sufficient frequency to justify application of the results obtained in one good year.

In the District of Mafeteng for example, rainfall records show that a favourable season for maize occurs only once in 14 years.

There are, however, certain measures which can be taken to increase the efficiency of fertilizer use under conditions of limited rainfall.

1. Make maximum use of all available rainfall through proper tillage, and timely planting.

2. Study the relationship of soil moisture content before planting, to yields, and also between pre-season rainfall and yields. On this basis some countries are already able to predict yields of certain crops, and to advise farmers accordingly as to crop, variety, and quantity of fertilizer.

3. Make use of split applications, particularly of nitrogen, not so much to prevent loss due to leaching as to avoid excessive rates of application in a season where moisture is insufficient for utilization of the full rate of application, and excessive vegetative growth due to excess nitrogen increases the demand for moisture.

4. Plant a number of crops with somewhat different moisture requirements so that drought does not necessarily result in a total loss.

Fig 9

Response of Maize to K at different P levels

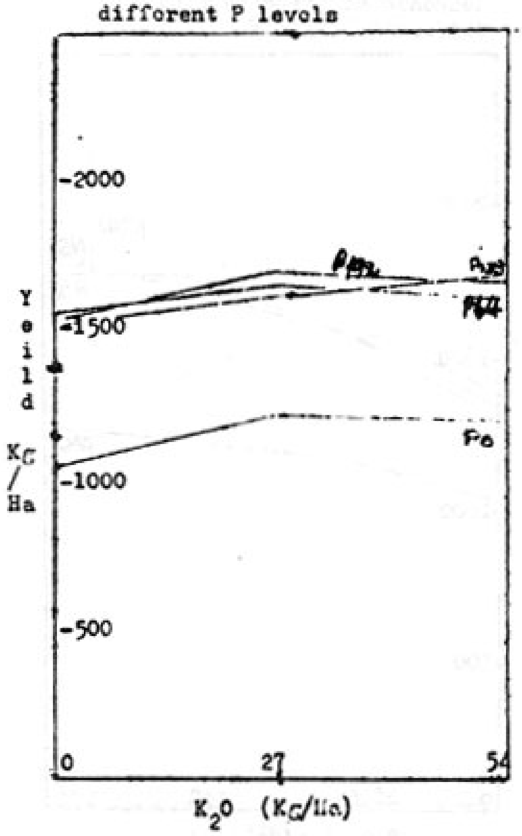


Fig 10

Response of Cotton to N

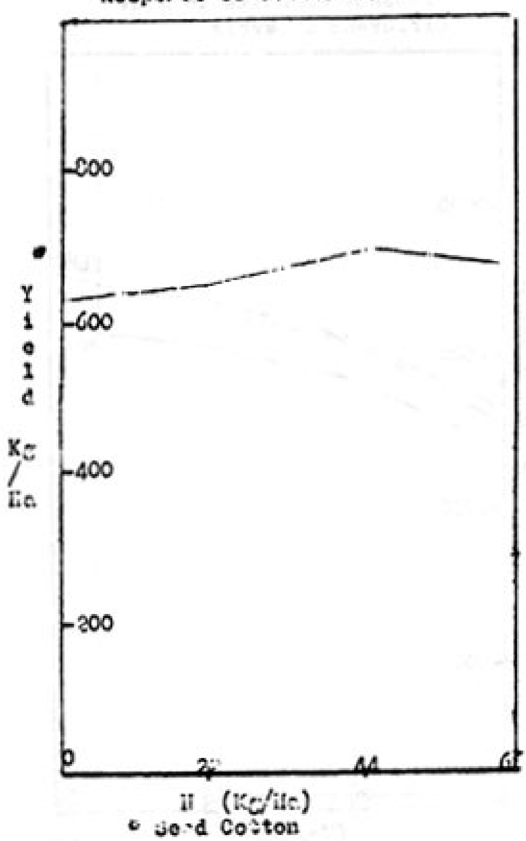


Fig 11

Response of Cotton to P

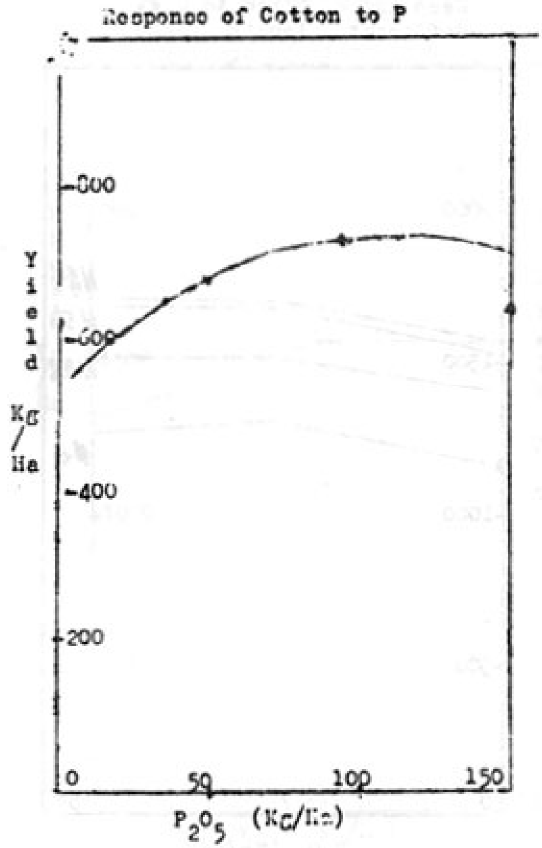


Fig 12

Response of Cotton to K

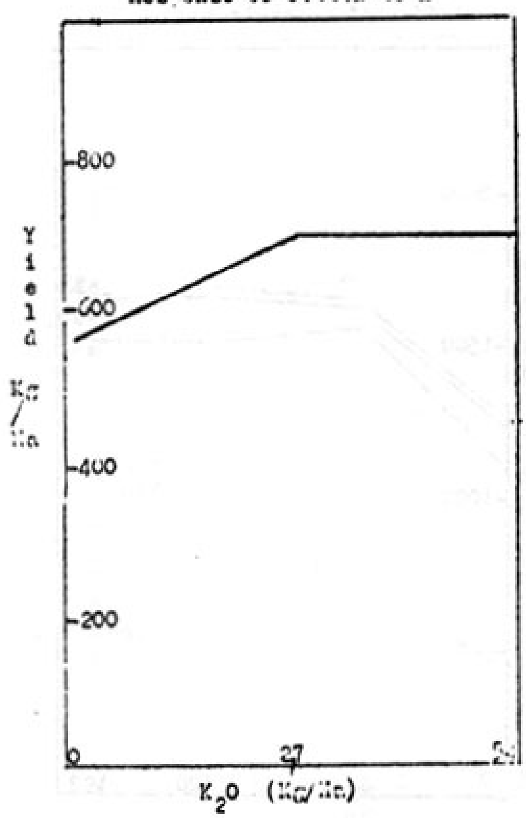


Fig 13
Response of cotton to N at different levels of P

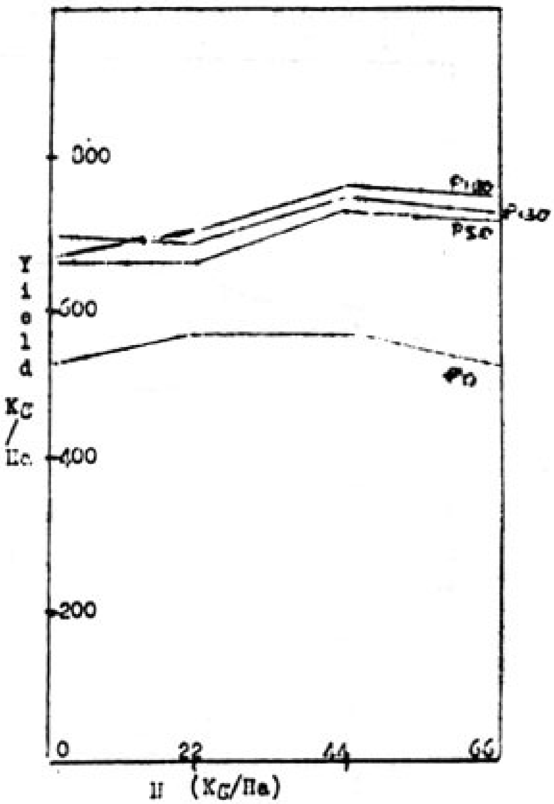


Fig 14
Response of cotton to N at different levels of K

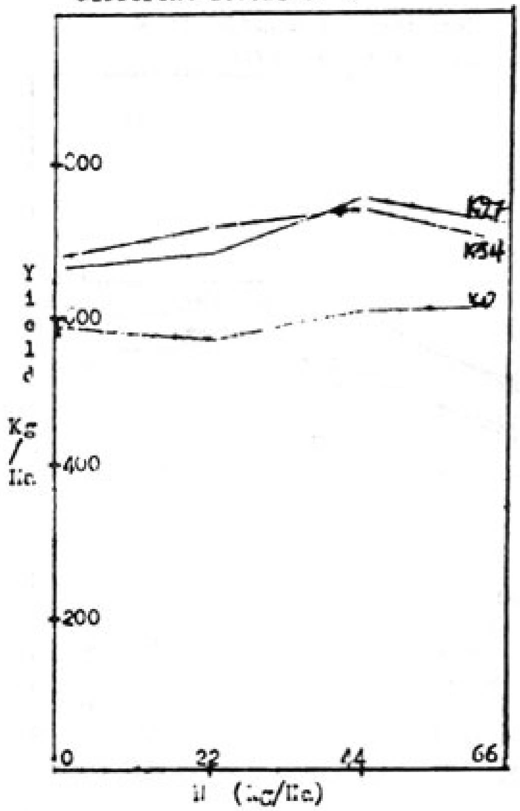


Fig 15
Response of Cotton to P at different N levels

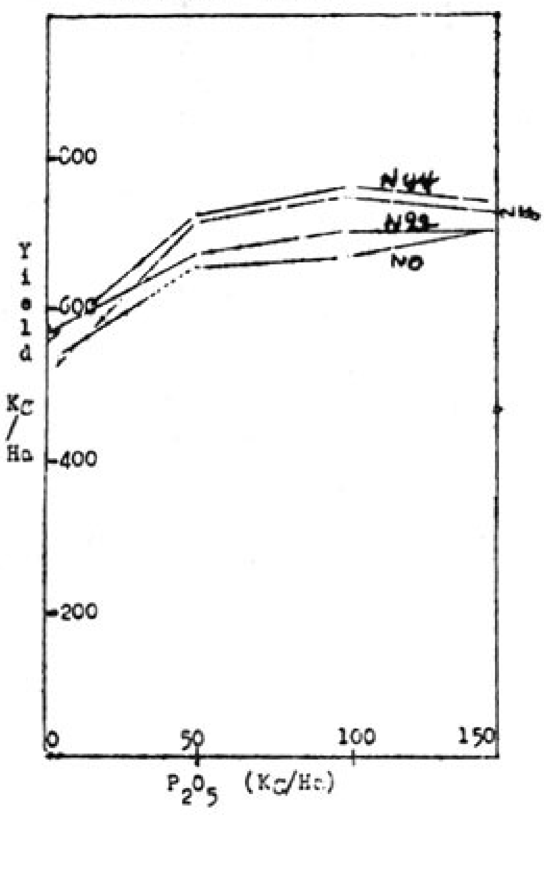


Fig 16
Response of cotton to P at different K levels

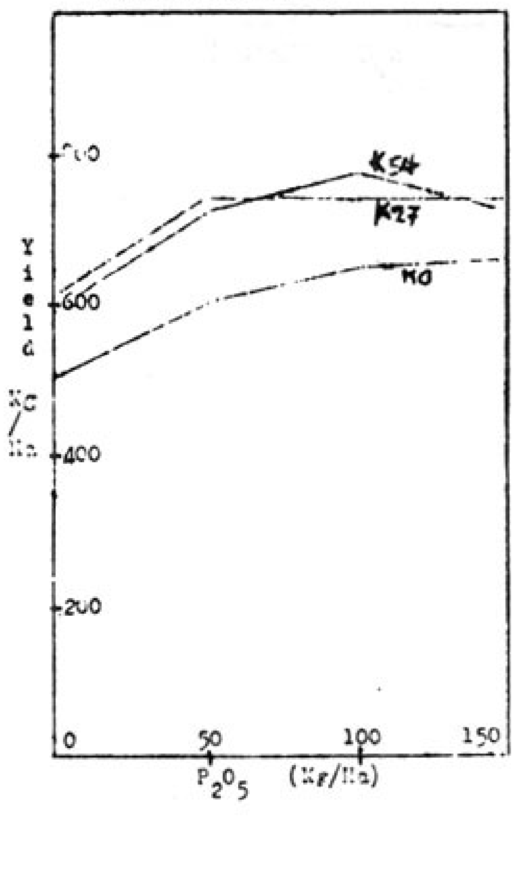


Fig 9

Response of Maize to K at different P levels

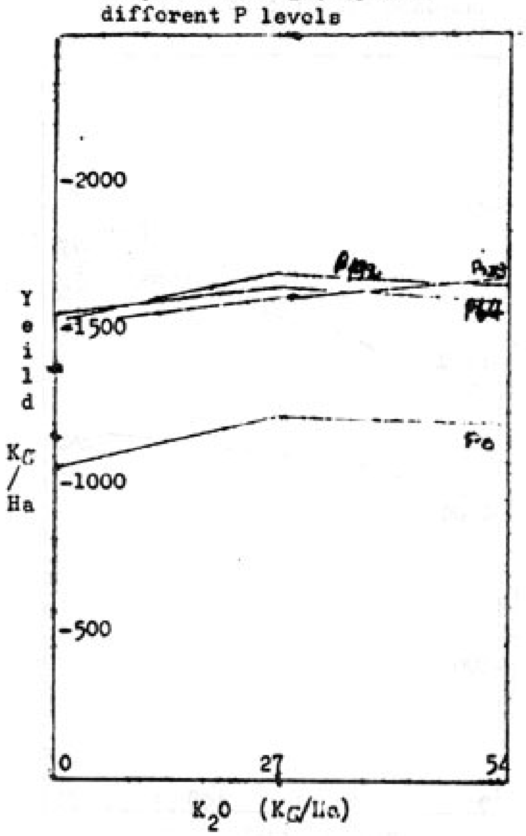
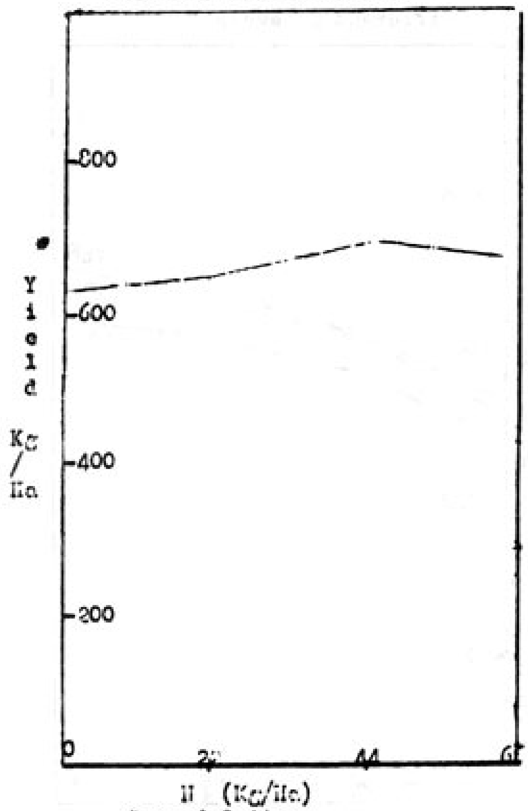


Fig 10

Response of Cotton to N



* Seed Cotton

Fig 11

Response of Cotton to P

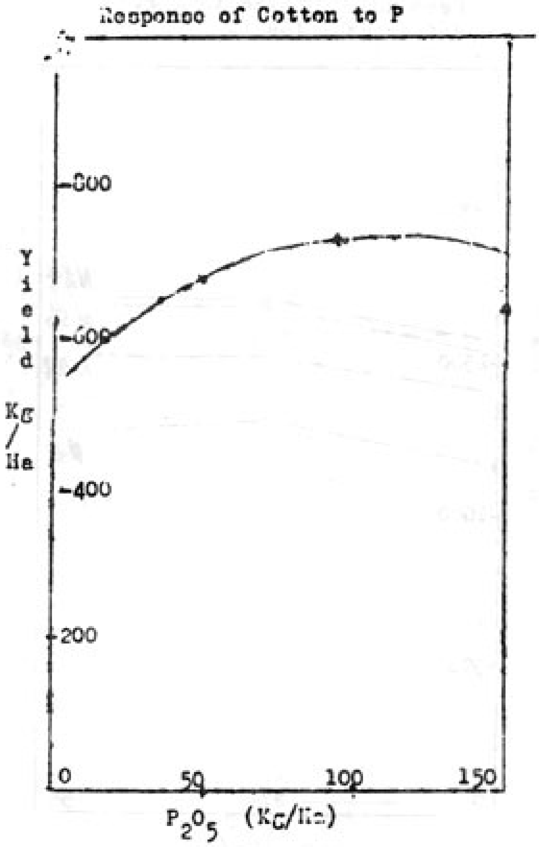


Fig 12

Response of Cotton to K

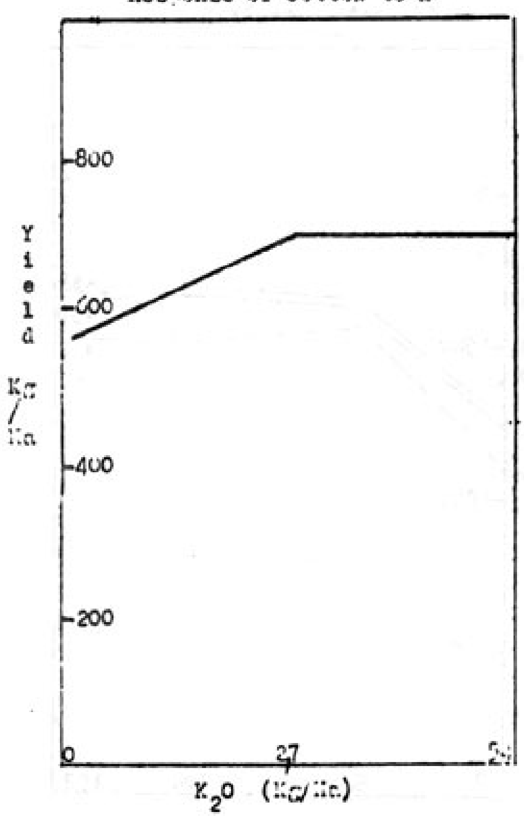


Fig 13

Response of cotton to N at different levels of P

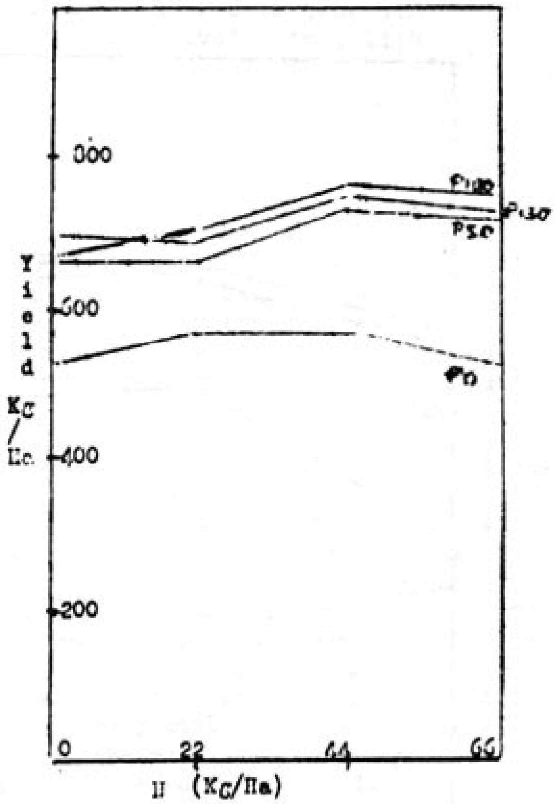


Fig 14

Response of cotton to N at different levels of K

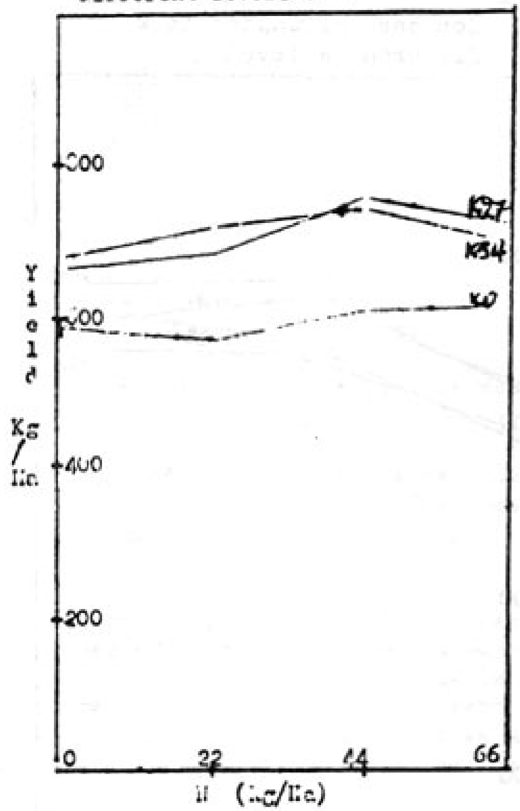


Fig 15

Response of Cotton to P at different N levels

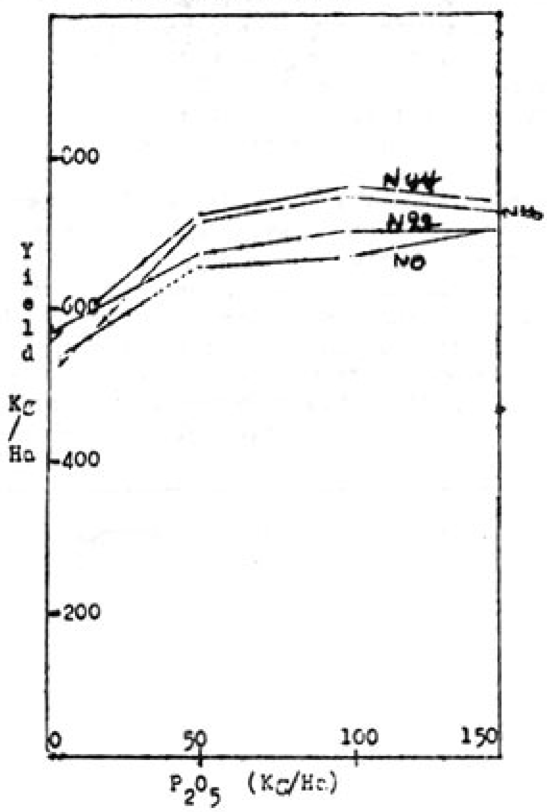


Fig 16

Response of cotton to P at different K levels

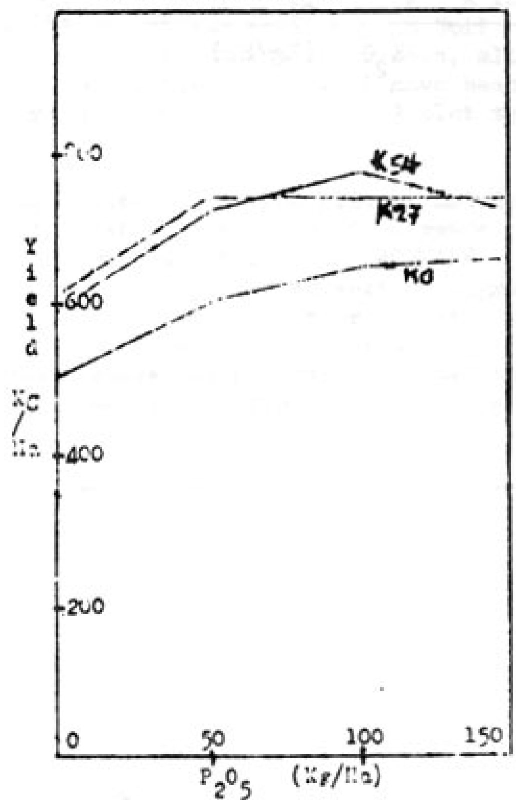


Fig 17
Response of Cotton to K at different N levels

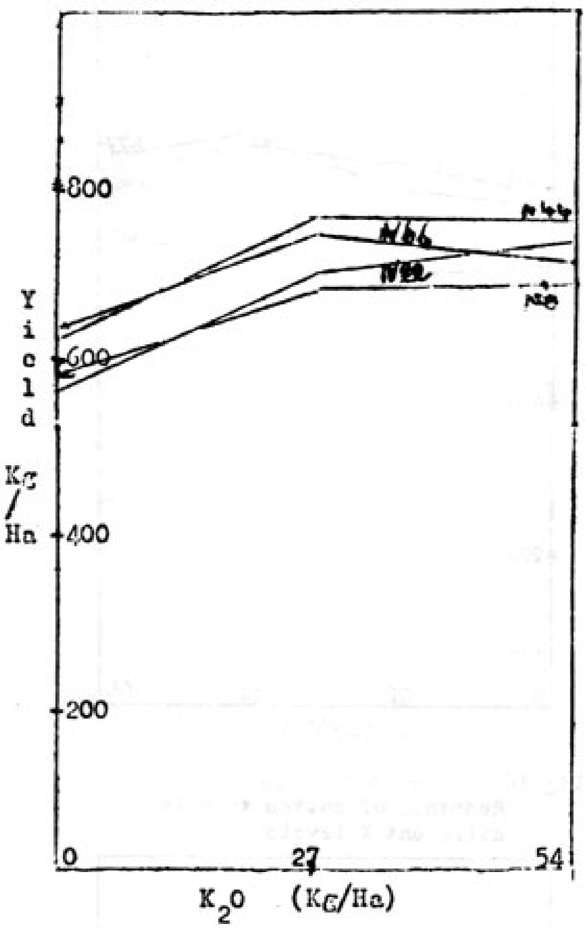
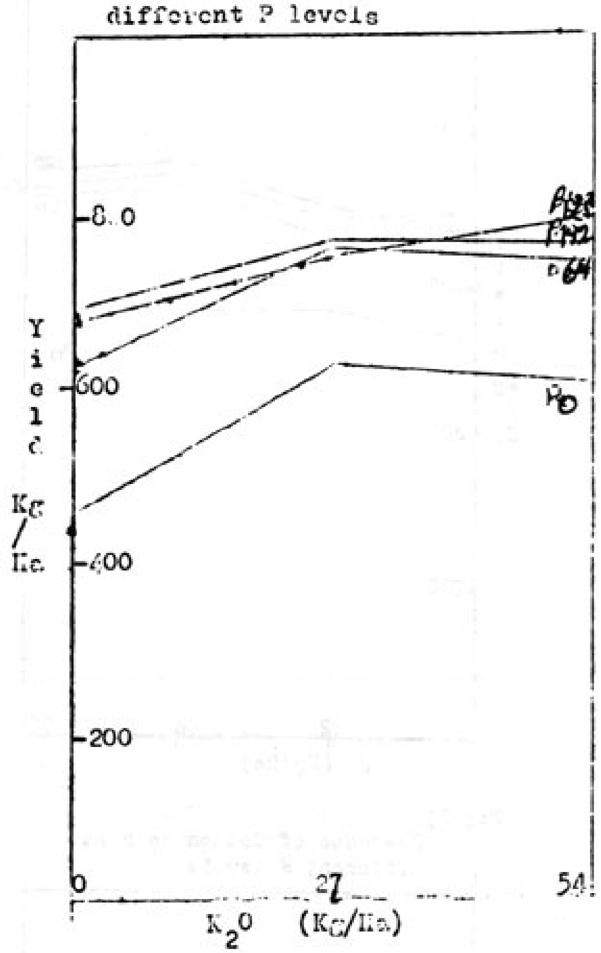


Fig 18
Response of Cotton to K at different P levels



SOME UP-TO-DATE RESULTS OF THE FAO/FFHC FERTILIZER PROGRAMME IN WESTERN STATE, FEDERAL REPUBLIC OF NIGERIA

by

L.A. Ayorinde* and S.H.R. Lampe**

Yield increase and economics of fertilizer use with upland rice, maize, yam and cassava are presented and discussed. Fertilizer recommendations are given where appropriate. All together 544 2^3 factorial trials and 137^6 plot demonstrations have been analysed covering the period 1963 to 1969. Trials and demonstrations were grouped together for the high rainfall forest zone and the southern guinea savanna zone of Western Nigeria.

All fertilizer trials and demonstrations were conducted on farmer's fields under local farming practices and carried out by the field staff of the Extension Services Division of the Ministry of Agriculture and Natural Resources as part of the FFHC Fertilizer Programme in Western Nigeria.

Fertilizer use was highly economical for rice and yam, and increased fertilizer use for these crops is highly recommended. Yield increases of maize in most cases were not high enough to give more than marginal profits. As long as the price for maize is low or improved varieties with a higher yield potential are not more commonly used fertilizer use for this crop will increase only slowly. Present price for cassava tubers is also very low and the market so insecure that only under optimum conditions fertilizer use for cassava is to be recommended.

INTRODUCTION

The FAO Freedom from Hunger Campaign Fertilizer Programme started in Nigeria in 1961/72 and still continues but only with non-residential assistance by a FAO Soil Fertility Specialist since early 1969. By the end of the 1970 cropping season, all together more than 17,000 fertilizer demonstrations and simple trials will have been laid out in Western Nigeria. Most of the demonstrations have been of the 2 or 3 plot type and are not reported in this paper.

A number of fertilizer experiments had been conducted by various Federal and Regional research organizations already so that the programme when initiated could be geared towards bridging the wide gap between Research and Farmers practice. The FAO/MANR Fertilizer Programme in Nigeria was built up as a purely fertilizer extension programme, using the best proven and recommended fertilizer types and rates in order to teach the farmers on their own fields and conditions its most economical use. Only a very limited number of 2^3 factorial trials and comparative 6 plot demonstrations have been carried out on part time basis by the field staff of the Ministry of Agriculture and Natural Resources Extension Services Division.

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* Higher Agricultural Superintendent
** FAO Soil Fertility Expert

Summaries of all together 681 trials and demonstrations are presented in this paper for upland rice, maize, yam and cassava. The total number is made up:-

Upland Rice	127	2^3 Factorial	trials	+ 16	6 Plot	demonstrations
Maize	128	"	"	+ 82	"	"
Yam	126	"	"	+ 39	"	"
Cassava	4	"	"	+ -	"	"
Total	544	"	"	+137	"	"

Description of Trials and Demonstrations

The 2^3 factorial trials consist of eight 1/40 acre randomised plots and one extra plot. The demonstrations have six 1/40 acre randomised plots. All plots are unreplicated. All trials and demonstrations have been laid out on farmer's field with crops grown under local farming practices and not under conditions normally applied at research stations. Only a small number of experiments was carried out using improved varieties such as N.S.1 and V.1 for maize and O.S.6 for rice, the vast majority was planted with local varieties. All experiments have been conducted by the field staff of the Extension Services Division working on part time basis.

Fertilizer Rates and Application

Sulphate of Ammonia, single superphosphate and muriate of potash were applied respectively at 20lbs N, 20lbs P_2O_5 per acre, singly and in all possible combinations in respect of the plots in the factorial trial pattern. The extra plot received 40lbs N, 40lbs P_2O_5 and 40lbs K_2O. The demonstrations tested N alone and in combination with P_2O_5 at the 20 lbs and 40lbs per acre level and allow comparison with a fully balanced NPK fertilizer treatment at the 20lbs nutrient level. All fertilizers were mixed where applicable and applied in one dose following present recommendation. Time of application was for Maize 1-2 weeks after germination by placement method 1-2 "deep 4-6" away from the plant and covered. All fertilizer to rice was broadcast 2-3 weeks after germination and hoed under with the following weeding. Yams were fertilized by placement into a shallow trench or ledge 3-4" deep around the upper half of the mound and covered with soil again. Time was after full germination at time of staking, generally not before second half of May. Fertilizer for cassava was applied as for maize but at a later date, 4-6 weeks after planting.

Economics of Fertilizer Use

The fertilizer prices used for the calculations are CIF, IBADAN plus average N£2:=:=d for transport charges and N£2:=:=d for sales agents commission. Storage costs, handling and profit margin are not included, being part and parcel of the Government fertilizer subsidy.

Fertilizer Farmgate Prices Used

Sulphate of Ammonia	(21% N)	N£27:=:=d	per ton.
Single Superphosphate	(18% P_2O_5)	N£26:=:=d	" "
Muriate of Potash	(60% K_2O)	N£32:=:=d	" "

Crop Prices Used

Rice (Paddy)	N£50:=:=d per ton
Maize	N£20:=:=d " "
Yam	N£10:=:=d " "
Cassava	N£ 4:=:=d " "

These prices represent the average for the period covered.

Yield Results

The yield data in Tables 1 to 8 are presented in terms of average and weighted average yield lbs. per acre and lbs increase over control. The value of increase in shillings less cost of fertilizer gives the profit or loss in shillings.

NOTE: For various reasons cost of applying fertilizer has not been considered.

Acknowledgements: Thanks go to the field staff of the Extension Services Division who actually carried out all the field work.

DISCUSSION

UPLAND RICE, (rainfed and grown mostly on freshly cleared forest land under high rainfall conditions).

127-2^3 trials conducted successfully in the high forest zone of Western Nigeria during 1963 and 1967 have been grouped together and analysed. The yield increase due to any fertilizer application tested ranged between 260lbs paddy per acre for muriate of potash alone and 440lbs. paddy with a full NPK treatment at the 20lbs pure nutrient level. The NPK treatment at the 40lbs nutrient level was not better than N or P alone or NP combined. This is to be explained by the use of the present cultivation of long straw varieties which are greatly affected by lodging after heavy fertilizer doses. Sixteen Fertilizer Demonstrations carried out in the forest in 1968 and 1969 show similar trends in spite of the wider use of the recently introduced upland rice variety OS.6 N-alone at 20lbs per acre was equal to 40lbs per acre and therefore more economical as a net return of about £6:=:=d could be realised on £1:=:=d spent for fertilizer NP at the 20lbs level was better and more economical than 20lbs N alone, NP at 40-20 yielded about the same at 20-20 but was less economic. The highest yield increase over control however was achieved with a fully balanced 20-20-20 NPK application which also gave the highest profit of all treatments tested but was only insignificantly higher than the 20-20-0 NP treatment. With the presently used long straw varieties susceptable to premature lodging resulting in reduced yields farmers are advised to use either NP or NPK fertilizer at the lower application rate. The fertilizer rate might be increased after better short straw varieties with higher yield potential and more resistant to lodging become available. At present 20-20-0 and 15-15-15 compound fertilizers are available for purchase and recommended for use by the farmers.

EARLY MAIZE: or Major Season Maize grown under high rainfall tropical forest conditions. In Table 2 80 2^3 factorial trial results recorded between 1963 and 1967 are grouped together and analysed. The yield increase due to any fertilizer treatment tested was relatively small with no significant differences between any given treatments. The yield increases ranged from 230lbs with the K application to 310lbs with the P application. It is surprising to note that NP and NPK did not perform better than P alone and that

NPK at the 40lbs nutrient level was less effective than P alone. Use of N, P and K and NK at the 20lbs level were just economical with a net return of about 2:1. Application of NPK at the 20lbs and 40lbs nutrient level was uneconomic. With 28 demonstrations carried out 1968 and 1969 only the 20-0-0 sulphate of ammonia application gave a yield increase big enough to allow a clear profit. The late maize in the second season showed equally unsatisfactory performances with only the N, P, K and NK treatments at the lowest level giving small profits. Reasons for the very disappointing yield increases of the maize in above trials and demonstrations should be seen in the light of extensive use of local varieties of a very superior grain and flour quality adopted to the environmental conditions but of a low yield potential. Fertilizer use for maize in this forest region will only become a worthwhile economic operation if the maize price goes up substantially or the fertilizer price goes down drastically. Fortunately for the farmers both trends are noticeable as the maize price has risen more than 50% recently and the government approved a 50% fertilizer subsidy as well.

EARLY MAIZE or, Major Season Maize in the Savanna woodlands (Southern Guinea Savanna) with 90 2^3 factorial trials recorded between 1963 and 1967 in this zone, the control yields were comparitively lower than in the forest zone but the overall fertilizer response was substantially higher. Yield increases between 420lbs and 490lbs of dry grain have been recorded for P, N, K, PK, NP and NK in this order. NPK at the 20lbs level gave yield increase of 510lbs and NPK at 40-40-40lbs of 570lbs. All fertilizer treatments were economic except the higher NPK 40-40-40 application which in spite of giving the physically highest yield increase was uneconomic. The best net return over the fertilizer investment was achieved with K alone with a Value Cost ratio of 6:1. 36 demonstrations in the Southern Guinea Savanna zone in 1968 and 1969 showed considerable yield increases to N and NPK application. The most profitable treatment tested was N 20-0-0 followed by NPK 20-20-20 and double the rate of sulphate of ammonia alone. 20-20-0 was not better than 20-0-0 and 40-20-0 was less profitable than 20-20-0.

54 trials with late maize in the second planting season confirm the results of the major season. K, N and P at the 20lbs level giving low yield increases and only marginal profits. Considering the economic performance of all fertilizer treatments tested on application of a NP = 2:1 or a NPK = 1:1:1 compound fertilizer at 1-2cwt per acre seems to be recommendable in the savanna woodland areas of Western Nigeria for the time being.

YAM - Forest Zone:

Summary of 23 factorial trials conducted between 1963 and 1967 in the forest zone gave good to very good yield increases in tuber weight ranging from 1300lbs with the N-20-20-0 to 2220lbs with the NPK 20-20-20 application. Noteworthy is the good performance of P and K alone and in combination.

As with any other crop tested also the yam did not respond favourably to a higher NPK 40-40-40 dose. 16 demonstrations in 1968 and 1969 showed that 40-40-0 was out-yielding 20-0-0 and 40-20-0 was out-yielding 20-20-0 with 20-20-20 showing the highest yield increase of 4,250lbs tubers. Generally the most economic fertilizer rate was NPK applied at the 20lbs nutrient level and in spite of all other treatments also being economical 1:1:1 balanced compound fertilizer seems to be the best recommendation to be made to farmers.

YAM, Southern Guinea Savanna (Savanna Woodland). This is the zone where yams are of considerable economic importance. In 82 2^3 factorial trials over 5 years high yield increases have been recorded to all fertilizers tested single or in combination. Noteworthy is the good performance of P and K alone and in combination with each other and with N. Most remarkable is the fact that of all crops tested only in this zone the yam gave substantially higher yield increases with the NPK 40-40-40 application and was as profitable as NPK 20-20-20. 23 demonstrations in this zone confirm above results that higher application rates can be used economically. A NPK 1:1:1 compound fertilizer up to 40-40-40 seems to be recommendable.

CASSAVA: Forest Zone:

Only a few 2^3 factorial trials have been recorded with this crop. The results have been too few and inconsistant so that no conclusions can be drawn. Generally however it seems that as long as the price for cassava remains as low as 4 shillings per cwt. no fertilizer is to be recommended.

With high yielding varieties presently being released and large scale commercial cassava plantings for industrial starch production under consideration, more fertilizer work is urgently required.

Table 1. Upland Rice - Forest 2 3 Factorial Trials - Economics of Fertilizer Use
Yields given in lbs. dry paddy per acre, value in shillings

Year	No. of Trials	Control 0-0-0	N 20-0-0	P2O5 0-20-0	K2O 0-0-20	NP 20-20-0	NK 20-0-20	PK 0-20-20	NPK 20-20-20	NPK 40-40-40
1963	39	1290	1514	1536	1422	1543	1515	1533	1592	1587
1964	17	753	1115	964	1019	1107	1112	1039	1126	1090
1965	27	955	1279	1347	1208	1285	1168	1247	1369	1287
1966	28	1307	1773	1765	1745	1663	1615	1637	1906	1694
1967	16	1327	1684	1660	1610	1687	1707	1671	1959	1725
TOTAL	127									
Weighted Average		1155	1489	1485	1417	1474	1434	1446	1598	1484
Increase over Cont.		-	334	330	262	319	279	291	443	329
Value of Increase		-	149	147	117	142	125	130	198	147
Cost of Fertilizer		-	23	26	10	49	33	36	59	118
Profit		-	126	121	107	93	92	94	138	29

Forest: Upland Rice: 6 Plot Demonstrations

Year	No. of Dem.	Control	N	N	NP	NP	NPK
1968	9	0-0-0	20-0-0	40-0-0	20-20-0	40-20-0	20-20-20
1968	9	1163	1485	1546	1583	1653	1555
1969	7	1227	1647	1581	1728	1695	1835
Weighted Average	16	1191	1556	1561	1646	1671	1678
Increase over Cont.		-	365	370	455	480	487
Value of Fertilizer		-	163	165	203	214	217
Cost of Fertilizer		-	23	46	49	72	59
Profit		-	140	119	154	142	158

Table 2. Maize 2 3 Factorial Trials - Economics of Fertilizer Use

Forest — Yields given in lbs. dry grain per acre, values in shillings

Year	No. of Trials	Control 0-0-0	N 20-0-0	P_2O_5 0-20-0	K_2O 0-0-20	NP 20-20-0	NK 20-0-20	PK 0-20-20	NPK 20-20-20	NPK 40-40-40
1963	16	1091	1408	1479	1352	1477	1489	1436	1441	1346
1964	15	1187	1308	1401	1321	1333	1280	1286	1338	1261
1965	16	1721	2012	1961	1908	1879	2119	1996	2055	2011
1966	15	1362	1546	1641	1623	1645	1630	1542	1608	1638
1967	18	1282	1540	1675	1578	1677	1585	1771	1682	1624
	80									
Weighted Average		1323	1566	1635	1559	1607	1624	1614	1630	1571
Increase over Cont.		-	243	312	236	284	301	291	307	248
Value of Increase		-	43	56	42	51	54	52	55	44
Cost of Fertilizer		-	23	26	10	49	33	36	59	118
Profit		-	20	30	32	2	21	16	(-) 4	(-) 74

Forest — Early Maize: 6 Plot Demonstrations:

Year	No of Dem.	Control. 0-0-0	N 20-0-0	N 40-0-0	NP 20-20-0	NP 40-20-0	NPK 20-20-20
1968	13						
1968	18	933	1247	1202	1272	1300	1276
1969	10	1198	1437	1293	1388	1561	1598
Weighted Aver.	28	1028	1315	1235	1313	1393	1391
Increase over Control		-	287	207	285	365	363
Value of Increase		-	51	37	51	65	365
Cost of Fertilizer		-	23	46	49	72	59
Profit		-	27	(-) 9	2	(-) 7	6

Table 3,
Forest

Late Maize 2 3 Factorial Trials - Economics of Fertilizer Use
Yields given in lbs tubers per acre, value in shillings

Year	No. of Trials	Control 0-0-0	N 20-0-0	P_2O_5 0-20-0	K20 0-0-20	NP 20-20-0	NK 20-0-20	PK 0-20-20	NPK 20-20-20	NPK 40-40-40
1963	15	1025	1115	1390	1293	1224	1383	1168	1214	1151
1964	11	968	1381	1209	1182	1532	1322	1352	1426	1535
1965	27	887	1120	1059	1182	1075	1145	1139	1154	1259
1966	10	1063	1202	1244	1170	1327	1269	1310	1278	1336
Weighted Av.	63	962	1186	1193	1206	1230	1251	1210	1235	1294
Increase over Cont.		-	224	231	244	268	289	248	273	332
Value of Increase		-	40	41	44	48	52	44	49	59
Cost of Fertilizer		-	23	26	10	49	33	36	59	118
Profit		-	17	15	34	(-) 1	19	8	(-)10	(-) 59

Forest Late Maize 6 Plot Demonstrations

Year	No of Dem.	Control 0-0-0	N 20-0-0	N 40-0-0	NP 20-20-0	NP 40-20-0	NPK 20-20-20
1967	15	993	1222	1222	1220	1255	1275
Increase over Cont.		-	229	229	227	262	282
Value of Increase		-	41	41	41	47	50
Cost of Fertilizer		-	23	46	49	72	59
Profit		-	18	(-) 5	(-) 8	(-) 25	(-) 9

Table 4.

Early Maize
Savanna

Maize 2 3 Factorial Trials - Economics of Fertiliser Use
Yields given in lbs. dry grain per acre, value in shillings

Year	No. of Trials	Control 0-0-0	N 20-0-0	P_2O_5 0-20-0	K_2O 0-0-20	NP 20-20-0	NK 20-0-20	PK 0-20-20	NPK 20-20-20	NPK 40-40-40
1963	23	1223	1597	1569	1492	1568	1681	1595	1640	1711
1964	10	1126	1524	1561	1726	1590	1619	1668	1751	1673
1965	28	1272	1768	1735	1731	1781	1722	1750	1771	1793
1966	21	924	1313	1282	1420	1446	1483	1400	1484	1604
1967	8		1249	1296	1120	1399	1105	1188	1244	1384
Weighted Av.	90	1108	1545	1529	1542	1593	1596	1571	1621	1678
Increase over Cont		-	437	421	434	485	488	463	563	570
Value of Increase		-	78	75	78	87	87	83	100	102
Cost of Fertilizer		-	23	26	10	49	33	36	59	118
Profit		-	55	49	68	38	54	47	41	(-)16

Savanna Early Maize **6 Plot Demonstrations**

Year	No of Dem.	Control 0-0-0	N 20-0-0	N 40-0-0	NP 20-20-0	NP 40-20-0	NPK 20-20-20
1968	22	1127	1500	1470	1420	1433	1540
1969	14	1214	1607	1768	1597	1797	1887
Weighted Av.	36	1161	1542	1586	1489	1575	1675
Increase over Cont.		-	381	425	328	414	514
Value of Increase.		-	68	76	59	74	92
Cost of Fertilizer		-	23	46	49	72	59
Profit		-	45	30	10	2	33

Table 5. **Maize 2 3 Factorial Trials - Economics of Fertilizer Use**

Late Maize **Yield given in lbs dry grain per acre, value in shillings**

Savanna

Year	No. of Trials	Control 0-0-0	N 20-0-0	P_2O_5 0-20-0	K_2O 0-0-20	NP 20-20-0	NK 20-0-20	PK 0-20-20	NPK 20-20-20	NPK 40-40-40
1963	6	970	780	1038	1138	1056	1156	867	996	1038
1964	13	940	1210	1159	1254	1185	1201	1210	1143	1258
1965	25	824	1146	1042	1112	1173	1072	1051	1180	1262
1966	10	766	1119	1104	1046	1080	1128	1158	1266	1173
Weighted Av.	54	858	1116	1082	1137	1146	1123	1089	1167	1220
Increase over Cont.		-	258	224	279	288	265	231	309	362
Value of Increase		-	46	40	50	51	47	41	55	58
Cost of Fertilizer		-	23	26	10	49	33	36	59	118
Profit		-	23	14	40	2	14	5	(-) 4	(-)60

Savanna **Late Maize** **6 Plot Demonstrations**

Year	No. of Dem.	Control 0-0-0	N 20-0-0	N 40-0-0	NP 20-20-0	NP 40-20-0	NPK 20-20-20
1967	3	591	977	1087	798	1074	1005
Incr.over Cont.		-	386	496	207	483	414
Value of Increase.		-	69	89	37	86	74
Cost of Fertilizer		-	23	46	49	72	59
Profit		-	46	23	(-) 12	14	15

Table 6. Forest

Yam 2 3 Factorial Trials - Economics of Fertilizer Use
Yields given in lbs tubers per acre, value given in shillings

Year	No. of Trials	Control 0-0-0	N 20-0-0	P_2O_5 0-20-0	K_2O 0-0-20	NP 20-20-0	NK 20-0-20	NPK 20-20-20	NPK 20-20-20	NPK 40-40-40
1963	8	6958	9057	9051	9029	9869	9385	9959	9069	9650
1964	14	9492	11447	11985	12427	11731	10944	11925	12530	11767
1965	11	10330	9964	10640	10516	10902	10360	10805	10970	11305
1966	7	10016	11958	12908	12420	12564	12844	12628	12290	12783
1967	4	5052	5868	5596	5947	8410	7363	6552	8875	6232
Weighted Av.	44	8922	10226	10681	10741	11016	10491	10911	11140	10925
Increase over Cont		-	1304	1759	1819	2094	1569	1989	2218	2003
Value of Increase		-	116	157	162	187	140	178	198	179
Cost of Fertilizer		-	23	26	10	49	33	36	59	118
Profit		-	93	131	152	138	107	142	139	61

Forest **Yam** **6 Plot Demonstrations**

Year	No. of Dem.	Control 0-0-0	N 20-0-0	N 40-0-0	NP 20-20-0	NP 40-20-0	NPK 20-20-20
1968	12	7386	8843	10048	8573	11344	10507
1969	4	8089	10963	14127	15046	11719	15742
Weighted Av.	16	7562	9373	11008	10191	11438	11816
Increase Over Cont.		-	1811	3506	2629	3876	4259
Value of Increase		-	162	313	235	346	379
Cost of Fertilizer		-	23	46	49	72	59
Profit		-	139	267	186	274	320

Table 7. **Yam 2 3 Factorial Trials - Economics of Fertilizer Use**
Savanna **Yields given in lbs tubers per acre, value given in shillings**

Year	No. of Trials	Control 0-0-0	N 20-0-0	P_2O_5 0-20-0	K_2O 0-0-20	NP 20-20-0	NK 20-20-20	NP 0-20-20	NPK 20-20-20	NPK 40-40-40
1963	24	8447	10486	10888	9656	11165	11107	9959	10552	11495
1964	21	7629	10206	10273	10394	10569	10376	10176	10660	11416
1965	19	9897	11667	12156	12200	12652	13213	12866	12876	12986
1966	15	8724	10948	11608	11294	10628	11875	11693	11973	12198
1967	3	9922	12947	13128	13612	12402	13189	13794	15185	16758
Weighted Av.	82	-	10862	11238	10879	11304	11624	111146	11548	12141
Increase over Cont.		-	2184	2560	2201	2626	2946	2468	2870	3463
Value of Increase		-	195	228	196	234	262	220	256	309
Cost of Fertilizer		-	23	26	10	49	33	36	59	118
Profit		-	172	202	186	185	229	184	197	191

Forest **Savanna** **Yam** **6 Plot Demonstrations**

Year	No. of Dem.	Control 0-0-0	N 20-0-0	N 40-0-0	NP 20-20-0	NP 40-20-0	NPK 20-20-20
1968	13	6375	9720	9298	8935	9638	9810
1969	10	8143	11023	11392	11029	13879	13419
Weighted Av.	23	7143	10287	10208	9845	11482	11379
Increase over Cont.		-	3144	3065	2702	4339	4236
Value of Increase		-	280	274	241	387	363
Cost of Fertilizer		-	23	46	49	72	59
Profit		-	157	228	194	315	304

Table 8.
Forest

Cassava 2 3 Factorial Trials - Economics of Fertilizer Use
Yields given in lbs tubers per acre, value given in shillings

Year	No. of Trials	Control 0-0-0	N 20-0-0	P_2O_5 0-20-0	K20 0-0-20	NP 20-20-0	NK 20-0-20	PK 0-20-20	NPK 20-20-20	NPK 40-40-40
1966	3	6716	8398	8825	9589	8164	8417	9444	7857	8975
1967	1	12886	12705	9438	6715	13370	10164	16577	9196	12886
Weighted Av.	4	8259	9475	8978	8871	9466	8854	11227	8192	9953
Increase over Cont.		-	1216	718	612	1207	595	2968	(-) 67	1694
Value of Increase		-	32	19	16	32	16	79	(-)	45
Cost of Fertilizer		-	23	26	10	49	33	36	59	118
Profit		-	9	(-) 7	6	(-)17	(-)17	43	(-) 59	(-) 73

FERTILIZER RESPONSE OF MAIZE OBTAINED ON FARMERS FIELDS IN THE CENTRAL AND VOLTA REGIONS OF GHANA

by

F. Donkoh* and G.T. van Renterghem**

INTRODUCTION

Experiments on fertilizer use with annual crops, especially maize were started systematically since 1948.

Prior to the FFHC - Fertilizer Programme, only N and P were tested on farmers fields and recommendations were formulated for cereals, yams and groundnuts.

The trial and demonstration programme established by the FFHC in 1962 used the 3 major nutrients with eventual higher applications.

Under this programme, numerous simple trials and demonstrations were carried out all over the country. While in the early stage only 2 levels of nutrients were tested from 1965 on more complex designs with 3 levels of N, P, K were laid out.

In the table below, some summarized data obtained through the FFHC trials carried out since 1962 are given. (Only those trials of the actual project areas are included).

TABLE I

SUMMARIZED RESULTS OF FFHC - TRIALS ON MAIZE IN HO-KPANDU AND SWEDRU AREAS

A. VOLTA REGION (Lbs/acre)

LOCATION	YEAR	No.	0-0-0	20-20-0	20-20-20	40-40-0	40-40-40
KPANDU	1964 M*	4	710	1010	1010	-	-
HOHOE	1964 M	6	1260	2420	1840	-	-
ZIOPE	1964 M	6	680	820	1080	-	-
ZIOPE	1964 m*	8	500	700	890	-	-
VOLTA**	1965 M	56	920	1340	1410	1370	1580
AVERAGE	-	-	890	1300	1120	1370	1580

* M: Major season   m: minor season   ** Average over different locations

* Crop production Division, Ministry of Agriculture, Accra. ** FAO Soil Fertility Expert.

B. CENTRAL REGION (Lbs/acre)

LOCATION	YEAR	No.	0-0-0	20-20-0	20-20-20
SWEDRU	1962 M	4	1130	1330	1490
	1963 M	18	720	1120	1570
	1963 m	2	540	1240	1870
	1964 M	10	900	1740	1820
AVERAGE	-	-	810	1340	1650

Based on these results, an application of 20-20-20 lbs/acre was generally recommended for maize.

This recommendation has been altered, however, using the results of a further extensive trial and demonstration programme of the Ministry of Agriculture.

At the present time, 40-40-0/acre (2 bags of 20-20-0) or 50-30-30/acre (2 bags 15-15-15 and 1 bag of SA) are recommended for maize to be planted in the major or minor season.

A follow-up of the previous FFIC - Fertilizer Programme, a UNDP Special Fund Project, has been under discussion since 1967.

A respective project titled "Increased Farm Production through Fertilizer Use" became then operational in February 1969.

The purpose of this project was to raise agricultural yields in selected areas through the proper use of fertilizers in combination with other improved agronomic practices.

As a supplementary but equally important function this project will help with the organization of operable fertilizer procurement and distribution system and the establishment of credit, supply and marketing facilities for farmers on a co-operative basis. Trials and demonstrations are forming the background for further improvement of fertilizer recommendations and the field correlation of the soil analytical methods under test.

The field programme of trials and demonstrations continues on an intensified scale the work previously done by FFHC with the purpose to either reconfirm former recommendations or to modify them on the basis of the newly obtained results.

In the early stage of the project, due to limited allocation of counterpart personnel, field operations were restricted to one particular area (Volta Region)* where all available staff was concentrated.

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* Volta Region: Ho-Kpandu
Central Region: Swedru-Ajumako

It was only since the beginning of 1970 that field activities in relation with the "Experimental and Demonstration Programme" could be extended also to Swedru-Adjumako (Central Region). Actually, the field programme is now operating in both regions, although on a different scale.

The field programme involves studies of various and numerous factors. It has to deal with different levels of fertilizers, forms of nutrients, time and method of fertilizer application, cultural practices, interaction of fertilizers with organic manuring, varieties and plant protection measures. Also relationships between soil type, soil conditions and fertilizer response should be established.

After 15 - 16 months of field work, however, some of the above mentioned studies on special subjects have not yet been started. This is not because they were considered as of minor importance, but that for immediate practical meaning and for organizational and training reasons, those presently conducted deserved higher priority.

The selection was made in such a way that it could be in harmony with the overall objective of the Project: "Motivate the farmer to increase yields by proper use of fertilizers as part of a good farm practice."

At least during the past period the main emphasis in the "Experimental and Demonstration Programme" was laid on "levels of fertilizers N P K" in combination with variety and spacing.

In how far these variables were considered in the establishment of the trial design, will be seen further.

The following table indicates the number of trials and demonstrations carried out during 1969/70 in both project areas:

TABLE II

Number of trials and demonstrations.

REGION	1969		1970	
	TRIALS		TRIALS	DEMONSTRATIONS
	Major season	Minor season	Major season*	Major season*
VOLTA	20 (15)	20 (13)	71 (59)**	60 (46)
CENTRAL	-	12 (10)	44 (34)**	-

* Became only available a few weeks ago.
** Some more results can still be expected.

Numbers between brackets represent trials with reliable results.

B. THE PROJECT'S EXPERIMENTAL AND DEMONSTRATION PROGRAMME

Up to now all agronomic technical field work was conducted in the form of the Experimental and Demonstration Programme. The extension activities needed to supplement those trials and demonstrations with the necessary promotional impact were performed on a rather limited scale.

The project, through mutual consultation between project staff, came to a somewhat different approach to the problem "trials – demonstrations" by studying the matter from various angles.

It was agreed upon that although "trials" and "demonstrations" are related to each other, demonstrations by nature had to be based on the results of trials. Each form should therefore keep its specific character and should serve its individual prupose.

It was further understood that this policy should apply to all trials, whether laid out on farmer's fields or not.

I. TRIALS

(a) FERTILIZER TRIALS:

During the first major season (1969) only "fertilizer" trials were established. In the following minor season also some "spacing" and "variety" trials were added.

The fertilizer trial design commonly used during the major and minor seasons 1969 was as follows (14 treatments):

0 0 0	–	2 0 0	–
–	1 1 0	2 1 0	3 1 0
0 2 0	1 2 0	2 2 0	3 2 0
–	–	2 3 0	3 3 0

\+ 221, 222, 223

(Levels 0,1,2,3 = 0, 40, 80, 120lbs. nutrients/acre)

During the major season 1970, 3 additional K treatments and 1 supplementary check plot were included. Thus the total number of plots (treatments) per block (replication) amounted to 18 with a revised design as given below:

0 0 0	–	2 0 0	–
–	1 1 0	2 1 0	3 1 0
0 2 0	1 2 0	2 2 0	3 2 0
–	–	2 3 0	3 3 0
+ 2 2 1	2 2 2	2 2 3	+ 0–0–0
3 2 1	3 2 2	3 2 3	

(Levels same as before)

The first design allows to establish the subsequent nutrient response curves:

(a) N in presence of P_1 (N/P_1) – 3 points of curve

(b) N in presence of P_2 (N/P_2) – 4 points of curve

(c) P in presence of N_2 (P/N_2) – 4 points of curve

(d) P in presence of N_3 (P/N_3) – 3 points of curve

(e) K in presence of N_2P_2 (K/N_2P_2) - 4 points of curve

(f) NP

(g) response surface.

The amended design allows:

a. same as before

+ K curve in presence of N_3P_2 (K/N_3P_2) - 4 points of curve.

LAY OUT

Replications: 3 per site

Planting distance: 2'6" x 2' (2 plants per hole)

Size of plot (excluding borderline): 10' x 20' (4 lines) - Plots separated by borderline.

Fertilizer application: 50% N + 100% P,K at planting time. 50% N at plant height of 1'6".

Variety: Diacol 153

Harvest: Weighing of cobs (4 lines)
weighing of grains
sampling for moisture testing.

PRACTICAL OBSERVATIONS

Per season, each supervisor with a team of labourers had to establish 5 trials, although some of them laid out 6 to 7. The supervisor was fully responsible for the overall execution of the field experiment, its regular observation and all cultivation and maintenance required.

The contribution of the farmer on whose field the trial was conducted, was limited to the land clearing and timely weeding.

Fertilizers were given free of charge, the harvest after weighing and recording of results was handed over to the farmer.

In general, there were only minor difficulties in finding farmers willing to provide land for trials.

Also, with the lay out of this quite complex design, no particular difficulties occurred.

The first crew of supervisors recruited for the project, had already worked for the FFHC - Fertilizer Programme in the area. They were quite experienced, understood the importance of their work and were capable to train "candidate supervisors" in most/all phases of their operations. It was also an advantage that those "candidate-supervisors" were mostly literate labourers who had acquired some field trial discipline.

ORGANIZATIONAL OBSERVATIONS

Trial policy was defined after technical discussions between project officers with the following major points as basis:

1. A field experiment by nature and objective is mainly explanatory and not demonstrative.

2. At least two, and preferably three to four replications should be laid out per treatment or variable.

3. The number of trials should correspond with the available capacity for proper supervision.

4. To obtain reliable and informative results all field operations have to be executed with the biggest possible degree of accuracy.

5. Appropriate modifications of trial policy should be made in consideration of the above mentioned points.

COMMENTS ON FERTILIZER TRIAL RESULTS (see TABLE III, p.78)

As the major season harvest 1970 only began a few weeks ago, it has not been possible to prepare detailed statistical analysis.

However, even without such details, it is possible to make some important observations.

A. VOLTA REGION

A clear distinction must first be made between trials conducted during the major season and those undertaken during the minor season.

The number of the first trials in the major season 1969 was restricted, as the supervisors allocated to the project (5 in total) were necessarily given intensive training. In general, the results obtained during that season were quite encouraging and in most cases the yield responses to 40-40-0, 80-40-0 and 80-80-0 were excellent.

In a few locations (Hohoe and Peki) a positive effect was also registered through an addition of K.

A major observation, valuable for all seasons concerned, are the high yields of the check plots (other than for Logba and Ziope). This again proves the positive effect of the introduction of the improved maize variety and the proper cultural practices.

During the major season 1970, the number of trials (always 3 replications per location) have been increased from 15 to 67.

Again, the positive effect of fertilizers is clear. In many cases, the highest increases were obtained through the use of 40-40-0, 80-40-0 or 80-80-0.

Regarding the response to K, the Hohoe results 1970 appear to confirm those from 1969. Also Logba, Kpetoe, Tsito, and Kponvi give high K response.

I think it is interesting to mention, here, that soil analysis of Tsito and Kponvi trials have indicated a K deficiency.

The results obtained for 80-80-40 in the Peki area during the major season 1970 barely confirm those of 1969.

The Minor season results are available only from 1969. The responses to fertilizers were less impressive, but this is mainly due to the extremely dry period during the last 2 months of the vegetation period. Indeed, practically no rainfall was recorded.

However, responses to 40-40-0 still seem to be quite appreciable, while for Hohoe, in particular, the high yields obtained using combinations with higher N level is quite remarkable.

B. CENTRAL REGION

Although, in general, an appreciable yield increase is obtained through the use of fertilizers as compared with the check plots for the minor season trials, no further difference can be seen between the various treatments tested.

In the first major season results (1970) it can be observed that very high yields were registered for the check plots.

There is an overall positive effect from the use of fertilizers but yield increases are less spectacular than in the Volta Region.

In some cases, 80-40-0 gave better results than 40-40-0, but the differences are generally too small to permit more definite conclusions.

In Abodom, Awutu and Ochiso, there seems to be a small but positive K effect.

TABLE III
VOLTA REGION
MAJOR SEASON 69 (Lbs/acre)

	No.	0-0-0	0-80-0	80-0-0	40-40-0	80-40-0	80-80-0	120-80-0	80-80-40
PEKI	3	1175	2450	1200	2800	3000	2475	2650	3100
VAKPO	2	1900	2225	3250	3250	3850	3800	3700	3600
LOGBA	2	550	1250	1850	2650	2250	2050	2650	2750
ZIOPE	4	950	1500	1425	1850	1975	1550	2000	1950
HOHOE	4	1450	2800	3400	3500	3400	3850	4225	3950

MINOR SEASON 69 (Lbs/acre)

	No.	0–0–0	0–80–0	80–0–0	40–40–0	80–40–0	80–80–0	120–80–0	80–80–40
PEKI	2	1050	1500	1375	1800	1400	1300	1600	1800
VAKPO	1	1600	1000	1600	2800	2600	2400	3100	2200
LOGBA	2	300	800	650	1600	1425	1625	1725	2000
ZIOPE	2	900	1000	950	2000	1725	1825	2225	2000
HOHOE	3	1400	1550	3325	2375	2325	2825	2750	2225

MAJOR SEASON 70 (Lbs/acre)

LOCATION	No.	0–0–0	0–80–0	80–0–0	40–40	80–40	80–80	120–80	80–40–40
ABUTIA	4	1500	2000	3200	3500	4450	3600	3625	3675
ADAKLU	4	1000	1300	2325	2600	3100	3300	3600	3200
ALAVANYO	3	1900	2300	2500	3750	3300	3800	4100	3800
BAME	3	1200	1800	2300	2250	2250	2375	2200	2400
GOLOKWATI*	1	1150	1800	3350	2650	3675	3750	3900	3700
HAVE	5	1000	1350	2350	2100	3100	2850	2450	2500
HO	3	1300	1900	2325	2900	2900	3100	2900	2675
HOHOE	3	1225	1850	2125	2500	2625	3050	3300	3575
KPALIME	4	1800	2300	2300	3650	3500	3200	3600	3050
KPANDO	8	1600	1925	3150	2900	3100	3125	3150	2750
KPETOE	3	1800	2100	2650	2700	3400	3500	3150	4025
KPONVI	4	1850	1775	2350	2600	2500	2600	2650	2900
LOGBA	3	975	1575	2550	2625	2700	2850	3300	4000
PEKI	4	1950	2000	2325	3000	3300	2800	2300	3050
TSITO	4	2000	1800	2800	2700	3300	3100	3750	3750
VAKPO	2	2500	3050	3100	4600	4700	4100	4200	3800
ZIOPE*	1	1150	1450	2650	2350	2300	2650	3200	2700

* Complete results not yet received.

CENTRAL REGION

MAJOR SEASON 70 (Lbs/acre)

LOCATION	No.	0-0-0	0-80-0	80-0-0	40-40-0	80-40-0	80-80-0	120-80-0	80-80-40
ABODOM	1	1850	2850	2400	1900	2650	2050	3050	2850
AJUMAKO	3	1200	1920	1656	1920	2250	2175	1950	2000
ASSIN MANSO	4	1100	1950	1800	2100	1750	2400	2800	2550
AWUTU	4	1950	2700	3500	3050	3600	3725	4500	3900
BAWSIASE	4	1900	2100	2300	2450	2550	2500	2150	2650
DARU-AMPONG	3	1850	2050	2375	2550	2750	2575	2475	2600
GOMOA ASSIN	4	2500	2800	2900	3400	3700	3850	4400	3600
OCHISO	2	1950	2100	1800	2000	2350	2100	2575	2800
SWEDRU	8	1550	2350	2600	2775	3200	3300	3300	3300

MINOR SEASON 69 (Lbs/acre)

	No.	0-0-0	0-80-0	80-0-0	40-40-0	80-40-0	80-80-0	120-80-0	80-80-40
SWEDRU	8	1350	1425	2025	2275	2300	2250	2475	2475

(b) VARIETY AND SPACING TRIALS:

"Variety - fertilizer" trials started with the minor season 1969, while the first "spacing" trials were established during the major season 1970.

Summary information is given below:

1. Variety trials:

   - Randomized Block design, 3 replications 16 plots per block.

   Varieties: 4 (Diacol 153, Mexican 17, Composite 1 Composite 2)

   Fertilizer levels: 4 (80-40, 80-40-40, 80-80-40, 120-80-40)

2. Spacing trials:

   - Split plot design, 3 replications, 18 plots per replication.

   Spacings: 3 (2' x 2', 2' x 2'6", 3'4" x 2')

   Varieties: 2 (Diacol + Mexican 17 or Composite 1,2)

   Fertilizer levels: 3 (40-40-0, 80-40-40, 120-80-40)

TABLE IV

NUMBER OF VARIETY AND SPACING TRIALS ESTABLISHED

AREA	VARIETY TRIALS		SPACING TRIALS
	MINOR SEASON 69	MAJOR SEASON 70	MAJOR SEASON 1970
VOLTA REGION	3 (3)	3 (2)*	4 (3)
CENTRAL REGION	-	3 (1)	-

* Number in brackets represent the number of trials with reliable results.

Although it is too early for reliable results as only few trials of this kind were conducted, the tendency seems to be in favour of Diacol 153, 2' x 2'6" and 40-40-0 or 80-40-0.

II. CORRELATION STUDIES

"SOIL TYPE - FERTILIZER RESPONSE"

The trial design has also been found suitable for correlation studies who have started in Ho-Kpandu area since the early stage of the project. A soil survey has been performed by technical officers from the Soil Research Institute in Kumasi to identify and classify major soil types in the project areas. It is still too premature to enter into details.

III. DEMONSTRATIONS

Based on the trials results, it became clear that in the Ho-Pkandu area, 3 successful fertilizer levels (40-40-0; 80-40-0; 80-80-0) were now to be compared under demonstrations conditions.

The risk of not obtaining considerable agronomic and economic effects through the use of those 3 treatments was the lowest possible.

In view of the high fertilizer response as recorded in trials by means of a combined application of better cultural practices (including improved seed) and the recommended fertilizer sales, yields of about 2000 lbs/acre could be expected.

In comparison, the average yield of unfertilized farmers fields is about 600-800 lbs/acre.

It is common knowledge that farmers are most reluctant to readily accept trial results, due to the fact that they are carried out by more or less experienced teams on very small fields.

However, by laying out the demonstrations on plots over experimental size, farmers generally became aware of the production potential of their lands.

LAYOUT:

As already mentioned 3 levels were selected for demonstration purposes. In the long run, however, due to some financial problems formulated by farmers willing to participate in the scheme, only 40-40-0 and 80-40-0 seem acceptable. For certain demonstrations 70-30-30 and 35-35-15 were used also. This was due to the fact that either soil analyses indicated a need for K or that simply the 20-20-0 grade for the formulation of 80-40-0 and 40-40-0 was not available.

TABLE V

LEVELS USED IN DEMONSTRATIONS - COST OF FERTILIZERS TO FARMERS

Lbs/acre	1st application	2nd application	Cost/acre*
80-40-0	2 x 20-20-0	2 x SA	N¢ 9.60
70-30-30	2 x 15-15-15	2 x SA	N¢ 9.60
40-40-0	1 x 20-20-0 1 x SS	1 x SA	N¢ 6.70
35-35-15	1 x 15-15-15 1 x SS	1 x SA	N¢ 6.70

* Based on following subsidized prices:

1 Bag (112 lb.) of 15-15-15 or 20-20-20 = N¢2.80 (± US$2.80)

1 Bag (112 lb.) of Sulphate of Ammonium (SA) = N¢2.00

1 Bag (112 lb.) of Single Super Phosphate = N¢1.90

TABLE VI

RESULTS OF 46 DEMONSTRATIONS
Yields in (lbs/acre)

LOCATION	80-40-0	70-30-30	40-40-0	35-35-15
ABUTIA (H)*	2750 (4)	-	1800 (1)	-
TSITO (H)	2200 (3)	-	1700 (2)	-
ABUADI (H)	2600 (1)	-	2100 (2)	-
KPETOE (H)	2300 (1)	3100 (1)	-	2000 (1)
GOLOKWATI (K)*	2200 (2)	2050 (2)	-	2000 (2)
KPANDU (K)	1850 (3)	1900 (1)	-	-
PEKI (K)	2050 (2)	-	-	1900 (5)
HOHOE (K)	-	2200 (3)	-	1750 (2)
VAKPO (K)	-	2000 (3)	-	-
ALAVANYO (K)	-	-	-	2050 (4)
SANTROKOFI (K)	-	2100 (1)	-	-
Total	15950	13350	5600	9700
Average I	± 2280	2225	± 1850	11950
Average II	2250		1900	

* (H): Ho ; (K): Kpandu. Numbers between brackets indicate number of successful demonstrations.

Each farmer willing to participate in the demonstration programme had to agree to the following conditions:

1. A field of at least 2 acres

2. Use of improved seed (Diacol 153) at the rate of 20 lbs/acre - Cash contribution : N¢ 0.20

3. Planting distance: 3' x 2'6", two seeds per hole

4. Planting in rows

5. First fertilizer application at planting time

6. Second fertilizer application when maize was about 1'6" high (45 cm) - After weeding.

7. 50% cash payment at reception of fertilizers

8. Balance to be paid after harvest.

There was no specific check plot included in the demonstration, since unfertilized adjacent farmers fields could easily be used for comparison.

Each farmer was assisted by a project field supervisor of the area who had to demonstrate to the farmer the practices of row planting and proper fertilizer application. The supervisor also had to inspect all his demonstration plots regularly and to advise the farmer on necessary and supplementary measures of cultivation.

Harvest was carried out at the rate of 5 samples of 1/100 acre each per field of 1 acre. An identical sampling method was applied to determine yields of unfertilized farmers field for which an average of 850 lbs/acre was recorded.

One of the obstacles was that demonstrations had normally to be established on lands of individual sometimes isolated farmers which resulted in a rather small promotional and educational impact.

Furthermore, a fertilizer demonstration on a 2 acre field with the condition to pay 50% cash at the reception of the fertilizers was somewhat unusual for most farmers. It took a considerable time to convince prospective co-operators through continuous contacts and discussions. Considerable support was obtained, however, through the "Maize Loan Scheme" launched by the Agricultural Development Bank in the project area.

Quite a number of farmers participating in the Fertilizer Demonstration Programme also took part in the above mentioned scheme.

The big shortcoming of all these efforts was that small farmers owning less than 2 acres and unable to clear or provide 6 acres as requested by the loan scheme had to be disregarded.

For this reason, during the minor season 1970 already the project Demonstration Programme had dropped the previous minimum acreage as condition for participation.

MAJOR COMMENTS ON THE RESULTS OF THE DEMONSTRATION PROGRAMME

Apart from the modest impact of the Demonstration Programme, the individual results are very encouraging and it can be considered as a first step towards real intensification of maize farming in the project areas of Ghana. Indeed, those farmers who had successfully participated in the programme, became now conscious that with an economic supplementary fertilizer input a considerable improvement in income can be obtained from their fields.

The following tables show the monetary benefit participating farmers got with the demonstration plots on their farms.

The economic returns are calculated on the basis of a minimum Government guaranteed price of N¢ 6.00 per bag (or 3 Np per lb.) for maize and of the subsidized fertilizer price levels (given in Table No.VII, pages 84-85).

Considering the remarkable fluctuations of the maize price during the year however, it can be stated that in most cases the use of 40-40-0 and even 80-40-0 can be definitely recommended to farmers. With this practice under "normal" conditions of rainfall a profit of at least N¢ 20.00 per acre can be expected.

Although the benefits of 80-40-0 versus 40-40-0 are not always 100%, the apparent tendency is in favour of 80-40-0 as probably the best recommendation for the time being.

TABLE VIIA

	ABUTIA		TSITO		ABUADI	
	80-40-0	40-40-0	80-40-0	40-40-0	80-40-0	40-40-0
Yield increase* lbs/acre	1900	950	1350	850	1750	1250
Value increase N¢/acre	57.00	28.50	40.50	22.50	52.50	37.50
Cost fert + seed N¢/acre**	9.80	6.90	9.80	6.90	9.80	6.90
Net Profit N¢/acre	47.20	21.60	30.70	18.60	42.70	30.60
V/C	5.8	4.1	4.1	3.6	5.3	5.4

TABLE VIIB

	K P E T O E			GOLOKWATI		
	80-40-0	70-30-30	35-35-15	80-40-0	70-30-30	35-35-15
Yield increase	1450	2250	1150	1350	1200	1150
Value increase	43.50	67.50	34.50	40.50	36.00	34.50
Cost fert + seed	9.80	9.80	6.90	9.80	9.80	6.90
Benefit	33.70	57.70	27.60	30.70	26.20	27.60
V/C	4.4	6.8	5.0	4.1	3.6	5.0

TABLE VIIC

	KPANDU		PEKI		HOHOE	
	80-40-0	70-30-30	80-40-0	35-35-15	70-30-30	35-35-15
Yield increase	1000	1050	1200	1050	1350	900
Value increase	30.00	31.50	36.00	31.50	40.50	27.00
Cost fert + seed	9.80	9.80	9.80	6.90	9.80	6.90
Benefit	20.20	21.70	26.20	24.60	30.70	20.10
V/C	3.0	3.2	3.6	4.5	4.1	3.9

TABLE VIID

	VAKPO	ALAVANYO	SANTROKOFI
	70-30-30	35-35-15	70-30-30
Yield increase	1150	1200	1250
Value increase	34.50	36.00	37.50
Cost fert + seed	9.80	6.90	9.80
BENEFIT	24.70	29.10	27.70
V/C	3.5	5.2	3.8

(*) Note: See Annex I where economic returns are calculated on the assumption that farmers should receive still the minimum price of N¢ 6.00 per bag and pay for the fertilizers:
CIF + inland transportation and handling charges.

C O N C L U S I O N S

Maize as the major food crop in Ghana enjoys the priority in government production planning. Therefore, with all trials and demonstration work conducted during the first period of the project emphasis was put on this crop.

Although by now on a small scale rice, cassava and cotton have been included in the trials and demonstration programme, it can be expected that as long as the project is operating in Ho-Kpandu and Swedru-Ajumako areas, maize will continue to remain the number one crop.*

In how far the trials (and eventually the demonstrations) thus far conducted, will lead to a confirmation or modification of the existing fertilizer recommendations is still too early to decide. There seems to be, however, an apparent trend in favour of 80-40-0/acre which under most conditions showed a very positive yield and economic response (particularly in the Volta Region).

On the whole, the overall judgement on trial values depend mainly from which angle their results are examined.

From a strict scientifical point of view, they are rarely fully satisfactory. For formulation of realistic and dependable fertilizer recommendations, however, trial results represent the soundest information base.

An experimental and demonstration programme has been included in the project.

In the promotion of progress in the use of fertilizers it has been considered as necessary to implement in practice (although with suitable reservations) the most successful treatments even if from the scientific point of view they may be 100% secure. The gain in time seems well worth the calculated risk of this approach especially where results have to be produced within a certain period of time.

Spirit and cooperation of the Ghanaian farmers participating in the project activities has contributed considerably to the continuation of the project trial and demonstration programme based upon the above mentioned policy.

As a final conclusion, a comparison is made between the overall averages of identical treatments from FFHC and Project trials.

TABLE IX

REGION	F F H C			PROJECT GHA 393		
	0-0-0	20-20-0	40-40-0	0-0-0	40-40-0	80-40-0
VOLTA	890	1300	1370	1450	2800	3050
CENTRAL	810	1340	-	1700	2570	2850

This shows obviously in how far Project trial results may influence the present recommendations particularly for the Volta Region where quite a substantial number of trials have been carried out.

(*) In certain areas of Hohoe, farmers nonetheless show a considerable interest in rice growing. Provided that improved varieties could be made available a slight expansion of our rice trial work would be justified.

ANNEX I

TABLE X

Comparison between subsidized prices, CIF prices and "CIF + Tpt" prices of some important fertilizers in Ghana (in N¢)

	Subsidized	CIF at Tema	CIF + Tpt
15-15-15	2.80	3.17	3.70
20-20-0	2.80	3.17	3.70
SA	2.00	2.33	2.90
SS	1.90	2.38	2.90

The prices indicated in the "CIF +Tpt" column are based on:

(a) 6 NP/Ton/Mile. for the demonstrations established in Ho-Kpandu area, an average of 120 miles is taken into account (or N¢ 7.20 per ton).

(b) a limited amount of N¢ 0.20 is added per bag for handling and other charges.

In the light of the above mentioned prices the economic returns as presented in Table No.VII will be amended as follows.

TABLE XI

LOCATION	TREATMENT*	BENEFIT N¢	V/C
ABUTIA	80-40-0	43.60	4.2
	40-40-0	18.80	2.9
TSITO	80-40-0	27.10	3.0
	40-40-0	15.80	2.6
ABUADI	80-40-0	39.10	3.9
	40-40-0	27.80	3.8
KPETOE	80-40-0	30.10	3.2
	70-30-30	54.10	5.0
	35-15-15	24.00	3.6
GOLOKWATI	80-40-0	27.10	3.0
	70-30-30	23.40	2.7
	35-35-15	24.80	3.6
KPANDU	80-40-0	16.60	2.2
	70-30-30	18.10	2.3
PEKI	80-40-0	22.60	2.7
	35-35-15	21.80	3.2
HOHOE	70-30-30	27.10	3.0
	35-35-15	18.30	2.8
VAKPO	70-30-30	21.10	2.5
ALAVANYO	35-35-15	26.30	3.8
SANTROKOFI	70-30-30	24.10	2.8

* Cost of treatment 80-40-0 = N¢ 13.20

Cost of treatment 40-40-0 = N¢ 9.50

Price of 200 lb. of Maize = N¢ 6.00

SIERRA LEONE, RICE PRODUCTION AND FERTILIZER

by

A.I.J. Sese * and H. Braun **

CHAPTER I

INTRODUCTION

Rice is the most important staple food crop in Sierra Leone. Due to increase of population, changes in nutritional habits and increased purchasing power the economy on rice has changed from a slight surplus to quite substantial imports.

Efforts are being undertaken to increase rice production. Three years ago the Ministry of Agriculture & Natural Resources initiated an Inland Valley Swamp Development Scheme which finds increasing response among farmers. Improved agricultural practices are introduced to farmers. A demonstration programme shows to farmers the effective use of fertilizers and the benefits deriving from their application.

Agricultural research is now investigating into improved varieities giving high response to fertilizer and better crop husbandry under the prevailing ecological conditions. This paper tries to underline the necessity of exchanging experiences in this regard, and last but not least, the common interest in the former West African Rice Research Institute at Rokupr, Sierra Leone.

To make it easier to understand problems and to exchange experience part I of this paper gives some information on the ecological and agricultural conditions of Sierra Leone.

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CHAPTER II

THE COUNTRY

1. Population

Total population: 2,500,000 (mid-year projection, 1969)

Average density: 90/sq.mile (35/sq.km)

Annual increase: 1.5%

2. Geography

Area of Sierra Leone: 27,925 sq.miles (about 72,350 sq.km). The relief is characterized by low land (0-250 feet or about 75 m of altitude) which covers about the Western half of the country, interrupted by relatively important creeks and rivers and isolated hill stretches.

The eastern half of the country is a plateau of 1000 to 2000 feet of altitude (about 300-600m) with some mountains in the North-East.

Natural Regions:

Swamp	2,337 sq.miles (6,200 sq.km)	8%
Closed forest (mainly secondary)	17,741 sq.miles (46,000 sq.km)	64%
Open Savannah-Woodlands	7,847 sq. miles (20,150 sq.km)	28%
Total	27,925 sq.miles (72,350 sq.km)	100%

3. Climate

Generally Sierra Leone has a tropical climate with one rainy season (May to October) and one dry season (November to April) per year. Mean annual rainfall is 125 to 150 inches (3.175 to 3.810 mm) in the coastal zone, below 100 inches (2.540 mm) in the north-eastern part, the largest proportion of the country receiving 100 to 125 (2.540 to 3.175 mm) inches per year.

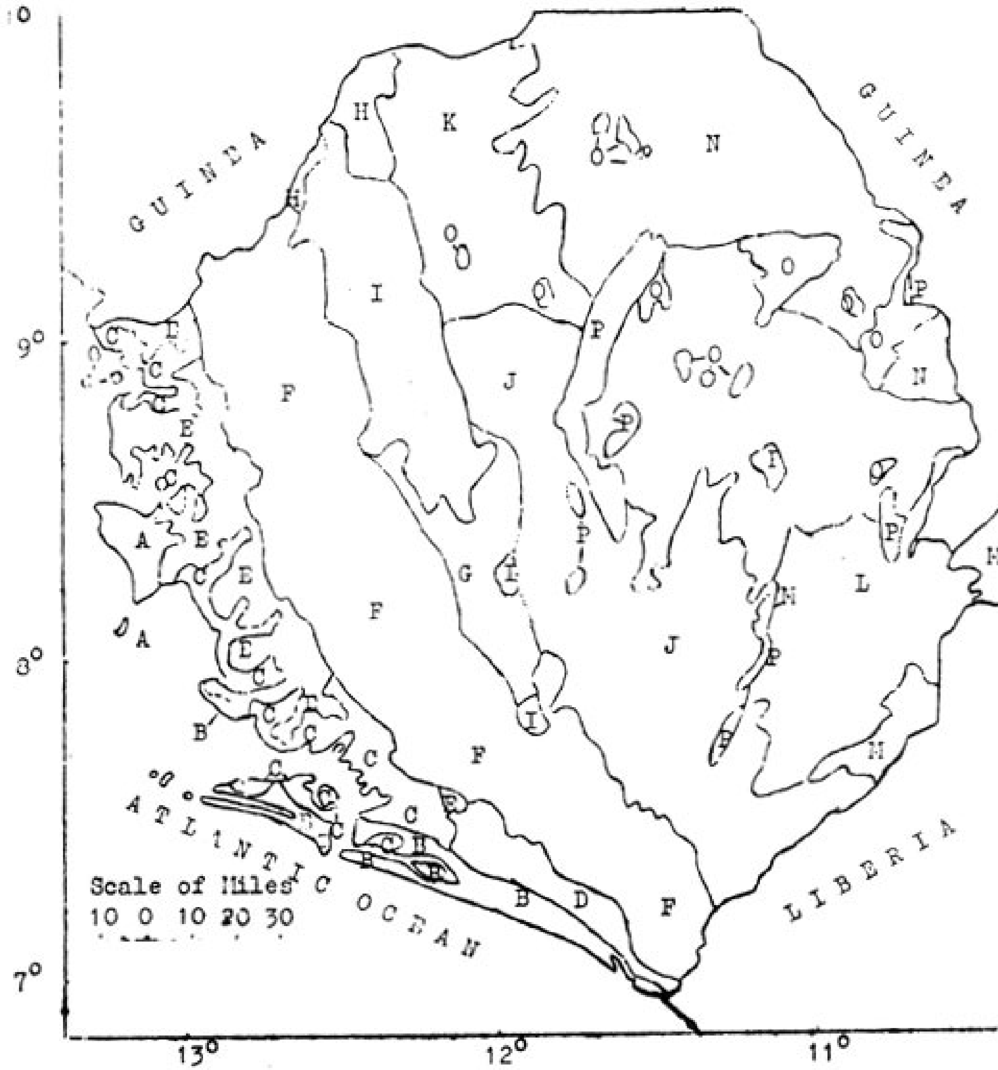
Mean annual temperature is around 80°F (about 27°C) with slight variations in the course of the year (rainy season lower, dry season higher). These variations are more accentuated in the interior (mean minima about 70°F/21°C, mean maxima about 90°F/32°C).

4. Soil

Considerable soil survey work has been carried out in the country so far but still more is required in many parts to obtain sound bases for agricultural development.

Generally, it can be said that soil conditions in Sierra Leone are greatly varying. Hardly any cultivated soil is of class one. The map showing the Soil Provinces should give some basic information on these conditions. (Fig. I). In the following table an attempt is made to characterize some soils according to their parent material, relative productivity and adaptation for various crops (Fig. I and Table I).

Rice is cultivated in the country on various soil types and generally the following classification is used:



SOIL PROVINCE MAP OF SIERRA LEONE

A Soils of the Peninsula Mountains from Noriteand Gabbro

B Soils of the Sandy Beach Ridges and Lagoons

C Soils of the Coastal Swamps

D Soils of the Alluvial Grassland Floodplaines

E Soils of the raised Beaches and Coastal Terraces

F Soils of the Interior Plaines from Acid Igneous and Metamorphic Rocks

G Soils from the Rokel River Series under Secondary Bush

H Soils from the Rokel River Series under Savanna

I Soils of the Bolilands

J Soils of the Escarpment Region from Granite and Acid Gneiss under Secondary Bush and Forest

K Soils of the Escarpment Region from Granite and Acid Gneiss under Savanna

L Soils of the Upper Moa Basin

M Soils of the Plateaus from Granite and Acid Gneiss under Secondary Bush and Forest

N Soils of the Plateaus from Granite and Acid Gneiss under Savanna

O Soils of the Hills and Mountains from Granite and Acid Gneiss

P Soils of the Hills and Mountains from the Kambui Schists

Fig.1 - Soil province map of Sierra Leone

Source: J.C. Dijkerman, Njala University College, University of Sierra Leone, May 1967.

4.1 Inland Valley Swamp Rice (Inland Swamp Development Scheme)

The total acreage available is about 738,000 and the acreage cultivated is 95,000 which is comparatively very low in terms of percentage (about 13%) and production has not been satisfactory.

However, with the traditional system of cultivation giving way to a better technical method of water control, stumping, efficient fertilizer use, improved or high yielding varieties coupled with good management, the Inland Valley Swamp Rice will reveal its true value in terms of increased production and higher yield.

Inland Swamp Rice is either transplanted or sown in inland depressions which are generally watered by small streams forming swamps. These are of varying fertility, and generally less poor than upland rice soils. Deep flooding rarely occurs and yields are higher than on uplands. Previously, a certain fertility level had been maintained by shifting cultivation, but the tendency is now towards permanent cultivation which embodies the factors enumerated before.

4.2 Inland Riverain Grassland Rice or "Boli" - Rice

Important areas of the central plain are covered with flat grasslands. They retain water from rain and become shallowly flooded due to the rise of rivers during rainy season. Fertility is relatively low but fertilizers and adopted varieties bring satisfactory yields. A Mechanical Cultivation Scheme for soil preparation and seed harrowing is operating in these areas. Rice is sown directly, firstly rainfed and then shallowly flooded.

4.3 Deep Flooding Grasslands

In the south some rivers are prevented by an ancient sand dune to enter the sea directly and flood deeply wide areas. Advantageous silt deposits exist. Floating varieties of rice are used.

4.4 Tidal Mangrove Swamps

Swamps bordering rivers and creeks still reached by tidal sea water. During rainy season enough fresh water is supplied to allow rice growing. Here again silt deposition appears. Yields may be somewhat lower than on deep flooding grasslands.

4.5 Upland Rice

The most important area is under this type of rice cultivation. Originally already relatively low soil fertility is maintained by shifting cultivation. With increasing pressure on the land fallow periods are diminishing and consequently, erosion becomes a problem. Comparatively, these soils have the lowest production capacity but represent for many farmers the only possibility to produce their subsistence rice as they do not dispose of other soils. Also under these conditions fertilizer and selected varieties give economical yield increases and higher returns especially for the considerable input of labour to clear the secondary bush every year.

5. Land Use

About one million acres (405.000 hectares) out of a total area of nearly 18 million acres (7,3 million hectares) are cultivated. The average size of agricultural holdings is about 4 acres (1.6 hectares).

Table I - Characteristics of some soils according to their parent material, relative productivity and adaptation for various crops

Parent material	Soil Province	Rel. Productivity	Nutrient Supply	Adapted Crops
Clayey gravel-free alluvium or colluvium	D,G,L	1	Fair	tree crops, grains, local food crops
Fine loamy residuum from granite or clayey residuum from quartz-rich granite	L	2	Fair	as above
Clayey gravel-free alluvium or colluvium	C,L	3	Fair	swamp rice, possibly dry season vegetables
Clayey or loamy gravel-free alluvium or colluvium	D,G	3	Poor	coffee, grains, oil palm, rubber, local food crops
Loamy gravel-free colluvium 24-24 inches thick over clayey gravelly material	G	3	Poor	coffee, oil palm, local food crops
Clayey gravel-free alluvium or colluvium 24-24 inches thick over clayey gravelly material	G	4	Poor	swamp rice, dry season vegetables
Loamy gravel-free colluvium 10-24 inches thick over clayey gravelly material	G	4	Poor	upland rice and other food crops after long bush fallow, groundnuts
Coarse sandy alluvium	B	5	Very poor	swamp rice
Loamy gravel-free colluvium 10 inches thick over clayey gravelly material	G	5	Very poor	upland rice and other food crops after long bush fallow, groundnuts

Source: Odell, R.T. and Dijkerman, J.C. - Properties, classification, and use of tropical soils, with special reference to those in Sierra Leone. Njala University College, University of Sierra Leone, 1967

TABLE II - Approximate areas under principal crops

Crop:	Area in 1,000 acres:	(in 1,000 ha):	Remarks:
Upland Rice	480	194.4	
Inland Swamp Rice	95	38.4	
Boliland Rice	27	11.0	
Mangrove Sw. Rice	18	7.3	
Deep Fl. Grassl. Rice	10	4.0	
(Total Rice)	(630)	(255.1)	
Pigeon Peas	56	22.7	
Coffee	55	22.3	28,000 acres in bearing age
Cassava	50	20.2	
Maize	50	20.2	
Groundnuts	47	19.0	
Cocoa	46	18.6	17,000 acres pure stands, 27,000 acres still stands
Yams	30	12.2	
Millet - Sorghum	20	88.1	
Sweet Potatoes	7	2.9	
Oil Palms	6	2.5	pure improved plantations only
Ginger	3	1.2	
Total	1,000	405.0	

Sources: - Ministry of Agriculture & Natural Resources

- Agricultural Statistical Survey of Sierra Leone 1965/66

TABLE III - Average annual production of principal crops (61-70)
(in 1,000 metric tons)

I. Foodcrops	61/63	63/66	66/68	68/69	69/70
Paddy (husk rice)	380	390	400	407	380
Cassava	61	60	60	60	60
Millet	12	12	12	12	12
Maize	9	10	10	10	10
Groundnuts	8	9	9	9	9
Sweet Potatoes/Yams	9	9	9	9	9

II. Cash Crops	63	64	65	66	67	68	69
Palm Kernels	51.6	43.0	46.5	50.3	19.8	52.8	50.8
Coffee	3.9	6.4	3.5	9.6	2.8	4.1	4.9
Cocoa	3.3	3.2	2.4	3.3	3.5	3.4	3.1
Piassava	5.6	7.0	0.8	1.5	0.6	2.5	2.4
Benniseed	0.2	0.3	0.1	0.2	0.2	0.2	0.1
Ginger	0.6	0.3	0.5	1.1	1.6	...	0.7

Source: - Ministry of Agriculture & Natural Resources.

CHAPTER III

RESPONSE TO NITROGEN OF RICE

EXPERIMENTAL RESULTS

The following should give some information how rice growing under various soil and crop conditions responds generally to fertilizer without considering varietal differences.

1. Inland Swamp Rice (Das Gupta, 1966)

Yield increase on rice due to the application of N was found out.

Fertilizer treatment:

Basic treatment of all plots - 100 lbs/acre of P_2O_5 as double superphosphate (44.5% P_2O_5) Nitrogen. 0 and 141 lbs/acre N as Sulphate of Ammonia.

Result on grain yield:

Treatment	grain yield (lb/acre)
Nitrogen	3883.8
No nitrogen	2028.0
Difference	1855.8

L.S.D. (P = 0.05) = 163.9

Productivity of N: One lb of N produced 13.13 lbs of grain (husk rice)

2. Mangrove Swamp Rice (Das Gupta, 1968)

The effects of levels of Phosphorus and Nitrogen on grain yield were found out in a split plot experiment (4 x 6) with four replications.

Fertilizer treatment:

N - 6 levels (0,30,45,60,75,90 lbs N/acre as Sulphate of Ammonia, 1/2 each at 15.37 and 59 days after transplanting;

P - 4 levels (0,30,60,90 lbs P_2O_5/acre as single superphosphate at transplanting)

K - Basic dressing of all plots, including control, by 30 lbs K_2O /acre as potassium sulphate.

Results on grain yield:

Effect of phosphorus and nitrogen on grain yield (lb/acre) under mangrove swamp cultivation.

Levels of nitrogen (lb/acre)	Levels of P_2O_5 (lb/acre)	0	30	60	90	Mean
0		2656.5	3161.2	2948.2	2897.1	2915.7
30		3057.2	3361.2	3367.3	3291.3	3274.2
45		3434.6	3639.9	3674.2	3710.0	3614.7
60		3417.4	3709.5	3729.0	3783.7	3659.9
75		3360.0	3650.0	3864.4	3875.0	3687.3
90		3322.3	3550.8	3699.9	3962.6	3633.9
Mean		3208.0	3512.1	3550.5	3586.6	

L.S.D. of phosphorus at 5 percent = 10.6

L.S.D. of nitrogen at 5 percent = 54.4

L.S.D. of phosphorus x nitrogen at 5 percent = 108.8

Productivity of N: Nitrogen, applied alone was most productive at the rate of 45 lbs/acre

One lb of N produced 17.29 lbs of grain (husk rice)

Productivity of P: Phosphate, applied alone was most productive at the rate of 30 lbs/acre.

One lb of P_2O_5 produced 16.86 lbs of grain (husk rice)

Both nutrients applied together at the same rate (N45,P30) gave the following productivity figures:

N - 1 lb = 10.60 lbs of grain (husk rice)

P_2O_5 - 1 lb = 16.86 lbs of grain (husk rice)

3. Boli - Rice (Das Gupta, 1968)

This experiment was carried out with the object to find out the best method of nitrogen application on Boli land rice. As the control plot received no nitrogen this experiment should also give some information on the effect of nitrogen on grain yields under Boli land conditions. The trial was designed as randomised block with three replications.

Fertilizer treatment:

N - 0 and 90 lbs/acre of N as Sulphate of Ammonia applied in three different ways:

(i) Whole quantity broadcasted at time of sowing

(ii) Whole quantity placed at depth of 6 inches (15cm) at time of sowing

(iii) 1/2 of total quantity broadcasted 4,10 and 17 weeks after sowing

P - All plots, including control, received a basal dressing of 40 lbs P_2O_5/acre as single superphosphate at time of sowing.

Results on grain yield:

Grain yield in different methods of nitrogen application under boli land rice cultivation

No.	Methods of nitrogen application	Grain yields (lb/acre)
1	Whole quantity broadcasted at the time of sowing of seeds.	1416.7
2	Whole quantity placed at 6 inches below the soil surface at the time of sowing of seeds	1683.7
3	Three split dressings	1676.4
4	No nitrogen	(1154.6)

L.S.D. at 1 percent = 55.4

L.S.D. at 5 percent = 36.6

Productivity of N:

Method of application	One lb of N produced lbs of grain (Husk rice)
(i)	2.91 lbs
(ii)	5.88 lbs
(iii)	5.80 lbs

4. Upland - Rice (Will, 1968)

A series of experiments had been carried out mainly to compare the effect on yields of two different nitrogen carriers on various rice soils. The design was a 3 N x 2 P split plot factorial with 4 replications.

Fertilizer treatment:

N - 0,40 and 80 lbs N/acre as Sulphate of Ammonia and another N carrier respectively applied 1/2 three weeks after planting and 1/2 seven weeks after planting.

Results on yields:

	N0	N40	N80
Am. Sulphate	1426	1854	1665

Productivity of N:

At a rate of 40 lbs/acre one lb of N produced 10.70 lbs of grains (husk rice).

TABLE IV - Productivity of Nitrogen (as Sulphate of Ammonia), summary of results from fertilizer experiments.

Yield increase in lbs husk rice per lb Nitrogen and value: cost ratios

	1966	1968		MEANS
Inland & Mangrove Swamp Rice				
Fertilizer treatment per acre	N14,P10,K0	H45	N45,P30	-
Productivity (yield increase in lbs Husk rice per lb Nitrogen)	13.13	17.29	10.60	13.54
Value of yield increase (cents of Leone)	43.3	57.0	35.0	44.7
Value: Cost Ratio	4.9	6.4	3.9	5.0
Boliland Rice				
Fertilizer treatment per acre		N90 P40		
Productivity (yield increase in lbs husk rice per lb Nitrogen)		5.88		5.88
Value of yield increase (cents of Leone)		19.4		19.4
Value: Cost Ratio		2.2		2.2
Upland Rice				
Fertilizer treatment per acre		N40		
Productivity (yield increase in lbs husk rice per lb Nitrogen)		10.70		10.70
Value of yield increase (cents of Leone)		35.3		35.3
Value: Cost Ratio		4.0		4.0
Mean per year of rice on all soil types (lbs. husk rice/lb Nitrogen)	13.13	10.17		10.92
Fertilizer cost, cents of Leone per lb pure Nitrogen	8.9	8.9		8.9
Crop price cents of Leone per lb husk rice	3.3	3.3		3.3

CHAPTER IV

RESPONSE TO PHOSPHATE

EXPERIMENTAL RESULTS

A series of experiments have been carried out on different rice soils and with varieties supposed to be well adapted to each soil type to find out the effects of levels of phosphorus on grain yield. Design randomised blocks with 3 to 4 replications.

1. Upland rice

Fertilizer treatment:

N - All plots, including control, received on equal treatment of 60 lbs N/acre as Sulphate of Ammonia, broadcasted 50% at 43, and 25% each 70 and 85 days after sowing.

P - 0, 15, 30, 45, 60, 75, 90 and 105 lbs P_2O_5/acre as single superphosphate applied at the time of sowing.

Results on grain yields:

Grain yield at various levels of phosphorus

Levels of P O (lb/acre)		Grain yield (lb/acre)
0		1569.2
15		1606.4
30		1617.8
45		1625.0
60		1768.0
75		1736.3
90		1664.2
105		1678.4
L.S.D. at 1 percent	=	55.6
L.S.D. at 5 percent	=	40.9

Productivity of P_2O_5:

At 15 lbs/acre one lb of P_2O_5 produced 2.48 lbs of grain (husk rice)

At 60 lbs/acre one lb of P_2O_5 produced 3.32 lbs of grain (husk rice)

2. Mangrove Swamp Rice

Fertilizer treatment:

N - All plots, including control, received an equal treatment of 90 lbs N/acre as Sulphate of Ammonia, applied ½ each at 14.49 and 77 days after transplanting

P - As in the before mentioned experiment (on upland)

K - All plots, including control, received 30 lbs K_2O/acre as potassium sulphate 62 days after transplanting.

Results on grain yields:

Levels of P_2O_5 (lb/acre)	Grain yield (lb/acre)
0	1887.4
15	2490.0
30	2770.2
45	2856.1
60	2953.1
75	2918.4
90	2895.7
105	2917.2

L.S.D. at 1 percent = 271.3

L.S.D. at 5 percent = 199.4

Productivity of P_2O_5:

At a rate of 15 lbs/acre one lb of P_2O_5 produced 40.17 lbs of grains (husk rice), at the rate of 30 lbs/acre one lb of P_2O_5 produced 29.43 lbs of grains (husk rice).

i. Boli Rice

Fertilizer treatment:

Entire treatment as in the experiment on Upland rice.

Results on grain yields:

Levels of P_2O_5 (lb/acre)	Grain yield (lb/acre)
0	751.4
15	835.5
30	923.4
45	928.0
60	1038.1
75	835.3
90	818.1
105	888.3

L.S.D. at 1 percent = 84.9

L.S.D. at 5 percent = 61.00

Productivity of P_2O_5:

At a rate of 15 lbs/acre one lb of P_2O_5 produced 5.66 lbs of grains (husk rice). At 30lbs/acre one lb of P_2O_5 produced 5.73 lbs of grains (husk rice).

TABLE V - Productivity of P_2O_5 (as single Superphosphate), summary of results from fertilizer experiments.
Yield increase in lbs husk rice per lb P_2O_5 and Value:Cost Ratios

	1969		MEAN
Mangrove Swamp Rice			
Fertilizer treatment per acre	N90,P15,K30	N90,P30,K0	
Productivity (yield increase in lbs husk rice per lb P_2O_5	40.17	29.43	34.80
Value of yield increase (cents of Leone)	132.6	97.1	114.8
Value: Cost Ratio	17.92	13.12	15.51
Boliland Rice			
Fertilizer treatment per acre	N60,P15	N60,P30	
Productivity (yield increase in lbs husk rice per lb P_2O_5)	5.66	5.73	5.70
Value of yield increase (cents of Leone)	18.7	18.9	18.8
Value: Cost Ratio	2.52	2.56	2.54
Upland Rice			
Fertilizer treatment per acre	N60,P15	N60,P60	
Productivity (yield increase in lbs husk rice per lb P_2O_5)	2.48	3.32	2.90
Value of yield increase (cents of Leone)	8.2	11.0	9.6
Value: Cost Ratio	1.11	1.48	1.29
Mean per year, rice on all soil types (lbs husk rice per lb P_2O_5)	-	-	14.47
Fertilizer Cost, cents of Leone per lb P_2O_5	7.4	7.4	7.4
Crop Price, cents of Leone per lb husk rice	3.3	3.3	3.3

CHAPTER V

RESPONSE TO N AND P_2O_5 OF RICE GROWN ON VARIOUS SOIL TYPES

RESULTS FROM FERTILIZER DEMONSTRATIONS

From 1966 to 1969 a total of 862 simple 3-plot fertilizer demonstrations on farmers' rice fields all over the country have been laid out, harvested and reported. The distribution of these demonstrations on the various soil types was as follows:

TABLE VI - No. and distribution on soil types of fertilizer demonstrations on rice, 1966 - 1969

Upland Rice	487 demonstrations
Inland Swamp & Mangrove Rice	291 "
Boli Rice	84 "
Total	862 demonstrations

The results of these demonstrations should also give an indication on the productivity of fertilizer under the ecological conditions of Sierra Leone.

Since in the case of Boli-Rice only fertilizer treatment did not vary throughout the years, effects of fertilizer on yields are also expressed in terms of productivity of one lb Nitrogen and Phosphate respectively.

It is quite obvious that results of demonstrations carried out under normal farming conditions by agricultural extension workers show a greater variation than data of experiments carried out by research stations.

The real value of fertilizer demonstration results derives from the following facts:

- Data are obtained straight from cultivators' fields. They are the results of a fertilizer application in the frame of various farm practices.
- The average results represent a relatively large number of samples, i.e. results of individual demonstrations, which tends to compensate for the inherent errors in singular sampling.

When evaluating the results all data coming from demonstrations which have not been carried out properly or where variable plot damage appeared are omitted.

A comparison between the average yield of a given area and the yield of the control plots in the demonstrations normally shows a difference in favour of the demonstration plots. That difference is explained by the superior care generally spent on demonstration fields.

TABLE VII - Productivity of Nitrogen (as Sulphate of Ammonia), summary of results from fertilizer demonstrations, 1966 - 1969.

Yield increase in lbs husk rice per lb P_2O_5 and Value: Cost Ratios

	1966	1967	1968	1969	Mean (M) Total (T)
Inland & Mangrove Swamp Rice					
Number of demonstrations	14	106	83	88	291 (T)
Fertilizer treatment per acre	N20,P20,KO	N30,P30,KO	N30,P30,KO	N40,P40,KO	
Productivity (Yield increase in lbs husk rice per lb pure Nitrogen)	3.60	8.57	8.70	12.33	8.30(M)
Value of yield increase (cents of Leone)	11.9	28.3	28.7	40.7	27.4 (M)
Value: Cost Ratio	1.3	3.2	3.2	4.6	3.1 (M)
Boliland Rice					
Number of demonstrations	3	37	24	20	84 (T)
Fertilizer treatment per acre	N20,P40,KO	N20,P40,KO	N20,P40,KO	N20,P40,KO	-
Productivity (Yield increase in lbs husk rice per lb pure Nitrogen)	21.25	3.15	11.80	31.15	16.84(M)
Value of yield increase (cents of Leone)	70.1	10.4	38.9	102.8	55.5 (M)
Value: Cost Ratio	7.9	1.2	4.4	11.5	6.2 (M)
Upland Rice					
Number of demonstrations	42	183	191	71	487 (T)
Fertilizer treatment per acre	N20,P20,KO	N30,P30,KO	N20,P20,KO	N10,P40,KO	-
Productivity (Yield increase in lbs husk rice per lb pure Nitrogen)	20.80	4.83	14.45	16.40	14.12(M)
Value of yield increase (cents of Leone)	68.6	15.9	47.7	54.1	46.6 (M)
Value: Cost Ratio	7.7	1.8	5.3	6.1	5.2 (M)
Mean per year of rice on all soil types (lbs husk rice/ lb N)	15.22(M)	5.52(M)	11.65(M)	19.96(M)	13.09(M)
Fertilizer cost, cents of Leone per lb pure Nitrogen	8.9	8.9	8.9	8.9	8.9
Crop price, cents of Leone per lb husk rice	3.3	3.3	3.3	3.3	3.3

TABLE VIII - Productivity of P_2O_5 (as Single Superphosphate), results from fertilizer demonstration, 1966 - 1969.

Yield increase in lbs husk rice per lb P O and Value:Cost Ratios

Inland & Mangrove Swamp Rice	1966	1967	1968	1969	Mean Total (M) (T)
Number of demonstrations	14	106	83	88	291 (T)
Fertilizer treatment per acre	NO,P20,KO	NO,P30,KO	NO,P30,KO	NO,P40,KO	-
Productivity (yield increase in lbs husk rice per lb P_2O_5)	14.00	6.33	14.80	13.70	12.21(M)
Value of yield increase (cents of Leone)	16.2	20.9	48.8	45.2	40.3 (M)
Value: Cost Ratio	6.2	2.8	6.6	6.1	5.4 (M)
Boliland Rice					
Number of demonstrations	3	37	24	20	84 (T)
Fertilizer treatment per acre	NO,P40,KO	NO,P40,KO	NO,P40,KO	NO,P40,KO	-
Productivity (yield increase in lbs husk rice per lb P_2O_5)	4.93	8.15	9.00	11.73	8.45(M)
Value of yield increase (cents of Leone)	16.3	26.9	29.7	38.7	27.9 (M)
Value: Cost Ratio	2.2	3.6	4.0	5.2	3.8 (M)
Upland Rice					
Number of demonstrations	42	183	191	71	487 (T)
Fertilizer treatment per acre	NO,P20,KO	NO,P30,KO	NO,P20,KO	NO,P40,KO	-
Productivity (yield increase in lbs husk rice per lb P_2O_5)	14.80	4.30	14.85	7.88	10.46(M)
Value of yield increase (cents of Leone)	48.8	14.2	49.0	26.0	34.5 (M)
Value: Cost Ratio	6.6	1.9	6.6	3.5	4.6 (M)
Mean per year of rice on all soil types(lbs.husk rice/ lb P_2O_5)	11.24(M)	6.26(M)	12.88(M)	11.10(M)	10.37(M)
Fertilizer cost, cents of Leone per lb P_2O_5	7.4	7.4	7.4	7.4	7.4 (M)
Crop price, cents of Leone per lb husk rice	3.3	3.3	3.3	3.3	3.3

CHAPTER VI

THE ROLE OF POTASSIUM

Reports of experiments with this nutrient are scanty, the main reason being that earlier work showed no yield responses to K especially under traditional cultivation with varieties best adapted to these conditions.

With increasing use of Nitrogen and Phosphate this nutrient will gain importance in the near future. New experiments are under way in this regard.

The Chinese Agricultural Mission to Sierra Leone uses on its rice fields the formula N100, P40, K50 with varieties of Taiwan origin and on soils well responding to Nitrogen. In an experiment laid out in 1970 this formula serves as control.

In other cases potassium is included in the basal dressing as an empiric measure.

In the frame of the fertilizer demonstration programme an additional treatment of Potassium as Muriate of Potash (40 lbs K_2O/ acre) has been added to the standard treatment (N40, P40) in four locations of sandy soil where poor response to the usual fertilizer treatment had been observed in previous years.

The averages of the results from the four sites show on the N40, P40, K40 plot yield increase of 721 lbs of husk rice (27.8%) over control, and an increase of 368 lbs (12.5%) as compared to the plot with the N40, P40 treatment.

C H A P T E R VII

FERTILIZER AND RICE VARIETIES

Following the generally prevailing conditions agricultural research concerning rice varieties formerly dealt mainly with those giving best yields under traditional methods of cultivation.

In many cases it was only during recent years that research turned to varieties well responding to fertilizer and other improved agricultural practices.

With increased applications of nitrogen lodging and blast problems appeared with some improved local varieties. This may also explain to a certain extent the phenomenon that during the 1969 fertilizer demonstration campaign local varieties have seemingly better responded to fertilizer than improved varieties.

1. Response to fertilizer of improved varieties, summary of results from recent experimental work.

The following tables are extracts and summaries of recent research work of the Rice Research Station Rokupr, Sierra Loene. They should provide some information on the production capacities of rice varieties. Some of these varieties are recommended in the country since sometime, others have been included into research more recently.

Figure 2 is based on results from an experiment carried out by the Chinese Agricultural Mission comparing the response to fertilizer of some varieties of Taiwan origin and other established varieties in use in the country.

2. Response to fertilizer of improved varieties and unidentified local varieties, results from fertilizer demonstrations on Inland Swamp Rice, 1969.

Table IX shows the average yield increases of 48 fertilizer demonstrations on Inland Swamp Rice with unidentified varieties as compared to those of 40 demonstrations on improved varieties.

On the plot treated with 40 lbs P_2O_5/acre the unidentified local varieties showed an average yield increase of 603 lbs of husk rice/acre (27%) over control whereas the average increase in yield of improved varieties was 481 lbs/acre for the same treatment.

An application of 40 lbs P_2O_5/acre together with 40 lbs N/acre brought about an average increase in yield of 1207 lbs/acre (55%) over control with unidentified local varieties and 361 lbs/acre (14%) with improved varieties.

The additional dressing with 40 lbs N/acre gave 604 lbs/acre (22%) more for unidentified local varieties as compared to 361 lbs/acre (14%) for the improved varieties.

TABLE IX - Inland Swamp Rice, response to fertilizer of various varieties, results from four different locations, in lbs husk rice/acre.

Fertilizer Treatments		Location No. 1 N40,P40,KO		Location No. 2 N60,P60,KO		Location No. 3 N60,P60,KO		Location No. 4 N60,P60,KO		Averages		
Variety:	Origin:	Mean	Fert. Response	Mean	Fert. Response	Mean	Fert. Response	Mean	Fert. Response	Mean(*)	Fert. Response(*)	
IR 5-198-1-1	Philippines(IRRI)	4284	+ 456	-	-	-	-	-	-	4284(1)	+ 456	(1)
Ecombouce	Senegal	3612	+ 216	2065	+ 235	1854	+ 383	-	-	2510(3)	+ 278	(3)
Faya	Malawi	2844	+ 120	2273	+ 847	1299	+ 95	-	-	2139(3)	+ 354	(3)
B 13	Rokupr (S.L.)	2748	+ 792	2556	+ 732	-	-	-	-	2652(2)	+ 757	(2)
IR 5-114-3-1	Philippines(IRRI)	2016	+1296	-	-	-	-	-	-	2016(1)	+1296	(1)
R.H. 2	Malaysia	4188	+1176	2184	+ 266	-	-	1646	+ 863	2673(3)	+ 768	(3)
Nachin 11	"	-	-	2099	+ 593	736	+ 192	1487	+ 736	1441(3)	+ 507	(3)
R.C. 4	"	-	-	2296	+1174	-	-	-	-	2296(1)	+1174	(1)
Radin China	"	-	-	-	-	-	-	1296	+ 422	1296(1)	+ 422	(1)
IR 8	Philippines(IRRI)	-	-	-	-	1375	+ 705	-	-	1375(1)	+ 705	(1)

(1) = No. of results, of which averages had been established.

TABLE X - Upland Rice, response to fertilizer of various varieties, results from three different locations, in lbs husk rice/acre.

Variety	Origin	Location No. 1 Mean	Location No. 1 Fertilizer Response	Location No. 2 Mean	Location No. 2 Fertilizer Response	Location No. 3 Mean	Location No. 3 Fertilizer Response	Averages from 3 locations Mean(C)	Averages from 3 locations Fertilizer (C) Response
Tikiri Samba	India (via Nigeria)	2061	+727	1680	+422	1920	+992	1887 (1)	+714 (2)
Bogutui	Sierra Leone	1861	+126	1920	+512	1189	+330	1657 (2)	+323 (11)
Niduaboi	" "	1668	+577	1512	+880	1068	+272	1416 (8)	+576 (6)
Anethoda	India (via Nigeria)	1648	+482	1632	+352	1808	+832	1596 (3)	+555 (8)
V. 2806 - D5	Ceylon	1593	+390	1936	+576	1085	+698	1538 (4)	+555 (8)
Baanyalojopoilum	Sierra Leone	1480	+418	1792	- 96	1017	+461	1430 (7)	+584 (5)
Filiwa	" "	1425	+598	1768	+786	1259	+797	1484 (5)	+727 (1)
IR 193 B	Philippines(IRRI)	1698	+564	-	-	818	+695	1258 (13)	+629 (4)
IR 140 A (12)	"	1607	+236	1568	+896	1117	+150	1431 (6)	+427 (9)
IR 127 C (7)	"	1592	+503	1560	+688	1008	+480	1387 (9)	+557 (7)
IR 140 A (3)	"	1282	-195	1320	+432	-	-	1301 (10)	+118 (13)
IR 140 A (1)	"	1228	+304	1195	+240	1384	+240	1269 (12)	+261 (12)
IR 142 A (11)	"	1088	+ 86	1176	+1040	1372	+851	1212 (14)	+659 (3)
IR 193 A (2)	"	1082	+551	1480	+272	-	-	1281 (11)	+411 (10)

Fertilizer treatment: N - 60 lbs/acre as Sulphate of Ammonia, 1/2 each broadcasted 30 and 50 days after sowing.

P - 60 lbs/acre as single Superphosphate, total quantity broadcasted 30 days after sowing.

(C) = Classification according to performance.

TABLE XI - Upland Rice - Response to fertilizer of various varieties (the seven best IRRI varieties vs. Anethoda) results from two different locations in lbs husk rice/acre.

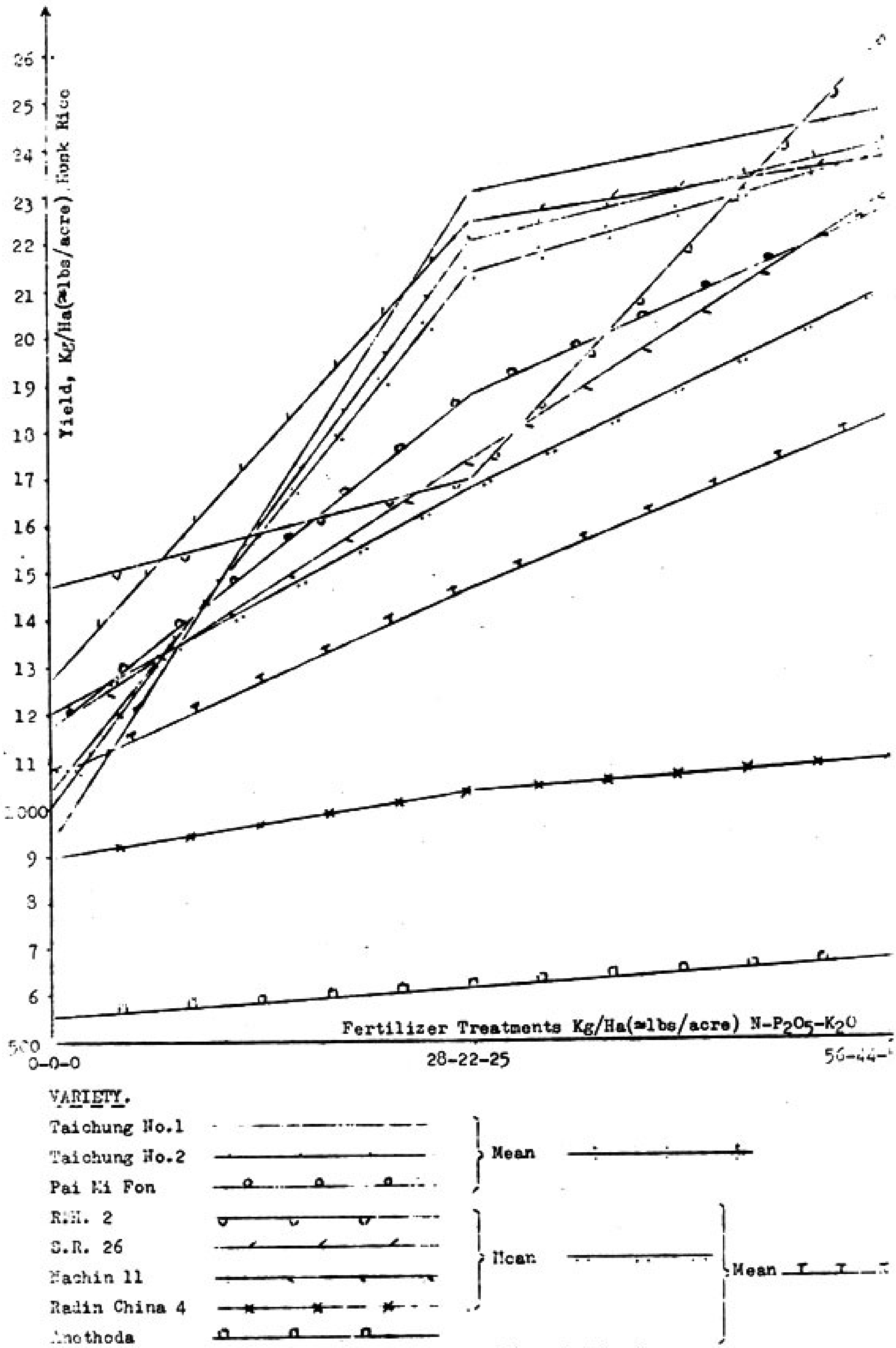
	Location No. 1		Location No. 2		Averages from 2 locations	
Variety	Mean/(C)	Fertilizer Response/(C)	Mean/(C)	Fertilizer Response/(C)	Mean/(C)	Fertilizer Response/(C)
IR 8-188-1	2033 (1)	+1079 (3)	885 (7)	+ 408 (7)	1459 (6)	+ 743 (6)
IR 8-172-3-1-2	1891 (2)	+1620 (1)	544 (8)	+ 545 (5)	1217 (8)	+1082 (3)
IR 3-140-3-1-2	1709 (4)	+ 985 (4)	1933 (3)	+1144 (3)	1821 (1)	+1064 (4)
IR 4- 90-2	1418 (5)	+ 675 (6)	2382 (1)	+1770 (1)	1800 (2)	+1222 (1)
IR11-288-3-1-2	1369 (6)	+1188 (2)	1473 (6)	+ 490 (6)	1421 (7)	+ 839 (5)
IR13-66-14-1	1314 (7)	+ 466 (8)	1943 (2)	+ 953 (4)	1628 (4)	+ 709 (7)
IR 4- 93-2	1309 (8)	+ 952 (5)	1783 (4)	+1225 (2)	1546 (5)	+1088 (2)
Anethoda	1844 (3)	+ 595 (7)	1634 (5)	Nil (8)	1739 (3)	+ 297 (8)

Fertilizer treatment: N - 60 lbs/acre as Sulphate of Ammonia, 1/2 each broadcasted 30 and 50 days after sowing.

P - 50 lbs/acre as single Superphosphate, the total quantity broadcasted 30 days after sowing.

(C) = Classification according to performance

Response of different Rice Varieties to Fertilizer
S.L.C.A.M., Mange, 1969, Inland Swamp.



Source: Sierra Leone Chinese Agricultural Mission

TABLE Comparison of response of unidentified local varieties and improved varieties from fertilizer demonstrations on Inland Swamp Rice, 1969.

Variety	No.of Dem	Average yields, lbs husk rice per acre Fertilizer treatment			Average yield increase in lbs husk rice per acre & %		
		Plot 0-0-0	Plot 0-40-0	Plot 40-40-0	Plot 2vs1	Plot 3vs1	Plot 3vs2
1.Local	48	2205	2808	3412	603(27)	1207(55)	604(22)
2.RH2	28	1887	2430	2801	543(29)	914(48)	371(13)
3.RC4	12	2383	2719	3057	336(14)	674(28)	338(12)
4.Average 2 & 3	40	2035	2516	2877	481(24)	842(41)	361(14)

3. Response to fertilizer of improved and local varieties results from an Upland Rice extension site of the Department of Agricultural Economics and Extension, Njala University College, 1969.

It is interesting to note that forementioned Department gained similar experience on a 130 acres (about 53 hectares) extension site where local varieties under Upland rice conditions gave better yields than improved varieties.

Fertilizer treatment:

N - 26 lbs/acre as Sulphate of Ammonia, broadcasted 5-6 weeks after sowing.

P - 26 lbs/acre as Basic Slag incorporated before sowing.

Variety	No. of Samples	Average yield lbs husk rice/acre	Yield as compared to Anethoda lbs husk rice/acre	
1. Teteki	2	1936	+113	+ 6.2
2. Jumukui	2	2016	+193	+10.6
3. Bojutui	1	1774	- 49	- 2.7
4. Falagui	2	1980	+157	+ 8.6
5. Fillie	1	2017	+194	+10.6
6. Jowanjei	1	2319	+496	+27.2
7. Gbongoi	1	1331	-492	-26.0
8. Anethoda	5	1823	-	-
9. Nachin 11	3	991	-832	-45.6
Mean of local varieties(1-7)	10	1910	+ 87	+ 4.8
Mean of improved var.(8 + 9)	8	1407	-416	-21.8

TABLE XIII - Responses to fertilizer of improved and local varieties, yield samples of Upland Rice on an extension site, 1969 (N.U.C.).

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APPENDIX

ADDRESSES

of institutions concerned with soil fertility and fortification.

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N.U.C.
ROKUPR
Sierra Leone

Factulty of Agriculture
Njala University College
Private Mail Bag
FREETOWN
Sierra Leone

The Fertilizer Officer
Fertilizer Unit, Agricultural Division
Ministry of Agriculture & Natural Resources
FREETOWN - KISSY
Sierra Leone

SUMMARY OF ECONOMIC RETURNS OF FERTILIZER IN AFRICAN COUNTRIES (In the FAO Fertilizer Programme)

by

J.W. Couston*

Knowledge on the part of farmers of the methods of using fertilizers and their effect on yield is, of course a precondition for using fertilizers. However, the question of whether or not to use fertilizer on a crop is an economic one. That is will their use be profitable? This depends on the physical response obtained, the relationship between the price of the crop and the cost of the fertilizer including transport, application, interest on credit, etc. the additional cost of harvesting and marketing the larger crop and the residual value in later years of the fertilizer applied. Generally in experimental, field trial or demonstration work the extra harvesting and marketing costs and residual values are not known precisely. It is common practice to assume that these extra costs are covered by the value of the residual yield to simplify the calculation of economic return to fertilizer use.

That crop response to fertilizers follows a curve which after a certain point increases at a diminishing rate and eventually declines is of greatest economic importance. The most profitable level of fertilizer may be well below the amount required to produce the highest possible yield. This is shown in Table 1, where the largest yield is obtained with six units of fertilizer but the maximum profit is attained at four units. If a fifth unit of fertilizer is applied the additional unit costs more than the value of the additional yield: \$17 vs \$12. Maximum profits are thus obtained when the cost of the additional unit of fertilizer equals the value of additional output: \$17 vs \$17. That is when the input/output price ratio is equal to the marginal physical product (i.e. $Px/Py = \Delta y/\Delta x$ or $Px\Delta x = Py\Delta y$: the value of the change in input is equal to the value of the change in output). Therefore, to determine maximum profit, information in the form of marginal yield and price relationships must be available. As price ratios change, the level of fertilizer must also change, to maintain maximum profits.

In practice, however, such precise marginal yield data are not usually available, or if so are not representative applying only to a discrete set of conditions. However, from research, field trial and demonstration data there is a predictable range of fertilizer rates which are economic under given cost and price relationships. It is within this range that fertilizer recommendations are made and in which farmers apply fertilizers. In many cases farmers use less than the recommended rates. This

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is because the amount of fertiliser that a farmer will use will depend on the anticipated yield response crop prices expected, fertiliser availability and cost, level of farmers incomes and credit availability, tenure considerations, the degree of risk and uncertainty that the farmer must take and his ability to absorb these risks.

Of course the uncertainty of some of these factors may be ameliorated by subsidies, price supports, credit and tenure regulations depending upon the policy and economic resources of the country. The uncertainty of weather, pests and diseases, etc. as they may affect yield, however, remain.

In the Fertilizer Programme the rates and ratios of nutrients used in the trials and demonstrations with different crops are those that are generally known to give responses within the economic range under the given conditions. When fixed treatments (rates and ratios of nutrients) are used, the determination of the economic returns is a simple calculation. The two measures used in the Fertilizer Programme are the net return and value/cost ratio (VCR). The net return is the value of the extra crop produced after deducting the cost of the fertiliser treatment, and the VCR the ratio of the value of the extra crop to the cost of the fertilizer. For example, a VCR of 2 represents a return above the cost of the fertiliser treatment of 100 percent. This measure is of particular interest to small-scale farmers who having limited resources are concerned with the return they get on the money they spend on fertilisers.

In Table 1 this would be at the first unit of fertilizer which gives the largest yield increase and largest value of added crop and VCR. The crop and fertiliser prices used in calculating these economic measures are those received and paid by farmers.

From Table 2 it can be seen that the trials and demonstrations gave good economic returns in countries where the Fertiliser Programme operated in Africa. The VCR's ranged from 2.5 in Morocco to 6.0 in Nigeria for all crops. The economic returns naturally varied by crop in each country (Tables 3 and 4). This was owing to yield response and particularly the price relationship between the cost of the fertiliser and the price of the crop. Generally speaking maize, millet, sorghum, wheat and barley, the lower priced cereal crops, showed the smallest returns while rice, groundnut and tubers showed the highest.

These economic returns show that it is profitable for small-scale peasant farmers employing traditional farming methods to use fertilisers if there is an assured market. Furthermore the crop yield per kilogramme of nutrients which ranged from about 8 to over 20 depending on the crop indicates that it is more economic in terms of saving foreign exchange to use fertilizers whether imported or locally produced, to provide needed food crop supplies, rather than to import them. Even if food grains can be imported on concessional terms, the social and economic benefits, of local production rather than importation should not be overlooked. Of course export of cash and other crops earns foreign exchange.

Table 1 - Optimum Level of Fertilizer

No. of units of fertilizer applied per ac. (X)	Total crop output lb/ac. (Y)	Marginal product (Y/X) for each unit of fertilizer	Value of added fertilizer at $17/unit	Value of added crop at $ 0.05/1b
1	1030	1030	17.00	51.50
2	1740	710	17.00	35.50
3	2230	490	17.00	24.50
4	2570	340	17.00	17.00
-	----	----	----	----
5	2810	240	17.00	12.00
6	2900	90	17.00	4.50
7	2820	-80	17.00	-4.00
8	2670	-150	17.00	-7.50

$P_X \Delta X = P_y \Delta y$; ($17) (1) = ($0.05) (340)

$17 = $17

Table 2 - Economic Summary of Trial and Demonstration Results, all crops 1961/62 - 1966/67 (a)

Country	Number	Average of Best VCR (b)
Morocco	2571	2.5
Nigeria	8124	6.0
Senegal	2019	4.9
Togo	288	2.9
Sierra Leone	511	4.0
Ghana	6269	5.3
Cameroons	231	3.0
Ivory Coast	164	2.8

(a) Results are for 1 or more seasons

(b) Average VCR of the best treatment weighted by the number of trials and demonstrations.

Table 3 - Economic Summary of Trial and Demonstration Results, by Selected Crops 1961/62 - 1966/67 (a)

Country and Crop	Number	Average of Best VCR (b)
Morocco		
Wheat: hard, dryland	1,030	1.9
irrigated	146	3.3
Barley, dryland	188	2.1
Broadbeans	120	3.7
Chickpeas	108	2.5
Cotton	97	2.6
Olive	157	2.0
Groundnut	45	10.4
Nigeria		
Maize	3,635	2.2
Rice	1,399	6.1
Yam	1,882	10.6
Cassava	254	4.5
Cotton	104	4.7
Groundnut	126	6.9
Senegal		
Millet	988	4.3
Rice	528	6.5
Groundnut	445	4.2
Togo		
Maize	56	1.8
Rice	40	3.6
Yam	64	3.9
Groundnut	70	2.3
Sierra Leone		
Rice	385	4.0
Groundnut	118	4.3
Ghana		
Maize	3,201	3.7
Rice	874	5.0
Millet	126	1.8
Yam	875	11.0
Groundnut	719	7.2
Cameroons		
Sorghum	25	1.8
Groundnut	104	1.9
Ivory Coast		
Maize	20	2.7
Rice	91	2.6
Yam	49	3.1
Ethiopia		
Teff	60	3.5
Wheat	181	3.0
Barley	57	1.9

(a) Results are for 1 or more seasons
(b) Average VCR of the best treatment weighted by the number of trials and demonstrations.

Table 4 - Economic Summary of Trial and Demonstration Results 1961/62 - 1966/67 (a)

Crop	Number	Average of Best VCR (b)
Maize	6,929	3.0
Rice	3,839	6.0
Millet	1,114	4.0
Yam	2,882	10.5
Groundnut	1,586	5.6

(a) Results are for 1 or more seasons

(b) Average VCR of the best treatment weighted by the number of trials and demonstrations.

FERTILIZER CREDIT AND CASH PILOT SCHEMES

by

M. Mathieu*

Definition

A fertilizer pilot scheme offers farmers enlarged possibilities to obtain the fertilizer used in demonstrations, for selected crops, on a limited surface per farmer on a Revolving Fund basis.

This is the third step in a Fertilizer Programme, the first being the assessment of the treatment to be recommended by trials, and the second showing the profit from this treatment to the farmers through demonstrations in their own fields.

Conditions of Success

1. No pilot scheme should be initiated unless a firm demand has been previously created through demonstration work. When farmers desire the fertilizer they have been using or seen used in demonstration fields, and are persuaded that its use leaves a clear net profit, then it is time to offer them this fertilizer through a pilot scheme. Demand is triggered when the value/cost ratio or ratio between crop increment output and fertilizer input goes beyond 2.

2. In order to have deep and durable mass impact on the whole selected area, a minimum percentage of farmers should preferably participate in the scheme. If participants are too scattered, they could provoke ostracism from others. For the first year, fifty percent of farmers in the area participating in the scheme is ideal. Ten percent is a minimum. In this respect, there is no real minimum number of participants in the scheme. It depends on the size of the selected area, which may only be a few neighbouring villages and as few as 20 farmers.

3. On the other hand, in order to keep control of operations, the number of farmers should not be too big if the educational process is to be thoroughly carried out on a personal contact basis by extension, banking and supply agents.

   From experience, over 200 participants per area start being difficult to handle. Also, it is preferable that all participating villages be neighbouring for mass impact purpose. However, to foster a mutual security feeling, large groups should be broken down into groups based on kinship, residential or ethnic ties, and lists should be small enough to enable members to acquire confidence in, and a knowledge of, one another. The target is to achieve a sense of personal participation in the group.

4. A pilot scheme first concentrates on the predominant crop in the area. Wheat - cotton - peanut - potato - tobacco - lentil - sugar-beet - citrus tree - olive tree - maize - have already been used. Later, a second crop can be added, e.g. potato after cotton.

5. A steady market must exist for the selected crop, so that the output/input ratio remains above 2 for years, in order to sustain demand for fertilizer.

6. How, if any, should selection among applicants be made is a debatable problem.

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For the first year, at least, experience shows that a selection should be based on an advanced appraisal of capacity and willingness of repayment. Here are three examples of how it can be done:

(a) Selection according to a certain level of income tax, where it has been established that the really progressive farmers can be selected that way. In Morocco the chosen level corresponds to farmers with full ownership of at least one pair of draft-oxen.

(b) Selection by the village-mayor, assisted by village council members and extension and bank agents.

(c) Auto-selection through a down-payment at ordering time, 15% for an order on credit (Morocco) and 25% for a cash order (Ethiopia).

The first-year selection is intended to eliminate known defaulters or heavily indebted farmers. Once a new mentality toward repayment is established in the said community, conditions of admission can be made easier.

7. A pilot scheme is based on a group approach, a group order and preferably a group guarantee (mutual security).

Since hopefully the demonstration work has been a village affair, then fertilizer ordering also becomes a village affair.

A village-list is established after careful screening of applicants whereby so much fertilizer is ordered for the village.

At the time of ordering and on an average of two months before delivery, the first scheme meeting takes place in the village with the assistance of extension, bank and supplier representatives who explain the new terms of credit, supply and application of fertilizer, each one for his own subject matter.

The group-order is established and in the case of a credit scheme all efforts are made to foster a mutual security mentality. However, it has been impossible to have non-defaulter participants pay for defaulters, so far, with the exception of the down-payment system. In this case, when the down-payment is deposited, participants know that the money is especially there to compensate defaults.

However, even if mutual security can be enforced in this case, its enforcement has a disrupting effect on the pilot scheme. Consequently, to have the scheme revolving fund maintained at 100% of its value, it is necessary to take other measures. An example of measure follows:

In a pilot scheme:

(a) the group order corresponds to a large quantity order which normally carries a discounted price compared to a price that could be obtained by an isolated farmer;

(b) the transport organized at a village level and for the minimum of a truck load normally carries a sizeable discount in the transport cost of the fertilizer;

(c) the considerable decrease in the credit risk for the supplier lowers the margin to be included in the cost price to cover such risk.

Consequently, in a pilot scheme, even when selling the fertilizer 5 to 10% above its actual cost price at farm site, the price offered to participating farmers remains appreciably below that which they would have to pay if outside the pilot scheme.

Experience shows that this 5 to 10% margin is usually enough to cover bad debts and to maintain the revolving fund at its initial value.

Incidentally, working through purely credit co-operatives, supposedly based on mutual security, shows that it does not improve the repayment rate above self-help or voluntary group created for such a specific target as a better fertilizer supply. However, the scheme participants, either with ethnic, residential or kinship ties, may form the best basis for future co-operative action. But, too often, farmers do not see official co-operatives as their society.

In any case, the training of farmers first in team-work is helpful to create formal co-operatives in a second stage.

8. So far, the best way to achieve better records of payment is to work out payment through a crop-lien. With this system, the farmer pays his loan in kind by delivering his crop at a state controlled marketing agency (e.g. East Africa's marketing board and co-operatives). Needless to say, the state controlled marketing agency establishes beforehand the proper administrative channels with the state controlled lending agency when they are not the same.

However, the system has its limits and only works properly in the following instances:

Either there is a state marketing monopoly for the given crop (e.g. cotton in Syria), or the price offered by the state marketing agency can compare with competing private interests (e.g. cotton in Turkey).

If there is a chance that the state marketing agency cannot compete at harvest time with private trade (e.g. wheat in Turkey and Lebanon, and cotton in Kenya), then the crop will go to private trade, and the loan will not be recovered that way.

9. The presence of bank and supply agency representatives in the villages during the initial stage of a pilot scheme, is part of the building-up of a new mentality toward a more personal credit. The first role of these representatives is to teach participants what the new terms are for fertilizer loans. The move of these representatives to the villages, instead of waiting in town for the villagers, is bound to induce farmers into a new, more favourable attitude at repayment time.

The presence of these representatives in the villages is essential during the first year, at least, when a group-order is signed and at harvest time.

10. In a pilot scheme all loans are in kind, and the fertilizer is to be used according to the recommended practice, i.e. given rate and method of application.

11. In a pilot scheme, credit facilities are only extended to a given limited surface. It is based on the intensity of the cropping (e.g. 0.5 ha. for tobacco or 2 ha. for wheat or maize). The individual area covered by loan facilities may grow from the first to the third year as a reward if the repayment rate is satisfactory (e.g. Morocco-wheat scheme: first year 2 ha., second year 5 ha., third year up to 10 ha.).

For cash sales understandably there is no limit.

12. It is questionable whether or not a normal bank interest should be included in a credit pilot scheme loan term.

Indeed, to focus farmers' attention and induce them into realization of a recommended but new practice, it is often easier to offer loans without interest. However, this has the disadvantage of raising discontent when, the pilot scheme being nicely operational, the time comes for normal banking practice which includes interest. Consequently, it is suggested to raise a minimum 5% charge on the loan from the start. This charge may be disposed of by splitting it into 1-2% to cover local secretarial expenditures and 3-4% to improve local distribution, e.g. improvement of the village storage place. After a few years of pilot operations, when the scheme turns to "routine" practice, this 5% or more may be used to cover normal bank interest.

13. It is essential for the smooth distribution of fertilizer in a pilot scheme that all fertilizer be sold in advance, e.g. 2-3 months before delivery time. This group-order in advance is a relief for the supply agency which, in addition, will appreciate knowing a rougher figure of global needs for the schemes, even earlier, to make sure that imports are geared to real needs and delivered in time.

14. Fertilizer delivery to the village centres is essential, and, from experience, a village temporary storage place is necessary. When the supplier's truck comes to the village, it has been found impossible for all participants to be present at the same time to take hold of their share. Consequently, a temporary storage place must be found in the village itself, or in its immediate neighbourhood, through the village mayor or the group's representative. Later one of them insures the retail distribution against a signature for receipt of the fertilizer. When the scheme is making use of local traders, they can provide a store-room and do the retail distribution, e.g. against a 2% minimum commission.

15. Timely delivery of the pilot scheme fertilizer to the villages should not be overlooked. Delays in delivery are a curse that should be avoided at all costs. The usual complaint of farmers at the time of their interviews prior to the selection of a scheme's area is that fertilizer does not come to their village or when it comes, it is too late (e.g. after sowing time).

16. Just after delivery of fertilizer to the village, a field-day takes place to explain once more, and visually, to participants how much and how fertilizer should be applied. Indeed, fertilizer is not magic and gives no return if wrongly used.

Then, just before harvest, a second field-day is organized to show the farmers the differences between fertilized and unfertilized fields, and prove to them visually that their loan is already repaid by the differences they can see. Consequently, defaults will not be accepted. However, if individual cases of damage by flood, or wandering animals, etc., are mentioned, they can be dealt with by postponing repayment.

17. It is one of the elementary lessons of experience that credit cannot be developed on a sound basis, unless, from the beginning, there is a strict insistence on repayment.

In many cases, farmers obviously could have paid but were not doing so, because experience had led them to believe that defaults would be tolerated.

Outside the FAO pilot schemes, poor repayment has also been due to the lack of clearly defined responsibility and institutional organization for the collection of payments.

In this respect, the extension service should be left to its duty; that is, farmers' education and the agricultural bank (or the agency that stands for it, like the Development Bank in Ethiopia, or the "Bancos de Fomento" in South America) should be involved in administering and supervising the finances of the scheme.

It is often necessary to exert strong pressure, so that the agricultural bank's agents move to the villages and establish a personal contact with the participants in the scheme.

When, due to past laissez-faire, government loans are bound to default, it is advisable to work through a commercial bank nominated for the pilot scheme by the government and no longer through a state controlled lending agency.

The setting up of new rules and stricter control of funds may favourably impress pilot scheme participants towards proper repayment.

18. During the second and third year of the pilot scheme, the extension workers should concentrate on helping the emerging local leaders in the different stages of operations, so that at the end of the third year of the scheme, the scheme's operations have become routine work for these local leaders, i.e.

- establishment of the group-order and the group guarantee;
- maintenance of the intermediate storage place;
- retail distribution;
- cash payment or loan repayment meeting.

19. The introduction of other improved practices in a pilot scheme is a debatable question. Experience proves that introduction of improved seed with fertilizer does not cause problems that cannot be overcome fairly easily. This favourable aspect meets nicely with the present FAO concern for high yielding seed varieties. The same facility in cases may apply for pest control chemicals, but insurmountable problems arise when it has been attempted to generalize mechanized application of seed and/or fertilizer in a pilot scheme.

20. A pilot scheme area is a specially and temporarily supervised area where the fertilizer bag is followed up from harbour to farm, and its money equivalent from farm to bank. The supervisory personnel must be above average,

and the relative success of the scheme depends on the standard of this personnel. Ideally, an officer with a secondary level of schooling is made responsible for the scheme, and he can supervise up to 3 pilot schemes in different, but not too far apart, areas. He is the brain and coordinates extension, banking and supply activities with the local help of one fertilizer level worker (FLW) per scheme. Then, one FAO officer can normally deal with 5 supervisors, making an average total of 15 scheme areas per FAO officer.

Conclusion

Fertilizer pilot schemes involve more services from the government against increased self help and better record of payment from farmers.

Additional services from the government entails:

Extension	More field contacts and direct explanations
Distribution	Delivery of right fertilizer, in time, to village-centres
Credit	Less formalities for loans which should take place in the villages

Self dedication from farmers entails:

- Early group orders
- Improved record of payment.

These goals can only be achieved through a team-work among government agencies co-ordinated by a Fertilizer Programme subject matter specialist attached to the Ministry of Agriculture.

RECENT DEVELOPMENTS IN FERTILIZER MATERIALS

by

Donald L. McCune*

The Tennessee Valley Authority was initiated in 1933 during Franklin D. Roosevelt's administration primarily to work with a very depressed region of the U.S.A. — The Tennessee Valley Region. The area makes up parts of seven states and is about one-half the size of Spain.

At the same time within this region, in Alabama, were some old nitrate plants that were constructed during World War I to make nitrate for explosives. Being government-owned these too were turned over to TVA to make fertilizers in time of peace and to make munitions in time of war.

Thus, was the beginning of what today has been known as the National Fertilizer Development Center. This is the only part of TVA that has more than regional responsibility. It has nation-wide responsibility and in fact is fast becoming an international centre for fertilizer information.

It was early decided that TVA's role in fertilizers would be one of research and development. We would research out new fertilizers and ideas, which would be patented, help develop these new processes and products and then licence them to industry for further development and production. The licensing of TVAs processes is free to U.S. industry and since we only hold patents in the U.S., it is also freely available to industry world-wide.

Although we hold the patents for many of the fertilizers produced in the U.S. today, we do not sell a single product that is normally found on the U.S. markets. We do not sell urea, ammonium nitrate, triple superphosphate, diammonium phosphate or normal NPK grades that are readily available to the American farmer. He must buy these from industry. We manufacture, but still only in small quantities, such products as ammonium polyphosphates, urea ammonium phosphates, various base solutions for liquids and suspension fertilizers and numerous high analysis fertilizers that contain significant levels of secondary and micronutrients. We are also beginning to manufacture various controlled release fertilizers where we are trying to make fertilizers that fit the needs of the crop to cut down on losses through volatilization runoff or leaching so that a higher percentage of the applied fertilizer can be used by the crop. I will speak more about these new fertilizers later.

Our goal has been primarily one of working through research and development to make fertilizers that are of better quality and cheaper to the American farmer. In the past we have done this principally by increasing the plant nutrient content of the fertilizers - making them of higher analysis and improving on fertilizer processes to make them more efficient.

Fertilizers analyses in the U.S.A. have actually been increased in plant nutrient content from an average of 20% plant nutrients in 1940 to over 40% plant nutrient today. Fertilizers have also actually decreased in price to the American farmer - being the only major input that has decreased.

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At the National Fertilizer Development Center we are organized with a Division of Agriculture, a Division of Chemical Development, and an International Staff. We have a total employment of about 1,100 people and a professional staff of scientists and engineers that numbers almost 300. In this we have many disciplines including chemists, chemical engineers, agronomists, economists, marketing specialists, transportation specialists, communication specialists, etc., just to name a few. As Director of the International Staff, I can call on people from all of these disciplines to help solve problems and to advise those in the developing countries on problems related to fertilizers. This we do at the request of our Agency for International Development, various UN organizations, including FAO, the World Bank, Regional Development Banks as well as the government of the developing countries.

Since 1964 we have responded to requests from some 25 countries and have sent some 50 teams utilizing over 60 different people as team members.

In addition we offer training courses at TVA and will assist in organizing or conducting training courses in the developing countries. We have also tried during the past five years to upgrade our library to make it the most complete working library that is possible on matters pertaining to fertilizers. We also encourage the use of this facility either by direct visits or through correspondence.

As you can see from the slide we are rapidly increasing the visitors and trainees from other countries.

We also make numerous studies that are of world wide importance and interest. As one example we try to keep an uptodate record of fertilizer production capacities, in operation, under construction and being planned. Then by working with FAO statistics on fertilizer production and use we can have available a better picture of fertilizer production in relation to demand. We keep all of this information available by computer methods and can easily make this information available to anyone who wants it.

We also publish, at least every two years, a summary of the world situation in a publication "Estimated World Fertilizer Production Capacity as Related to Future Needs." Here we show present and projected fertilizer capacities as well as present and projected usage. We do this worldwide as well as by regions and subregions and even for some of the larger countries. We make our own estimates of future needs as well as considering the estimates of others. From this we can give guidance on the planning of future production facilities to help meet anticipated needs. We also do this on a product basis.

Also included are individual country statistics on use of individual nutrients, per capita use, per hectare use as well as imports and exports. This information is also available on request for others to use.

Our projections show that by 1975 the world will be using about 89 million metric tons of plant nutrients and by 1980 upwards to 115 million tons of plant nutrients as compared to a little over 60 million tons used today.

The so called developing countries are increasing their fertilizer rapidly but are still using less than one-fifth of the total fertilizer. This is a rapid gain as in 1960 they used only one-tenth of the total plant nutrients that were used. We are projecting that by 1975 the developing countries will be using about 24 million tons of plant nutrients as compared to the 11 million they are using today and by 1980 that they will be using 34 million metric tons about 30% of the world-wide use of 115 million metric tons.

Our data also permit us to follow trends in the types of fertilizer that are being used and that will be produced in the future.

In nitrogen there is a definite percentage-wise shift towards increased use of urea and a decrease in the use of ammonium sulfate. This is due primarily to the costs of shipping and handling. There is also an increasing quantity of nitrogen being used in ammoniated phosphates as well as complex fertilizers.

In phosphate fertilizers there is a rapid shift toward greater use of the ammonium phosphates at the expense of single superphosphate. Triple superphosphate is only gaining slightly when expressed on a percentage basis.

We expect these trends to continue. At least the fertilizer plants that are now planned to begin production over the next five years would indicate this to be the case.

In potash there is little or no indication of any major change in the types of material that will be available. Potassium chloride now makes up about 90% of the potassium consumed and will continue. Other products such as potassium sulfate and potassium nitrate will still continue to be available for use under special situations but will remain more expensive on a per unit of plant nutrient basis.

Fertilizers Currently or Soon to be Available

We feel that the shift toward high analysis will continue. At least two new products bear mentioning that definitely fall in the high analysis category.

The first is ammonium polyphosphate. Ammonium polyphosphate is made from superphosphoric acid instead of normal phosphoric acid. Typical analyses include 15-62-0 or 12-57-0 depending on whether they are made from electric furnace or wet process super acid.

Advantages of this product other than its extremely high analyses are that it is 100% water soluble and under certain conditions appears to have agronomic advantages over the orthophosphates that are found in the present phosphatic fertilizers. It is also easy to ship and mixes well with other products to make extremely high analysis complete fertilizers either in dry or liquid forms.

Another new category of fertilizers recently produced by TVA that are causing much interest in the industry are the urea-ammonium phosphates or the urea-ammonium polyphosphates. Normal grades of these products would include 30-30-0, 34-17-0 and 39-13-0. Complete 1-1-1 ratios as high as 19-19-19 or 20-20-20 can also be made. We feel that these products are especially well suited for paddy rice since all of the nitrogen is in the urea or ammonia forms, thus eliminating some of the problems of nitrogen loss that are encountered with the nitrate forms of nitrogen. Again the phosphorous is 100 percent water soluble.

Another group of products, not a step toward high analysis, in which there is much interest are controlled release fertilizers. Here the attempt is to tailor fertilizers so that their release patterns will coincide with the uptake rate of the plant. As you know, uptake rates vary greatly between species so you are actually attempting to tailor a fertilizer for a specific crop.

The basic concepts and the objective behind this approach are:

1. To save labour - through eliminating the necessity of multiple applications.

2. To reduce fertilizer burn when nitrogen naturals are applied directly with the seed or to the growing crop.

3. To reduce nutrient losses through metered release.

The overall objective is to improve nutrient use efficiency by metering release in line with plant needs thus reducing losses through leaching and volatilization and cutting down on luxury consumption.

Although many materials and approaches have been tried, TVA's approach is through sulfur coating. This is due to the fact that it so far makes the most economic sense. By adding a 10% to 20% sulfur coating to granular products such as urea we feel confident that we can materially increase the efficiency of nitrogen use to more than pay for the increased cost of production.

Fertilizers for the Distant Future

We do not feel that we have yet reached the ultimate in high analysis fertilizers. For example, we have made a number of fertilizers that produce excellent plant response and have extremely high analyses. Among these materials are involved such analysis as:

11-58-0-30 S   55-92-0   27-60-0   37-62-0-29 S

Although these have been made only on a small scale and are good materials agronomically, much work still needs to be done on methods of producing them economically. Their future depends on the economics of scale up in production.

Possible Effects of New Products on Future Plant Nutrient Problems

Most present dry fertilizers have been tailored to fit the conditions of the crops, the soils, the distribution systems and labour situations. Whether we should assume that these same fertilizers best fit the needs of other countries that have different crops, soils, climates, etc., may be questionable. For example, we assume in the developed countries that if secondary nutrients or micronutrients are needed we can add these by other means or on a prescription basis where they are needed. Your conditions may not be the same. Thus, we should take a look at your real needs before we adopt present day fertilizers and technology directly.

For example, there is evidence that sulfur deficiencies may be more widespread in the tropics than in temperate climates. Maybe you should consider sulfur as a major plant nutrient and reconsider such products as ammonium sulfate and single superphosphates. Under these conditions ammonium sulfate would contain about 43-44% plant nutrient as compared to the 20-21% nitrogen and single superphosphate would have an analysis of 30% rather than the 18% when only the phosphate content is considered. Also such secondary nutrients as calcium and magnesium may have considerably more value under your conditions than ours. Thus, before we go overboard in accepting the present technology I feel we need to evaluate your situation so that we know more what we are doing in tailoring fertilizers for your specific need.

The Shift to Chemically or Physically Combined High Analysis Fertilizers

Throughout the world there is a definite trend toward greater use of high analysis complete fertilizers. The question then becomes do they need to be chemically combined or will physical mixing be satisfactory? Our feeling is that either can be satisfactory if well made and well controlled.

Physical mixing which we term "bulk blending" has caught on at a rapid rate in the U.S. and is widespread throughout the country. It is also catching on in other countries.

Although it is almost synonomous with bulk spreading and application in the U.S., it is being successfully bagged in many areas. Products that are widely used in bulk blending are:

Ammonium Sulfate; Urea; Ammonium Nitrate Triple Superphosphate;

Ammonium Phosphate; Potassium Chloride and Potassium Sulfate.

Not all of these materials are chemically compatible with each other. One advantage of bulk blending, however, is that a minimum number of products need be produced or imported in order to make most all of the analyses that a country would need. For example, by having available urea, diammonium phosphate and potassium chloride practically any analysis can be made. All three of these materials are compatible.

Another advantage is that multiple nutrient fertilizers can be made with a minimum of investment in production facilities. Also if properly spaced geographically, blending plants that receive the basic materials in bulk can provide prescription fertilizers to its local clientel at minimum cost where secondary or micronutrients are needed these too can be added efficiently and at a minimum of cost. Micronutrients, for example, can be added to blends as powdered materials in measured amounts by sticking them on the granule either by using small quantities of water (1-2% by weight) or such things as diesel fuel (1.5-3% by weight).

To properly blend fertilizers, however, precautions must be taken and I would strongly suggest that a thorough study be made to assure success.

Probably the greatest hazard to overcome is proper mixing and the prevention of segregation after mixing. This however is primarily a problem of matching particle sizes although bulk density and particle shape do have some effect.

To minimize segregation there are four basic things to consider:

1. Selection of similar sized materials;
2. Avoid coning of piles;
3. Minimize handling, and
4. Use multinutrient materials where possible.

Thus, in conclusion many developing countries are seriously looking into bulk blending as a means of initiating their evolving fertilizer industries. I feel that it has potential for this part of the world as well, and I would encourage you to consider this as a means of providing the fertilizer needs of the farmers as far as complete fertilizers are concerned. This can be a minimum cost operation and can be a first step in an evolving fertilizer industry.

SOIL FERTILITY AND SHIFTING CULTIVATION

by

F.W. Hauck*

Summary

About 36 million square kilometres of land or over 30 percent of the world's exploitable soils are under shifting cultivation. They produce the bulk of the food for nearly 10 percent of the world population. Shifting cultivation is universal but it has more importance in Africa than in other parts of the world.

Shifting cultivation is defined as "a very extensive system of food crops production whereby the productivity factor is almost exclusively human labour, the capital expenses being extremely low and the land having a practically negligible value."

The question, if shifting cultivation in its present form is still adequate, is related to yield levels, population pressure, economic aspects, inputs and general agricultural development. Possibilities for improvements include cultivation methods, genetic improvements of crops and livestock, pasture and fodder cultivation, measures to protect crops and livestock, problems of mechanisation, problems concerning processing and marketing of produce. Experiences with the use of mineral fertilizers for changes in shifting cultivation are presented, which could lead to more static forms of land use.

The possibilities of FAO's assistance in the field of shifting cultivation are mentioned.

1. Scope of the problem

About 36 million square kilometres of land or over 30 percent of the world's exploitable soils are at present under shifting cultivation. They produce the bulk of the food for more than 250 million people or nearly 10 percent of the world population. Shifting cultivation is used in Africa, South America, Oceania and South East Asia, by people of widely varying origin and culture, on a very wide range of soils and many different types of vegetation. There are great variations in the types of crops grown, the length of cropping and fallow periods, and the methods of cultivation (4). Although precise figures are not available, it can be estimated that in Africa the percentage of the area under shifting cultivation of the total exploitable area is considerably higher than the world figure of 30 percent, it is probably more than 50 percent.

There has always been some confusion in the use of the term "shifting cultivation" particularly in relation to the point "whether it is only the fields of the cultivators or their homes as well as their fields which shift." (4). The Unesco Commission on World Land Use Survey (1952) suggests to restrict the term "shifting cultivation" to the cases where the farmers are shifting their fields and settlements, whereas it calls "land rotation" the shifting of the fields only. The large number of modifications of both types however do not, in many cases, allow a clear distinction. Hagreis (cited in 1) defines shifting cultivation as follows: "It is a very extensive system of food crop production on well drained land whereby the productivity factor is almost exclusively human labour, the capital expenses being extremely low (a few tools and seeds) and the land having a practically negligible value."

In this paper the term "shifting cultivation" is used for the cultivation aspects of the problem.

The types of shifting cultivation show considerable differences between forest (with rainfall above 1250 mm p.a.) and savanna (up to 1250 mm p.a.). The description of Nye and Greenland (4) of types of shifting cultivation in West Africa is summarized as follows :

Forest : In the forest the farmer cuts the vegetation during the dry season, leaving some trees for shade. The mass of vegetation, when dry, is burned, the ash is left on the surface. After the first rains maize is planted, followed by cassava, cocoyam and plantain often already during the growing period of maize. Peppers, okras, spinach plants and other vegetable crops are usually added. In the following year the plantains and some of the cassava and cocoyam are harvested. The remainder is left for the third or fourth year and the field is abandoned to the regrowth of forest, which is rapid. Secondary forest may well be 6 to 7 metres high after 5 years and about 17 metres high after 10 years. A three years cropping period alternating with eight years of fallow is considered as adequate for

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maintaining the fertility in the semi-deciduous forest (1150 to 1750 mm rain p.a.). In the evergreen forest (above 1750 mm rain p.a.) 1 1/2 to 2 years of cropping should be followed by about 10 years of fallow.

Savanna : The moist savanna which adjoins the forest consists of tall grasses (up to 4 metres high) and a widely varying density of scattered, fire resisting trees, rarely over 17 metres high.

For clearing the land most of the trees are cut and burned together with the grass. In a typical cropping sequence yams are planted in mounds and some side crops like beans, squash, maize are added. The next year the yam mounds are destroyed and sorghum and maize planted on narrow ridges, which may run up and down the slope and lead to considerable soil wash. The third year groundnuts, interplanted thinly with millet, complete the cropping period.

Using this system the land is, in contrast to the forest, without cover during the dry season and is exposed to the early rains for at least 4 weeks before a cover has developed. The labour of weeding is more urgent than in the forest, particularly if the rhizomatous grass (Impera cylinilica) is present. Unlike the forest fallow the grasses do not continue to increase their store of nutrients year by year, and the improvement in the physical conditions of the top soil is less marked than in the forest.

In savanna areas with less rainfall and longer dry seasons the vegetation consists mainly of tall bunch-grass and the main crops are groundnuts and beans, cotton and sweet potatoes. In the short bunch-grass savanna the limit of dry-land cultivation is reached with millet as the main crop.

The table on the following page summarizes the situation of shifting cultivation in a number of countries (4).

There is a large number of modifications of the basic system and the relation between shifting cultivation and settlement can only be mentioned. As a whole, shifting cultivation is part of the social, economic and religious life of many millions of people in Africa. In shifting cultivation no minerals or other chemicals are used. The crop rotation is simple or non-existent, mixed cropping is a very common practice. Usually no provision is made for erosion control. After the cropping period, when the soil fertility has declined sharply, the soil is left to recover its original level of fertility under its natural vegetation, either grass or forest (1).

In the countries concerned it is recognized more and more that shifting cultivation represents a most extravagant use of land. However, "when not pushed to excess shifting cultivation has for centuries given man his livelihood in the humid tropics" and it was not possible up to now to introduce a method of food production superior to natural fallowing used in shifting cultivation (4).

The general problem of shifting cultivation includes many fields of knowledge and "an assessment of the value of the system must be based on a thorough survey of the problems of agricultural development among which questions of soil fertility form only a part. Nevertheless, the interaction of the system with the soil is supremely important." (4) Other problems are botanical and agronomical in nature followed by socio-economic and ethnological.

2. Is shifting cultivation still adequate ?

a. Yield levels

Although shifting cultivation is considered in many countries as the only available form, under the circumstances, to maintain the productivity of the soil, it is also realized that the maximum level of productivity which can be reached by this system is well below the yields of more modern types of cultivation. Maize yields in Ghana, for instance, are influenced by shifting cultivation in the following way (2) :

Yield of grain in the last year before fallow : 700 kg/ha

First year after fallow :	1 100 kg/ha
Second " " " :	800/900 kg/ha
Third " " " :	700 kg/ha

Table 1

The Length of the Crop and Fallow Periods under Shifting Cultivation

No	Place	Rain p.a. in inches	Crops	Fallow	Periods in Years				Remarks
					Normal		Excessive		
					C	F	C	F	
					Moist evergreen forest zone				
1	Sarawak	c. 150	Hill rice	Forest	1	>12	2	12	Early abandonment of land necessary to prevent invasion of Imperata
2	Guatemala	135	Maize	Forest	1	>4			'Ando' type soil
3	Liberia	80–180	Rice, cassava	Forest	1–2	8–15			
4	Sierra Leone	90–130	Rice, cassava	Forest	1½	8	1½	5	Grasses (esp. Chasmopodium sp.) invade with excessive cultivation
5	Assam	c. 100	Rice/millet, maize, rice	Forest	2	10–12	2	<7	
6	Sumatra	c. 90	Rice, root crops	Forest	2	10–16			Imperata invades, but may give place to forest
7	Philippines	> 100	Rice, root crops, maize	Forest	2–4	8–10			
8	Nigeria (a) Umuahia	c. 90	Yams, maize cassava	Acioa barteri	1½	4–7	1½	2–2½	Loam derived from tertiary sands and clays, stumps of fallow carefully preserved
	(b) Alayi	c. 90	Yams, maize, cassava	Macrolobium sp.	1½	7			Very loose sandy soil
9	Central Congo	> 70	Rice, maize, cassava	Forest	2–3	10–15			
					Moist semi-deciduous and dry forest zone (including humid zone of derived savanna)				
10	West Africa	60–80	Maize, cassava	Moist semi decid. forest	2–4	6–12			
11	N. Burma	50–70	Hill rice	Grassland & pine forest			5	10	Kachin Hills area at c. 6 000 ft.
12	West Nile	55	Eleusine, sorghum Simsim, maize	Grass, mainly Setaria sp.	2–3	8–15	3	3	Refers to 'outside' fields
13	Abeokuta, Nigeria	c. 50		Thicket			2	4–5	Soil derived from tertiary sand; evidence of nitrogen deficiency
14	Ilesha, Nigeria	c. 50		Thicket	2	6–7			Soil derived from granite

Table 1 (cont'd)

No	Place	Rain p.a. in inches	Crops	Fallow	Periods in Years Normal C	F	Excessive C	F	Remarks
15	Central Uganda	c. 50		Elephant grass	3	8	1	2	
16	Ivory Coast	c. 50		Elephant grass	3	3	9	6	
17	N. Rhodesia	c. 50		Thicket	6–12	6–12			"Chipya" forest soil
				Savanna Zone					
18	Ivory Coast	47		Imperata	2–3	6–10	2–3	4–6	
19	Uganda	c. 45		Andropogoneae	1	2½	1	2	
20	N. Ghana	c. 40		Andropogoneae	3–4	7–10			
21	French Sudan	30–40		Short bunch grass	3	12–15 up to 25			
22	N. Rhodesia	c. 45		'Miombo' woodland	2				Pallid sandy soils

The whole effect of 7 to 10 years fallow, plus the high labour input of clearing 1 hectare of land, are an additional 600 kg of maize in 2 years. The effect of fallow is improved, to a limited extent, by mixed cropping, but the improvement of the soil fertility by shifting cultivation is short-lived. It is apparent that this type of land use cannot be the answer for the future requirements of agriculture.

b. Population pressure (1)

If the population pressure becomes too great, the cropping periods are usually extended and the fallow periods are shortened. This leads to irreversible soil degradation. Under normal conditions of shifting cultivation degradation of the soil and vegetation is bound to occur, when the population density exceeds 25 per square kilometre. This figure may vary from one region to the other, but it can probably help to identify areas in which the critical stage has already been reached. The increasing population pressure in a country as a whole will make it necessary to rely more and more on the areas of shifting cultivation.

c. Economic aspects

The increasing need of the country for more food and the improving infrastructure (marketing of produce) encourage the subsistence farmers to produce partly for sale. The possibility of a higher profit leads to an extension of the cropping periods.

d. Inputs

The technical and economic knowledge about the effects and efficient use of agricultural inputs like fertilizers, pesticides, weedkillers, seeds, is growing rapidly. In particular the rational use of fertilizers has been investigated recently under practical conditions in many African countries. The improving availability of inputs to the individual farmers at economic prices introduces changes in the shifting cultivation system.

e. General development

The general improvement of agricultural production, including mechanisation (5) of different types, irrigation, use of high yielding varieties, crop diversification, the increasing use of inputs, call for changes in the system of production. In view of the apparent need for such changes and the possibilities available for improvements in the interest of the economy of the countries and the individual farmers, it would appear that the time has come for tackling the problem systematically.

3. Possibilities for changes

Concerning the short and long term improvements of soil fertility, the following findings of H. Laudelout (1) are of interest : if the type of fallow used aims only at the rebuilding of the organic matter content, it is possible to limit its duration to a very few years. On the other hand, it is well known that the effects of the fallow are not limited only to a reconstitution of the organic matter content. The plant nutrients, if they cannot be provided by commercial fertilizers, have to be manufactured on the spot by the natural process of mineral immobilization by the fallow, which is then cut and burned. It is likely that the minimum duration of the forest fallow, which has been estimated to be between 10 and 20 years, is largely determined by the rate of mineral immobilization.

Again according to Laudelout (1), alternatives to the forest fallow which are satisfactory from the point of view of either the immediate crop returns or the long range soil conservation, should fulfill the following conditions :

(a) The content of easily decomposable organic matter should be restored to a value corresponding to that of the forest fallow; and conditions for speedy decomposition of this supply should be provided in order to ensure the nitrogen and phosphorus nutrition of the cultivated plant.

(b) The content of bulk organic matter, to ensure a good tilth, should be rebuilt after each cropping cycle. If no fallow is used, the rotation should contain legumes to provide the necessary nitrogen for conversion of crop residues into soil organic matter.

(c) The mineral potential of the fallow should be approximated, either by the mineral immobilization of the fallow or a corresponding mineral fertilization.

Jurion and Henry (3) make the following proposals on how and how far to intensify shifting cultivation : starting from the conditions in which subsistence agriculture is practised, attempts at rationalisation aim at making cultivation systems more and more independent of nature by continually increasing the number of production factors and the intensity of their application. How far the research results available can be put into practice depends on local economic conditions and the professional skill of the farmers.

The aspects with which experiments and practical application in the field have been concerned can be classified as follows :

- cultivation methods : fallows, farming calendar, date and density of sowing, weeding, fertilizers, rotations;
- genetic improvement of crops;
- genetic improvement of livestock;
- research into pasture and fodder cultivation in connexion with improvements to herbaceous fallows;
- measures to protect crops and livestock from pests and diseases;
- problems of mechanisation and of rationalising tools and equipment;
- problems concerning processing and marketing of produce.

Jurion and Henri come to the conclusion that obviously intensification of agriculture leads ultimately to the point where fallow is no longer required.

4. The role of mineral fertilizers

As stated by Laudelout (1) it is likely that the minimum duration of the fallow is largely determined by the rate of mineral immobilization. For increasing the plant nutrient content more rapidly, the use of organic manure, particularly farmyard manure, could help and would even allow for continuous cultivation. However, farmyard manure is not available in most cases.

Increasingly, mineral fertilizers are used also in areas of shifting cultivation for replacing mineral losses. In Kalanga (3) the use of mineral fertilizers - with or without organic manures - has made it possible to obtain heavy and profitable yields. In each of these cases the possibility of continuous cultivation has been proved or at least very strongly indicated.

Most of the trials of the FAO Fertilizer Programme in West Africa have been laid out on farmers fields under shifting cultivation, including the first, second and third year after clearing the land. The yield increases by mineral fertilizers alone have been at the same level in all three stages, e.g. on maize in Ghana, with a yield of 700 kg/ha before the fallow started (the figures give the order of magnitude, based on 715 fertilizer trials (2) :

1st year : yield increase by fallow :	400 kg/ha
" " " fertilizer :	400 kg/ha
	Total 1500 kg/ha
2nd year : yield increase by fallow :	200 kg/ha
" " " fertilizer :	400 kg/ha
	Total 1300 kg/ha
3rd year : yield increase by fallow :	0 kg/ha
" " " fertilizer :	400 kg/ha
	Total 1100 kg/ha

Thus, in the first year, by a modest fertilizer application (22.5 kg/ha of NP, in some cases NPK) the effect of a 7 to 10 years fallow can easily be doubled. In the third year, by the use of fertilizers the yield is still as high as it is normally in the first year of the cropping period but without using fertilizers (700 + 400 kg/ha), it is worthwhile to extend it. The regular use of a modest quantity (at the level of 22.5 kg/ha per plant nutrient) has even had an accumulative effect and consequently a yield increase above 400 kg/ha. In most cases the use of mineral fertilizers has proved to be economic, provided the types and quantities have been adjusted to the prevailing conditions : in West Africa in 1961 to 1964, out of 5 658 fertilizer demonstrations 79 percent showed positive economic returns to at least one fertilizer treatment and an average Value: Cost Ratio (VCR) of the best treatments of 3.5. Out of 1 334 9-plot trials, 99 percent showed positive economic returns and the average VCR of the best treatment was 7.8. The results obtained up to now from several thousands of fertilizer trials indicate : after the effect of the fallow on the plant nutrient content of the soil has gone, it is possible and economic to increase by relatively small quantities of fertilizers, not only the immediate yields but also, gradually, the fertility level of the soil. Although more investigations are still needed in this field, it can be seen that the rational use of fertilizers can become the main factor for the intensification of the cropping period and eventually for a complete abolishment of the shifting cultivation.

5. Possibilities of FAO's assistance

FAO is aware of the extraordinary task ahead in the areas of shifting cultivation to more static forms of land use. The problem has been presented in more detail in the Indicative World Plan. The urgency for appropriate action was emphasized by a number of delegates during the last FAO Conference (1969) and on other occasions.

For supporting the efforts in the countries to improve shifting cultivation, FAO, in principle, can provide the following assistance :

- serve as focal point for all information available and requested on the subject;
- provide experts under the various types of projects (UNDP/Special Fund or Technical Assistance, Trust Funds, FFHC) on the request of the countries;
- organize meetings and seminars;
- give individual advice to the countries.

The Land and Water Development Division of FAO has adjusted its Programme of Work to the increasing requirements for improving the agricultural productivity in areas of shifting cultivation and is ready to join the efforts in the countries concerned to deal with this problem.

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GUIDE FOR PLANNING SOIL FERTILITY AND FERTILIZER USE DEVELOPMENT

by

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INTRODUCTION

1. According to IWP the fertilizer consumption in the developing countries (Zone C) which was 3.7 million tons (in terms of N, P_2O_5, K_2O) in 1966 should increase to 15.6 million tons in 1975 and 33 million tons in 1985. The total value of this will represent approximately 45 percent of the total value of all current inputs into agricultural production. An extraordinary effort will be necessary by the countries concerned to achieve these goals in order to produce enough food for the rapidly growing population.

2. The urgent need to increase the productivity of soils and the use of fertilizers was recognized by the 15th Session of the FAO Conference in November 1969. The problem was much discussed by delegates to the Conference.

3. Although there is an increasing concern about the low productivity of soils in developing countries and a strong desire by the countries to improve the situation, in many cases the necessary and possible activities need clearer specification.

4. On the following pages the whole range of possible activities for the improvement of soil fertility and the introduction of mineral fertilizers into practical agriculture is presented. In the first part, called "Purposes", the results which can be achieved are mentioned briefly under the following subheadings:-

General

Field Programme to promote fertilizer use

Applied Research Programmes on specific soil fertility and fertilizer use problems

Infrastructure for long term fertilizer use development

Training in soil fertility and fertilizer work

The second part called "Description of Activities", gives detailed information under the same subheadings on what can be done in order to achieve the purposes. The Guide is based on FAO's experience in many countries. A timetable is attached which gives an indication on the sequence of the activities and the periods of time which are required under average conditions.

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5. FAO has included the purposes and activities given in the Guide in its field projects in soil fertility and fertilizer use. Normally, not all purposes or activities will need to be included in a project. They are required, however, to ensure that long term fertilizer use is successfully established, and the Guide can therefore be used by Governments as a checklist of specifications for this purpose.

6. The number of purposes and activities to be included in any new project depends not only on the requirements of the country but also upon the type of project. UNDP (Special Fund) projects are the largest projects of FAO and usually include a team of five or more experts and a considerable amount for fellowships, equipment and supplies. The UNDP (Technical Assistance) projects usually consist of one expert and limited funds for fellowships, equipment and supplies. The FFHC Fertilizer Programme of FAO has similar projects to those of Technical Assistance but is financed by a trust fund. Besides this there is an increasing number of projects under government trust funds.

7. The basis for UNDP's and FAO's assistance is a request from the country concerned. The Guide shows FAO's possibilities and can help in requesting assistance. This is usually done by a Letter of Intent as a first step. The Letter of Intent should be directed to UNDP (through the UNDP Representative in the country) for Special Fund and Technical Assistance Projects and to FAO Headquarters (Land and Water Development Division) for FFHC and Trust Fund projects. It should contain: a brief summary of the agricultural situation, information on the specific problems, the reasons for the request for assistance, a summary of the type of assistance requested (using information from the Guide), and the possibilities of the country to contribute to the project.

For additional information please approach the FAO soil fertility experts in the country, regional officers, the Senior Agricultural Adviser and staff from FAO Headquarters.

PLANNING SOIL FERTILITY AND FERTILIZER USE DEVELOPMENT

A. Purposes

I. General

The overall purpose is to increase economic development in agriculture through fertilizer use. This may include:

- Field programmes to promote fertilizer use.
- Approved research programmes on specific soil fertility and fertilizer use problems.
- Fertilizer distribution to farmers.
- Infrastructure for long term fertilizer use development.
- Training in soil fertility and fertilizer work.

Each activity may have several discrete purposes.

II. Field programmes to promote fertilizer use

1. Obtain more detailed information regarding fertilizer responses under different conditions and their economic effect by an intensive trial programme on the fields of farmers.
2. Combine the fertilizer use with the use of high yielding and improved varieties.
3. Combine fertilizer use with better cultural practices, water control, plant protection measures.
4. Combine fertilizer use with improved soil management and conservation practices.
5. Lay out a large number of fertilizer demonstrations to show farmers the use of, and the benefits to be obtained from, fertilizer use in combination with related improvements, and arrange contests for highest yields between farmers.
6. Establish an efficient and rational soil testing service to provide recommendations on fertilizer use to the farmers.
7. Identify soils of trials and demonstration sites and relate soil characteristics to experimental results.

8. Establish a correlation between soil analysis and response of crops to fertilizer on different soil types and under different climatic conditions.

9. Carry out benefit/cost studies on the improvements to be introduced into the agricultural practice.

10. Prepare from the results available a series of recommendations to farmers and cultivators on the optimum economic use of fertilizers.

III. Applied research programmes on specific soil fertility and fertilizer use problems

11. Establish close working relationships between agricultural research institutions and extension service for the production and analysis of technical and economic data relating to increased crop production through fertilizer use under various conditions.

12. Provide information on specific problems like micro nutrients, efficiency of nutrient carriers, use of isotopes.

13. Establish long-term fertilizer trials and experiments on interactions between fertilizer use and other agricultural practices.

14. Where necessary aim at the gradual replacement of bush fallow by more permanent forms of agriculture, through the efficient use of fertilizer combined with other improved management and soil conservation practices.

15. Develop a reclamation programme for saline and alkaline soils to improve the efficiency of fertilizer use.

16. Establish a soil microbiology programme in relation to nitrogen fixation and the problems of nutrient utilization.

17. Establish studies on the fertility and chemistry of problem soils like volcanic ash soils, organic soils, etc.

IV. Fertilizer distribution to farmers

18. Assist in establishing or strengthening the infrastructure for the distribution of fertilizer and other agricultural materials. (For a fertilizer distribution scheme within the project, UNDP might make available a substantive quantity of fertilizers).

19. Establish or strengthen, in connection with the fertilizer distribution, farmers cooperatives for supply of inputs and for marketing, storage and processing of agricultural produce.

20. Improve storage techniques on farms for grains and other crops.

21. Coordinate the roles of government, cooperatives and private commercial enterprise in the distribution of fertilizers.

22. Assist in establishing credit on easy terms to the farmers for the purchase of fertilizers and other inputs and to advise on fertilizer subsidy and taxation.

V. Infrastructure for long-term fertilizer use development

23. Establish a fully effective fertilizer office normally in the Ministry of Agriculture, which will be responsible for all aspects of long-term fertilizer use development.

24. Provide the Government with realistic figures on the possibilities of increasing production in agriculture in view of earning and saving foreign exchange through the rational use of fertilizers and additional improved farm practices, and advise on fertilizer prices, subsidy and taxation.

25. Assist the government in formulating long-term fertilizer policy and projections.

26. Provide information needed on the types and quantities of fertilizers as a basis for the planning of local fertilizer production.

27. Assist in the formulation of fertilizer legislation.

VI. Training in soil fertility and fertilizer work

28. Train local personnel in the various fields of the project: experimental and demonstration work, extension, distribution of fertilizers to farmers and long-term planning of fertilizer use development.

B. Description of Activities

I. General

1. The project will have a duration of five years. It will be carried out with the appropriate Ministry and with the participation of other divisions and organizations, e.g.:

   Soils Department
   Crops Research Institute
   Faculties of Agriculture
   Extension Service
   Department of Cooperatives
   Agricultural Development Bank
   Food Marketing Board
   Multilateral and bilateral development aid projects.

2. Project operations will be either nationwide or will be concentrated in the selected areas.

3. Data on the response of crops to fertilizer and various agricultural practices that are of importance to project activities will be assembled and analyzed if possible according to soil groups and geological conditions, to form a basis for the planning of the experimental work.

II. Field programmes to promote fertilizer use

4. Fertilizer trials will be carried out on the fields of the farmers. The responses to nitrogen, phosphorus and potash will be recorded in terms of yield increases and economic effects. The efficiency of different forms of fertilizer materials will be compared. The best time and method of fertilizer application, interaction of fertilizer with organic manuring improved with high yielding varieties, cultural practices and plant protection measures will be investigated. Relationship between soil type, soil conditions, drainage, aeration and fertilizer responses will be established.

5. Fertilizer demonstrations will be carried out on the fields of the farmers in order to show to the farmers the effects of fertilizers and to teach them how to apply fertilizers correctly. Contests for highest yields between farmers (on a village, province and country basis) should be held to draw the attention of farmers to the use of fertilizers. These activities will be carried out in cooperation with the extension service after special training on fertilizer use extension work has been given to the extension staff.

6. For establishing a soil testing service the most appropriate methods for routine analysis will be tested and selected. A central and several regional laboratories will be re-equipped and the routine analytical work will be standardized and rationalized. The analytical results will be calibrated in relation to the results of the field experiments.

7. In order to facilitate coordination of countrywide results, the soil types of all experimental and demonstration sites are identified and yield results grouped in accordance with these findings or, if available, with existing soil maps.

8. The correlations between soil types, soil analysis, and fertilizer responses will be established in cooperation between the project and the appropriate Research Institute involved in soils work.

9. Benefit/cost studies should be undertaken on fertilizer use and improved soil management and cultivation practices based on data of previous experiments and those collected by the project.

10. A soil data bank should be built up gradually. The available information on field experiments and soil types can be stored for use with computer based methods of evaluation.

11. Fertilizer recommendations for farmers will be worked out, based on field experiments, greenhouse and laboratory work. The recommendations for the various crops will be reviewed yearly in the light of experimental results.

12. Cooperation with the extension service with regard to fertilizer demonstrations will be intensified by joint meetings, lectures, seminars and publications. This will enable the extension service (a) to show to the farmers the physical and economic effects of fertilizers, (b) to help the farmers to buy fertilizers, (c) to teach the farmers how to apply the fertilizers effectively.

III. Applied research programmes on specific soil fertility and fertilizer problems

13. Research and experimental work on more specific soil fertility problems will be carried out in cooperation with the Soil Research Institute (or other appropriate research stations):

Exact field experiments:

(a) residual and cumulative effects of N, P and K and their interaction on the quantity and quality of the produce;

(b) comparison of the relative efficiency of different nitrogen and phosphorus carriers and of compound fertilizers;

(c) experiments on time and methods of fertilizer application;

(d) effects of organic manures in combination with fertilizers;

(e) study on low phosphate availability;

(f) use of isotopes.

Greenhouse studies:

(g) effects of secondary and micronutrient elements;

(h) calibration of soil tests.

14. A programme of research and demonstration on soil management and related cultural practices will be established covering the following topics: high yielding varieties, row planting versus broadcasting, increased plant population, weeding, plant protection. Soil management and conservation, as appropriate, will be introduced into practical agriculture (crop rotations, contour cropping, strip cropping, terracing, water conservation techniques, etc.).

15. Experimental work on the improvement of the productivity in areas with shifting cultivation and on the gradual replacement of shifting cultivation by more intensive and economic methods of cultivation will be carried out.

16. A research and action programme for the reclamation of saline and alkaline soils should be developed especially to improve the efficiency of fertilizers, regarding the quality of irrigation water and its effects on the soils, and including leaching and drainage, with and without soil amendments.

17. A soil microbiology programme should include the establishing of a laboratory and studies about the two main lines of applied soil microbiology: (a) nitrogen fixing organisms such as Rhizobia aiming among others at the establishment of a legume inoculation service, (b) humification and composting.

18. Problem soils in relation to fertilizer use, particularly in rice cultivation will be the subject of an intensive research programme which should lead to practical results in the shortest possible way.

Fertilizer distribution to farmers

19. Pilot schemes for fertilizer distribution will be organized in the project areas for (a) making fertilizers available to farmers at easy terms and (b) guiding and assisting the development of a distribution organization for fertilizers and other inputs. For this UNDP is requested to provide an adequate quantity of fertilizers (e.g. 1,000 tons) and the government will contribute the same quantity.

20. Emphasis will be placed on establishing or strengthening the agricultural supply and marketing system by the introduction of fertilizers. Other inputs should be included into the sales programme as soon as possible as well as an efficient marketing of agricultural produce.

21. Simple and inexpensive improved storage techniques on the farm level for agricultural produce will be tried out under the conditions of the farms before they will be introduced on a large scale.

22. Arrangements for selling inputs on credit on easy terms to the farmers should also be made. This could be done jointly by the Rural Development Bank, its agencies and the cooperatives of the village level.

Infrastructure for long-term fertilizer use development

23. A compact and efficient fertilizer (or input) office should be built up at an early stage of the project and staffed by well trained counterpart personnel. It should be responsible for directing the research on fertilizer use; arranging for dissemination of fertilizer recommendations; improving the fertilizer distribution system; making proposals for credit facilities, price policy, subsidies; compiling data for planning of fertilizer consumption, import and local production, fertilizer legislation.

24. The evaluation of the results from the experiments and soil analysis will provide the Government with realistic figures on the possibilities of earning foreign exchange by the economic use of fertilizers on export crops and saving foreign exchange by (if applicable) importing fertilizers instead of food and producing more food locally.

25. Based on the technical and economic information gained by the field experimental work advice should be given to the Government on fertilizer price policy, subsidy and taxation.

26. The project should provide the government with realistic technical and economic data for the formulation of its long-term fertilizer policy. In due time a study should be prepared on the quantities and types of fertilizers and the economic aspects as a basis for the planning of local fertilizer production. Depending on the conclusions a technological feasibility study on fertilizer manufacturing should be carried out.

27. Fertilizer legislation should cover the following points: (a) licensing requirements regarding manufacture, import and sale of fertilizers; (b) declaration to be made as to plant nutrient content; (c) analytical methods to be used for determining the various nutrients; (d) official inspection and control measures; (e) the penalties for non-compliance with the provisions of legislation.

Training in soil fertility and fertilizer work

28. The training of local personnel should consist of: on the job training, training courses in the country, fellowship and study trips outside the country. It should cover all activities of a project. In the first instance the counterpart staff at different levels should take part in the training. The extension service should be trained in fertilizer use practices and the suitable means for publicising these recommendations and supervising their application. High level officers, responsible for the planning of long-term fertilizer use development in the country, should have the possibility of making themselves acquainted with the most efficient and up-to-date methods in this field.

——————— = FAO's assistance - - - - - - - = Continuation of activities by the country	TIMETABLE Years 1	2	3	4	5	6	7	8	9	10
1. Fertilizer trials	———	———	———	———	———	- - -	- - -	- - -	- - -	- - -
2. Soil Management and Conservation trials including shifting cultivation)	———	———	———	———	———	- - -	- - -	- - -	- - -	- - -
3. Agronomic trials (including hyv)	———	———	———	———	———	- - -	- - -	- - -	- - -	- - -
4. Soil reclamation		———	———	———	———	- - -	- - -	- - -		
5. Demonstrations and extension on 1. 10. 4		———	———	———	———	- - -	- - -	- - -	- - -	- - -
6. Soil classification in relation to experimental work	———	———			———					
7. Soil testing	———	———	———							
8. Benefit/cost studies			-	-	-					
9. Soil Data Bank			———	———	———	- - -	- - -	- - -	- - -	- - -
10. Applied research on specific problems		———	———	———	———	- - -	- - -	- - -	- - -	- - -
11. Improving infrastructure for fertilizer distribution and produce marketing			———	———	- - -	- - -	- - -	- - -	- - -	- - -
12. Fertilizer distribution				———	———	———	———	———	- - -	- - -
13. Establishing fertilizer office				———	———	———	———	———	- - -	- - -
14. Formulation of fertilizer use development plan					———	———	———			
15. Feasibility study on local fertilizer manufacturing				———	———					
16. Fertilizer manufacturing										