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FERTILIZERS IN EAST AFRICA

CONTENTS

65-2494

I. RESOURCES FOR AGRICULTURAL DEVELOPMENT

1. According to the FAO Africa Survey,[1] the Eastern African Region is subdivided into a number of sub-regions or zones determined by differences in rainfall and temperature. The interrelation of these climatic factors with soil and water resources determines the type of natural vegetation and also, to a large extent, the agricultural potential. Because of variation in altitudes, temperature as well as rainfall is a major climatic factor in the Eastern Region, which extends from the arid lands of low altitude in the Horn of Africa southward across the plateaus and highlands of East Africa.

2. This region is classified into six sub-regions and zones:

1. Eastern equatorial desert and sub-desert zone
2. Eastern equatorial savanna zone
3. Eastern coastal zone
4. Lake Victoria zone
5. Eastern Plateau
6. East African highlands.

Eastern equatorial desert and sub-desert

3. This zone, of about 700,000 km^2 covers much of the Horn of Africa in Ethiopia and Somalia and northern Kenya. Nomadic grazing is the main form of land use. Cropping is possible only with irrigation. The agricultural potential is very low and there is no hope for much improvement. This zone is of minor interest to this paper.

Eastern equatorial savanna

4. This rather large (1,560,000 km^2) zone surrounds the highlands of Ethiopia and spreads down into parts of Somalia, Kenya, Tanzania and Uganda. Rainfall is lower in the north and varies from 120 millimeters

1/ FAO Africa Survey, Report on the Possibilities of African Rural Development in Relation to Economic and Social Growth, FAO Rome, 1962.

large part of this area was covered with forest. At present they are the regions of the greatest concentration of African farmers (Ethiopia, Ruanda-Urundi), especially in the valleys, where the soils are deep and fertile and rainfall is high with good distribution for vegetation. The food crops for very dense populations are plantains, maize, sorghum, pulses and - on high plateaus - barley. The cash and export crops are coffee (Arabica), pyrethrum and tea. Cattle are very important in this zone and are kept either in free-range grazing (Ethiopia) or, on European ranches, in mixed farming system (Kenya, Rhodesia). The characteristic feature of this zone are the volcanic-origin soils. They are very productive and can occur either as black or brown forest soils, or as dark-red forest soils. The former are found at high elevations and are usually acid, friable and well drained; they can be used for intensive production. The latter appear at lower levels and are suitable for a wide range of crops.

II. THE ROLE OF FERTILIZERS IN EAST AFRICAN AGRICULTURE

12. Although fertilizers are little used outside European settlement and plantation areas in the sub-region concerned, their role is known well. Experimental work on fertilizers has been carried out during the past 40 years, and it shows promising results. It should be noted that this work has been carried out mostly in experimental stations, which in most cases are located on more fertile soil and where conditions are unlike those normally found. It is rather difficult to apply the findings of such experiments to farmers' fields. They must be adjusted to ordinary conditions. But in any case, lack of knowledge cannot be allowed to impede the increase of fertilizers use. From the examples given below it is obvious that agricultural knowledge as far as fertilizer application is concerned is pretty far ahead of the agricultural practice.

Food crops

13. Using information contained in the "Kenya Fertilizer Working Party Report" (see Annex Table 3)*, one can calculate some very interesting crop responses to fertilizer application.

TABLE 1

Food crop responses to fertilizer application in Kenya

Crop	Type of fertilizer	Value per unit cost of fertilizer: Gross increase in output	Net increase in output
Maize	D.S.a/	3.5	2.5
	S.A.b/	2.9	1.9
Potatoes	D.S.	5.4	4.4
	S.A.	5.4	4.4
Wheat	D.S.	4.1	3.1
Barley	D.S.	3.0	2.0
Rice	D.S.	1.8	0.8
	S.A.	2.4	1.4

a/ Double superphosphate – b/ sulphate of ammonia

* T.C.J. RYAN and R. KEMPTON, The Economic Aspects of Using Fertilizer Kenya Fertilizer Working Party Report, Appendix E/3, Ministry of Agriculture, Nairobi, 1963.

TABLE 1 (CONT'D)

Food crop responses to fertilizer application in Kenya

Crop	Type of fertilizer	Value per unit cost of fertilizer: Gross increase in output	Value per unit cost of fertilizer: Net increase in output
Pineapples	S.A.	2.1 - 5.0	1.1 - 4.0
Tomatoes	S.A.	11.2	10.2
Strawberries	S.A.	5.6	4.6
	Urea	5.2	4.2
Sugar	S.A.	6.1	5.1
	D.S.	5.1	4.1
Average	D.S.	3.8	2.8
	S.A.	5.3	4.3

14. These figures represent the average responses of various food crops to double superphosphate or to sulphate of ammonia applied in many parts of Kenya over a period of 10 years. The average responses to sulphate of ammonia were higher (gross - 5.3 and net - 4.3) than to double superphosphate (gross - 3.8, net - 2.8). The average responses of cereals (maize, wheat, barely, rice) to fertilizers were rather lower: to double superphosphate 3.1 and 2.1 and to sulphate of ammonia only 2.7 and 1.7. Nonetheless, all the responses are promising, if we take into consideration that a given expenditure invested in all kinds of fertilizer gave a gross return of around 4.7 and a net return of around 3.7.

Maize

15. With the exception of Uganda, maize is the main food crop in the region under consideration. Results of experiments with fertilizer applied to maize are available from Kenya, Tanzania, Zambia and Rhodesia. In all those countries maize responses to fertilizer are significant and promising. For instance, on the volcanic soil at Arusha, Tanzania, nitrogen as ammonium sulphate and phosphate as double superphosphate,

applied at 180 kg per hectare and muriate of potash at 90 kg per hectare, both separately and in combination, gave very good results. Especially significant was the response to potash which gave a 17 per cent increase over the control yield. This was very good, although unexpected on very fertile volcanic soil.

16. Work carried out by the Tanganyika Agricultural Corporation has shown that the application to maize of 125 kg per hectare of single superphosphate and the same amount of sulphate of ammonia gives a high return. From the economic point of view these amounts give the best results, i.e., the highest value response. Diagram 1 shows the influence of expenditure on fertilizers on returns in Rhodesia, as shown by a sample survey on about 50 farms each year. The curves, as it is obvious on the diagram, show that the highest value response can be obtained at lower expenditures on fertilizer, although there is an unbroken rise in the average yield per acre.

17. The average fertilizer recommendations for Kenya, Malawi, Zambia, Rhodesia and Tanzania for maize are therefore 40-60 P_2O_5 kg/ha and 20-60 kg/ha N.

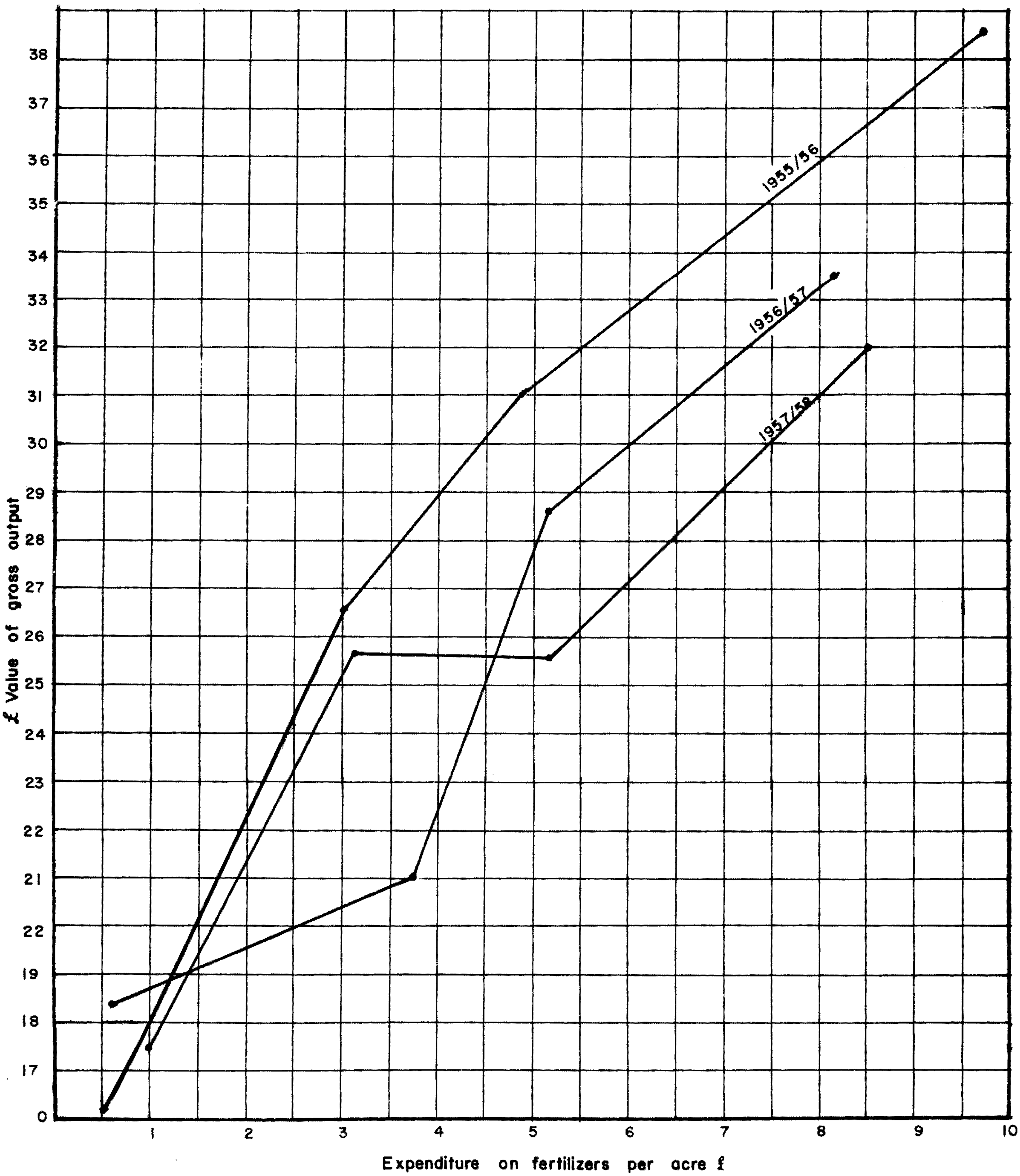
18. In Kenya, the findings of many hundreds of fertilizer experiments and demonstrations which the Department of Agriculture has undertaken in peasant farmers' fields suggested that on an average 1 kg of fertilizer N yields 20 kgs and 1 kg of fertilizer P_2O_5 yields 12 kgs maize grain.

Rice

19. The most complete data exist for Madagascar as given by A. Angladette (see Table 2).

20. Most interesting is the last column of Table 2 which presents the coefficient of the yield of rice per 1 kg of plant nutrients. Only one figure is lower than 5 kg. The others are above 5 kg per 1 kg of pure nutrients. As a rule, rice is one of those crops which give low responses to fertilizer (see Table 1).

Diagram I. The influence of Expenditure on Fertilizer on Returns in Rhodesia



Finger millet

21. The existing data taken from Uganda show that an application of only 110 kg per hectare of sulphate of ammonia (22 kg N per ha) when the finger millet was 6 inches high gave very considerable responses. Trials with fertilizer were carried out on more than 400 millet plots throughout the TESO BUKEDI and KATAKWI districts. Yields were as high as 60 per cent over the mean control yields. In the trials at SEVERE the increases were lower, between 11 per cent and 30 per cent. Responses to applications to the red soils of the southern districts were also small.

Sugar cane

22. A whole series of trials showed in Mauritius that:

1. there was always a response to nitrogen fertilizers;
2. the response was higher for the older ratoons;
3. the depressing effect of nitrogen application on sucrose content decreased with the age of the cane.

23. Applications of 30 kg/ha of nigrogen produced an increase of 37 per cent in yield of cane. A supplementary dose of 30 kg/ha produced an additional increase of 15 per cent. There was no individual response to phosphate application and cane responded significantly to potash application in only two trials.

24. In Uganda, a larger amount of fertilizer is applied to sugar cane. Figures obtained from the Lugazi Sugar Estate show the following picture:

Nitrogen - 198 kg N per hectare in the form of urea (46 per cent N) under every crop.

Phosphorus - 283 kg P_2O_5 per hectare in the form of triple superphosphate (47 per cent P_2O_5) once for three crops, at the beginning of that period of time.

Potassium - 165 kg K_2O per hectare in the form of muriate of potash under every crop.

TABLE 2

Fertilizer recommendations and responses of rice to fertilizer in Madagascar[a]

Region	Fertilizers recommended kg of pure nutrients/ha	Responses kg of rice/kg of pure nutrients
Alluvial soils of lateritic origin		
ALAOTRA	20 kg N	
AMBOSITRA	30 kg N + 120 kg P_2O_5 + 75 kg K_2O	58 kg per 1 kg N 9.1 kg per 1 kg mixture
Alluvial soils of basaltic origin		
ANISIRABE	100 kg N + 30 kg P_2O_5 + 75 kg K_2O	3.0 kg per 1 kg mixture
Alluvial soils of crystalline origin		
ANKAZOBE	100 kg P_2O_5 + 15 t of yeard manure	5.0 kg per 1 kg P_2O_5
Swamp soils developed		
ALAOTRA	60 kg N + 125 kg P_2O_5 + 75 kg K_2O	5.6 kg per 1 kg mixture
MAHITSY	30 kg N + 100 kg P_2O_5 + 15 t of yard manure	5.0 kg per 1 kg mixture
Swamp soils, lowmoor		
ALAOTRA	60 kg N + 125 kg P_2O_5 + 100 kg K_2O	7.8 kg per 1 kg mixture
ANJOROZOBE	30 kg N + 100 kg P_2O_5 + 75 kg K_2O	7.1 kg per 1 kg mixture

a/ Source: A. Angladette, "L'Utilisation des Engrais Outre-mer," Extrait de *Marchés Tropicaux du Monde*, p. 6.

25. With these applications the Lugazi Sugar Estate was able to attain an average yield of 137.5 tons of sugar cane per hectare, at 8-10 per cent of sugar.

Export crops

26. One can assume that nowadays almost the entire amount of fertilizer used in the region under consideration is applied to cash crops, most of which are exported. The region is a very important production area of sisal, tobacco, coffee, tea, cotton, pyrethrum and other crops. Experiments with these cash crops have been carried out on many research stations in the region, some of the results of which are presented below.

TABLE 3

Export crop responses to fertilizer application in Kenya

Crop	Type of fertilizer	Value per unit cost of fertilizer	
		Gross increase in output	Net increase in output
Tea	S.A.a/	12.1	11.1
Coffee	S.A.	10.9	9.9
Sisal	S.A.	0.2	- 0.8
Pyrethrum	D.S.b/	15.8	14.8

a/ sulphate of ammonia

b/ double superphosphate

Sisal

27. Sisal is the only crop presented in the Table above which did not show a very high response to fertilizer application. It is interesting to note that in Tanganyika, the largest world producer and exporter, satisfactory results were obtained by applying sulphate of ammonia to

sisal; nitrogen accelerates growth of the plants, but large dressings of sulphate of ammonia to sisal give rise to increasing acidity on certain soils, which in turn causes chlorotic mottling of sisal leaves.

Tea

28. Tea is cultivated on a large scale in the region under consideration. Much experience in fertilizer application has been gained in Malawi. Fertilizer experiments with tea have been under way at Swazi since the mid-thirties. In summary of these experiments one can state that nitrogen produces the fastest results of any fertilizer that is applied to unshaded tea and its use should, for the present, form the basis of a fertilizer policy. Neither phosphate nor potassium have had measurable effects on yields or bush growth at Swazi where they have been used for six consecutive years on mature unshaded tea. But in the face of experience in the Far East (India, Ceylon) and of inconclusive evidence found in Malawi, dressings of phosphate and potash are recommended for the time being to be on the safe side. For the present, recommendations of the Tea Research Station at Mlanje are:

Nitrogen - 113 kg/ha N per year
Phosphorus - 34 kg/ha P_2O per year
Potassium - 34 kg/ha K_2O per year.

Nitrogen application gives a linear response up to 136 kg/ha N. The average responses to N reach 5 kg of tea produced per 1 kg N applied.

Tobacco

29. Those countries in the sub-region which produce tobacco on a large scale are Rhodesia and Malawi. Responses of dark fired tobacco to fertilizers have been investigated in Malawi for the past 12 years. In general there has been a gradually increasing response, as cultivation has progressed, first to nitrogen and more recently to nitrogen and phosphate combined. Application of nitrogen alone to phosphate deficient soils has in fact reduced yields. Therefore, recommendations for Chitedze soils are about 225 kg/ha "C" compound ($5N-15P_2O_5-12K_2O$) and 225 kg/ha sulphate of ammonia or calcium ammonium nitrate.

This combination has been devised to give a good quantity of nitrogen and phosphate with a basement dressing of potash in case responses do occur. The choice of sulphate of ammonia or calcium ammonium nitrate depends mainly on the p^H levels of the soil.

30. Many field experiments on the application of fertilizer to tobacco have been carried out in Rhodesia. Flue-cured Virginia tobacco above (which is the most important cash crop grown in Rhodesia), was produced in the amount of 88.4 thousand tons in 1963 in Rhodesia and Zambia. The Report of a Survey carried out by the Economics and Market Branch, Rhodesian Ministry of Agriculture, for the Rhodesia Tobacco Association shows that fertilizers applied to flue-cured Virginia tobacco by 248 growers in 1962-63, affected both yield and price, and that any increase in expenditure up to US$100 per hectare generally increased profits.

Grasslands

31. A trial at Kawanda, Uganda, on a permanent grass ley showed that grass will respond well to sulphate of ammonia. A nearly four-fold increase in green matter was obtained from dressings up to 90 kgN per hectare, and the pasture, which was previously useless, provided some very valuable dry season grazing (November and December).

32. Livestock nutrition in Zambia largely depends on food available from the natural grasslands. Plot trials measured the effect of fertilizers on Hyparrhenia veld. Hyparrhenia veld is more or less open grasslands with scattered trees and shrubs. Nitrogen is the only nutrient limiting growth, and N fertilizer markedly increases the herbage yield and crude protein percentage. The herbage response is linear up to the highest amount of nutrient used, 215 kg N/ha, with a calculated N recovery of approximately 35 per cent. N fertilizer does not alter the botanical composition of the veld.

33. In Rhodesia, it has been proved that Nitrogen and Phosphorus are needed for good growth. Nitrogen is needed in large quantities, and where amounts of up to about 135 kg of N per hectare per year are used, the responses are for practical purposes proportional to the amount

applied. Lower and less consistent responses are obtained from phosphate fertilizers, and such responses are normally recorded only where phosphate is applied in combination with nitrogen.

34. In Mauritius fertilizer experiments using different levels of nitrogen in the form of sulphate of ammonia were carried out during recent years. The yield of grass was greater on plots which received 170 kg of sulphate of ammonia (35 kg of N) per hectare of each cut than from those plots receiving 50-100 kg per hectare. In some instances an application of 225 kg per hectare at each cut gave the highest yield, particularly for elephant grass.

III. FERTILIZER OUTPUT AND APPLICATION IN EAST AFRICA

35. According to the FAO's Annual Review of World Production, Consumption and Trade of Fertilizers for 1961, 1962, 1963, the consumption of fertilizers in the East African countries in 1961/62 exceeded 100,000 tons in pure nutrients. The consumption of fertilizers was static during the past three years due to political changes in the sub-region. Relatively speaking the highest consumption was in Rhodesia and the two islands of Mauritius and Reunion. In Kenya, Tanganyika and Uganda, fertilizer consumption is still in a rudimentary stage. Only the European settlers, especially those in Kenya, use some amounts of fertilizers. Table 4 gives more detailed information.

36. Only two countries in the sub-region under consideration produce phosphate fertilizers - Rhodesia and Uganda. In Rhodesia (Salisbury) the production of single superphosphate and concentrated superphosphates started in 1958/59 with 11,953 tons of P_2O_5. In the next two years, production increased to 18,607 and 16,756 tons, respectively. The present production of all forms of superphosphates (single, double and triple) amounts to about 30,000 tons. The Rhodesian plants use phosphate rock imported from Senegal. Starting next year superphosphate production will be based more and more on domestic phosphate rock deposits located at Dorowa where there is a processing plant. Salisbury plants also produce about 60,000 tons of sulphuric acid per year and about 16,500 tons of phosphoric acid, which is indispensable for concentrated superphosphate production. As the production of sulphuric acid will be increased to the level of 105,000 tons next year, the production of superphosphates can be also increased to the level of 40,000 tons.

37. Tororo Industrial Chemicals and Fertilizer Ltd, Uganda, are at present manufacturing single superphosphate from the apatite deposit at nearby Sekulu. Production started in 1962 with a design capacity of 25,000 tons of single superphosphate, and in 1964 production reached the level of 12,000 tons. At the end of 1964 it was shown that the

design capacity could be exceeded in 1965 if there is a higher demand for superphosphate in Kenya, Tanganyika, and Uganda. Tororo plant is also manufacturing sulphuric acid from imported sulphur at the level of 1400 tons per year. This acid is used for single superphosphate production.

38. Only in Rhodesia are small amounts of locally produced superphosphates used directly in agriculture in the form of a phosphorus fertilizer. Most superphosphates are used for the production of mixtures. Twelve different mixtures are produced by three companies: Rhodesia (producer of superphosphates), Windmill Fertilizers and Fisons. All three companies produce the same mixture, containing the same proportion of nutrients (N, P_2O_5, K_2O) these are solved in three countries: Rhodesia, Zambia and Malawi. Eighty per cent of this fertilizer is used in Rhodesia, 15 per cent in Zambia and only 5 per cent in Malawi. The K_2O and N used in rolling this mixture are imported.

39. The East African sub-region is on the whole more advanced in fertilizer consumption than the other sub-regions of tropical Africa. But looking at column 9 of Table 35, one easily sees that the consumption of fertilizers is still at the very low level of 3 kg per hectare. Consumption varies significantly in different countries, from practically none in Ethiopia, Somalia, Burundi and Rwanda to high in Mauritius and Reunion. Of the large countries, Rhodesia has a moderate fertilizer consumption of 33.3 kg/ha which shows notable signs of increasing significantly in the future.

40. Taking the <u>per capita</u> use of fertilizer in East Africa (Table 5, Column 11) into consideration, we find that on the whole it is very low, much lower than in any other continent taken as a whole (Table 6). Only the three countries mentioned previously have a large consumption (Mauritius - 25.9; Reunion - 20.3 and Rhodesia - 14.2). The others remain at a very low level.

TABLE 4

Consumption of fertilizers in East Africa

(in tons of pure nutrients)

Country	Nitrogen			Phosphorus			Potassium			Aggregate		
	1955/56	1961/62	1963/64	1955/56	1961/62	1963/64	1955/56	1961/62	1963/64	1955/56	1961/62	1963/64
Ethiopia	.	.	160	.	.	219	.	.	70	.	.	449
Kenya	1700	2628 a/	2890	2200	6087 a/	7300	350	1131 a/	1020	4250	9846	11210
Tanganyika	500 b/	1423	1850	500 b/	810	430	400 b/	490	990	1400	2723	3270
Uganda	600 b/	1172 a/	1200 b/	500 b/	1135 a/	1200 b/	300 b/	300	300 b/	1400	2607	2700
Rhodesia c/	7963	20458	21244	12643	18787	23735	7329	11987	15063	27935	51232	60042
Malawi c/	498	1278	1200	790	1174	1400	458	749	880	1746	3201	3480
Zambia c/	1493	3836	3156	2370	3522	3065	1374	2247	1657	5237	9605	7878
Mozambique	2000 b/	2585 b/	2600 b/	400 b/	500 b/	500 b/	200 b/	300 b/	300 b/	2600	3385	3400
Madagascar	600	808 b/	800 b/	180	300 b/	300 b/	398	690 a/	700 b/	1178	1798	1800
Mauritius	6428	7996	8500 b/	728	5162	7000 b/	3121	4961	5500 b/	10277	18119	21000
Reunion	2363	2354	2400 b/	996	803	900 b/	1520	2925	3000 b/	4879	6082	6300
Total	24145	44538	46000	21307	38280	46049	15450	25780	29480	60902	108598	121529
Index	100	184	195	100	180	216	100	167	191	100	178	200

a/ 1960/61

b/ estimated

c/ The figures for the Federation (for 1963/64) can roughly be divided as follows:

Rhodesia, 80%
Zambia, 15%
Malawi, 5%

TABLE 4a

Consumption of fertilizers in East Africa

Index: 1955/56 = 100

Country	1963/64
Ethiopia	
Kenya	264
Tanganyika	234
Uganda	193
Rhodesia[c]	215
Malawi[c]	200
Zambia[c]	150
Mozambique	131
Madagascar	153
Mauritius	204
Reunion	129
Average, sub-region	200

c - The figures for the Federation are divided as follows: Rhodesia, 80 per cent; Zambia, 15 per cent; Malawi, 5 per cent.

41. On the whole we can characterize the sub-region under consideration as a vast area populated by over 80 million inhabitants. Only 6.4 per cent or 40 million hectares of this area is cultivated. Average consumption of fertilizer is 3.0 kg per hectare but most of the land gets no fertilizer.

TABLE 5

Some demographic and Agro-fertilizer indicators of East African countries

Country	Population, (million)a/			Total area (million hectares)	Agricultural area (million ha)b/ around 1960-1961		Fertilizer Consumption 1963/64		Arable land per capita (in ha) 1960	Per capita consumption of fertilizer (kg of nutrients 1960
	1960	1970	1980		Land under crops	Meadows and pastures	Total '000 kg of pure nutrients	kg of NPK per ha of arable land		
1	2	3	4	5	6	7	8	9	10	11
1. Ethiopia	20.0	23.8	29.0	118.4	11.5	58.7	0.4	0.04	0.6	0.02
2. Somalia	2.0	2.4	2.9	63.8	1.0	20.6	.	.	0.5	.
3. Burundi	2.5	3.3	4.2	2.8	1.2	.	.	.	0.5	.
4. Rwanda	2.7	3.0	3.5	2.6	0.9	0.7	.	.	0.3	.
5. Kenya	8.1	10.3	13.6	58.3	1.7	3.9	11.2	6.6	0.2	1.2
6. Tanzania	9.5	11.6	14.6	94.0	9.5	32.6	3.3	0.5	1.0	0.3
7. Uganda	6.7	8.1	10.0	24.0	2.9	..	2.7	1.0	0.4	0.4
8. Zambia	3.2	4.2	5.7	74.6	1.7	.	7.9	1.1	0.5	2.7
9. Malawi	3.5	4.6	6.1	11.9	2.9	0.6	3.5	1.2	0.8	0.9
10. Rhodesia	3.6	5.0	7.1	35.9	1.8	4.9	60.0	33.3	0.5	14.2
11. Mozambique	6.5	7.6	9.1	78.3	2.0	44.0	3.4	1.7	0.3	0.4
12. Madagascar	5.4	6.2	7.6	59.6	2.7	34.0	1.8	0.7	0.5	0.3
13. Mauritius	0.7	0.8	1.1	0.2	0.09	0.03	21.0	233.0	0.1	25.9
14. Reunion	0.3	0.4	0.5	0.25	0.06	0.02	6.3	105.0	0.2	20.3
East Africa	74.7	91.3	115.0	624.7	40.0	.	121.5	3.0	0.5	1.5
				100.0	6.4					

a/ Source: United Nation, Provisional Report on World Population Prospects as Assessed in 1963, ST/SOA/SER.R/7; ECA, Demographic Section.

b/ Source: FAO Production Yearbook 1963.

TABLE 6

Per capita use of fertilizer (thousands of metric tons of plant nutrients) 1962-1963*

Specification	Oceania	USA and Canada	Europe a/	Japan	USSR	Latin America	Africa	Asia b/
Nitrogen (N)	50	3,554	4,920	669	1,070	356	400	1,781
Phosphorus (P_2O_5)	890	2,937	4,830	465	853	323	310	405
Potash (K_2O)	90	2,291	4,880	506	826	219	100	194
Total nutrients	1,030	8,782	14,630	1,640	2,749	898	810	1,780
Population, millions (1962)	17.2	206	434	95	221	224	269	952
Nutrient, Kg/capita	59.9	42.6	33.7	17.3	12.5	4.0	3.0	1.8

* Source: Dr. Raymond Ewell, Famine and Fertilizer, State University of New York a Buffale, Chemical and Engineering News, December 19, 1964, based on FAO Production Yearbook, 1963.

a/ Excluding USSR.

b/ Excluding China and Japan.

IV. FUTURE FERTILIZER CONSUMPTION IN EAST AFRICA

42. The growth of the population is very rapid (see Columns 2, 3, 4 of Table 5). It is expected that before 1980 the population will exceed 110 million. For our calculations here we can assume that the increment of the population between 1960 and 1980 will be approximately 40 million.

43. What is virtually sure is that this additional population will not find enough food for itself with the present methods of land cultivation. One can see that nowadays there is some kind of balance in the sub-region between the existing population (74.7 million in 1960 - Table 12) and the food supply. Even with this balance many people in the sub-region suffer from undernourishment and malnutrition especially as far as animal origin proteins are concerned. If additional population appears, the existing balance between number of people and food supply will be upset, and some new improved methods of agricultural production have to be introduced in order to produce more and better food.

44. We can assume therefore, that the agricultural production increment for 1980 has to cover two different requirements:

(a) The total food demand of the 40 million additional people,

(b) Improvement in the nutrition basic of the population of 74.8 people (1960), at least 20 per cent of that which is calculated per capita under a.

45. (a) If we take into account that one man needs about 2,500 calories daily and that 1 kg. of grain contains approximately 3,400 calories, we see that the daily requirement of one man is 735 g. of grain or about 268 kg. of grain yearly. Together with loss in store and wastage (20 per cent of yields) it would be about 335 kg. of grain. To provide 335 kg. of grain per year for 40 million people, East Africa would require about 13.4 million tons of grain (maize, wheat, teff, rice, barley and so on).

46. To make the problems more understandable, we should explain that 1 kg. of grain containing 3,400 calories cannot necessarily be the only

food. **Other foods** or even animal products produced on the basis of grain are here represented in their grain equivalent. Grain has here been used as a symbol and equivalent of that which is necessary to maintain a human being. It must be understood that the grain symbol is a considerably simplified and conservative one. In practice the problem is much more complicated and the demand perhaps greater than we assumed here. But neither the simplification nor the underestimation of food demand can weaken our argument since, if the estimates presented in this paper are really conservative ones, how large must the future demand be in reality?

47 (b) We can assume that the improvement in the nutrition of the existing population can be represented by 20 per cent of that what was calculated under a, or 74,700,000 x 335 x 20 per cent = about 5.0 million tons of grain. This, when added to the 13.4 million tons already computed, gives 18.4 million tons of grain required. How to obtain such an amount of grain? In the light of the results of the trials and demonstrations carried out for years in the sub-region under review (Chapter II of this paper) fertilizer seems to offer the best possibility of a substantial increase in agricultural production between now and 1980. The other technical inputs in agriculture probably cannot be brought into action fast enough on a sufficiently massive basis to play a major role. It is true that in the agriculture one has to apply a large range of different inputs in order to get good results from each of those inputs. But it is also obvious that a high level of agricultural production would not be possible at all without the application of plant nutrients to the soil. The other inputs significantly increase the efficiency of the use of fertilizer. Improved seeds, increased irrigation, pesticides, and all other technical inputs must be utilized to the fullest possible extent, yet it should be recognized that the principal means of raising agricultural productivity will have to be fertilizer.

48. Taking into consideration the experience of other countries, for instance of the United States,[1] Japan[2] and India,[3] it can be assumed that 50 per cent of the 18.4 million tons of grain required, or 9.2 million tons, can be obtained by increasing fertilizer applications. The most difficult choice is that of the proper co-efficient of the yield of 1 kg. of plant nutrients. The findings of many hundreds of fertilizer experiments and demonstrations in peasant farmers' fields in Kenya suggest that on an average:

1 kg. of fertilizer N yields 20 kg. of grain and
1 kg. of fertilizer P_2O_5 yields 12 kg. of maize grain.

As the proportion between N and P_2O_5 in Kenyan conditions is about 1 : 2,1 kg of that mixture would give about 14 kg. of grain.

49. Dr. Raymond Ewell assumed in his article mentioned above that "one ton of plant nutrient results in 8 tons of additional grain and that two thirds of the fertilizer would be used on grain, one third on all other crops."

50. Assuming a proportion of 1 to 10 (which conforms with the experience gained in the sub-region under consideration, see Chapter II of this paper), in 1980 it would be necessary to apply about 670 thousand tons of fertilizer in the East African sub-region in order to obtain enough food for the additional population (40 million people) and another 250 thousand tons for the nutrition improvement of the existing population, or 920 million tons of plant nutrients all together.

51. Additional amounts of fertilizer will be necessary for the expansion of cash crops for export, but it is difficult to determine how great this increase should be. Let us assume for our purposes that cash crops alone will require double the present over-all fertilizer consumption.

1/ How the United States improved its Agriculture, Development and Trade Analysis Division, Economic Research Service, US Department of Agriculture, Washington, 1964.

2/ W.Y. Yang, Farm Development in Japan, FAO, Rome, 1962.

3/ Movle S. Williams and J.W. Causton, FAO, Rome, 1962.

Thus about 240,000 tons of plant nutrients will be required. According to the calculations outlined above, the potential demand for fertilizer in 1980 will be about 1,160 thousand tons of pure plant nutrients consisting of about 464 thousand tons of N, about 464 thousand tons of P_2O_5 and about 232 thousand tons of K_2O.

TABLE 7

Potential Demand of Fertilizer in East Africa in 1980

'000 ton of pure nutrients

Specification	Nitrogen N	Phosphorus P_2O_5	Potash K_2O	Total
Total	464	464	232	1,160
Food crops	.	.	.	920
Cash crops	.	.	.	240

52. It must be understood that this potential demand for fertilizer can be met only under especially favourable conditions. Country targets, if they exist, plan a much lower level of fertilizer application in the future.

Country Targets

Nitrogen

53. Targets of six countries (Kenya, Uganda, Tanzania, Rhodesia, Zambia, Malawi) which are available at ECA are shown on diagram 2.

Kenya

54. A working party estimated future trends in the fertilizer needs of Kenya, based on a FAO publication entitled "Fertilizers and Economic Development." In common with this publication, the working party used 1980 as its Target Year. The conclusion of the working party was: "Kenya's total fertilizer requirement in 1980 becomes about 100,000 tons of nutrient - mainly phosphate and nitrogen."

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55. Taking into account Kenya's fertilizer use pattern, we may assume that in 1980 nitrogen will compose 33 per cent of the whole consumption, in other words, 33,000 tons of N will be required.

Uganda

56. In June 1964 the potential need for ammonium sulphate in Uganda in 1970 was estimated on the assumption that a heavy subsidy would be effected, possibly as much as 75 per cent of the cost at the farmer's gate and based on existing recommendations for fertilizer use. The target for 1970 was 92,000 tons of sulphate of ammonia, or 18,400 tons of N (20 per cent). The prolonged line on diagram 2 gives 36,500 tons of N for 1980.

Tanzania

57. Although the consumption of fertilizers is very low in Tanzania, agricultural needs are nevertheless worthy of note, if not actually very large. The Research Department of the Board of Agriculture has carried out a very comprehensive investigation in order to determine the country's exact requirements. In 1968 Tanzania is expected to consume about 30,000 tons of ammonium sulphate, or 6,000 tons of N. The prolonged line which has been adjusted to the yearly increments of the other countries, gives about 24,000 tons of Nitrogen for 1980.

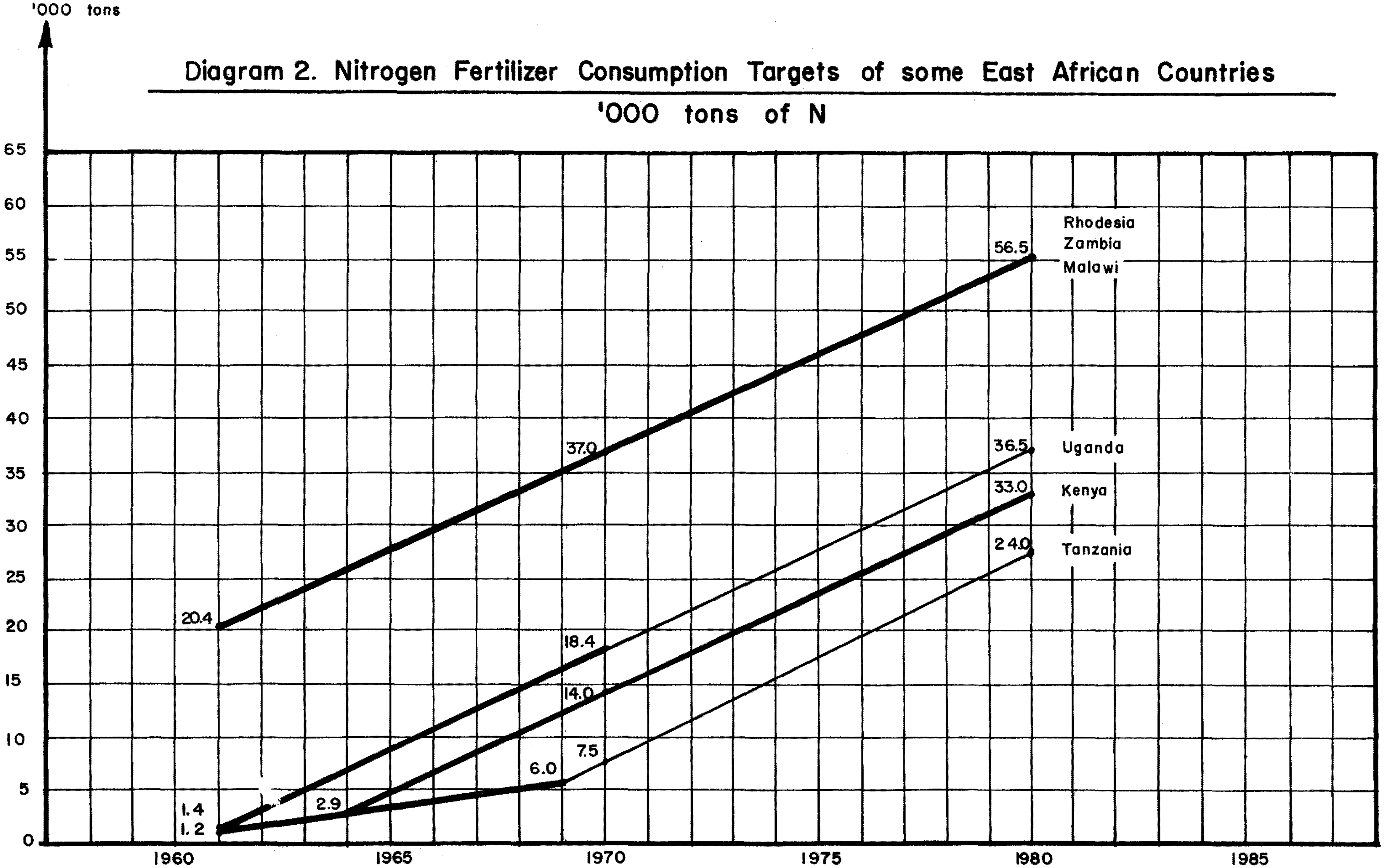
Rhodesia, Zambia, Malawi

58. Consumption estimates accepted by the Ministry of Agriculture were discussed with officials of the Ministry of Trade, Industry and Development. It was agreed to adopt the following estimates (in thousand of tons):

1965	-	30.7
1970	-	38.7
1975	-	47.1
1980	-	56.5
1984	-	63.7

Diagram 2. Nitrogen Fertilizer Consumption Targets of some East African Countries

'000 tons of N



59. These are over-all figures for the three countries: Rhodesia's requirements represent about 85 per cent, Zambia's 10 per cent and Malawi's 5 per cent. The line on diagram 2 starts at 20.4 thousand tons and ends at 56.5 thousand tons of Nitrogen.

TABLE 8

Nitrogen Fertilizer Consumption Targets for 1980

Country	Consumption in 1980 '000 tons of N
Tanzania	24.0
Kenya	33.0
Uganda	36.5
Rhodesia	48.0
Zambia } Malawi }	8.5
Total	150.0

60. The six countries listed above represent nearly 70 per cent of the present nitrogen fertilizer consumption in the sub-region (Table 4 - Column Nitrogen - 1963/64). If we assume that the rest of the countries will increase their fertilizer consumption at the same yearly increment, we can easily estimate the target for the whole sub-region. It would be:

$$150 \times \frac{100}{70} = \text{approximately 215 thousand tons of Nitrogen}$$

Phosphorus

61. Diagram 3 shows the targets of five countries.

Kenya

62. Kenya's pattern of fertilizer application differs from those of other East African countries. The rôle of phosphorus is the most important.

For this reason we assume that P_2O_5 will comprise 50 per cent of future fertilizer consumption (N-33 per cent, P_2O_5 - 50 per cent and K_2O - 17 per cent).

Tanzania

63. This country is starting almost from naught and intends to increase its consumption of phosphorus to 10 thousand tons by 1968. The prolonged line gives 34 thousand tons in 1980.

Rhodesia, Zambia and Malawi

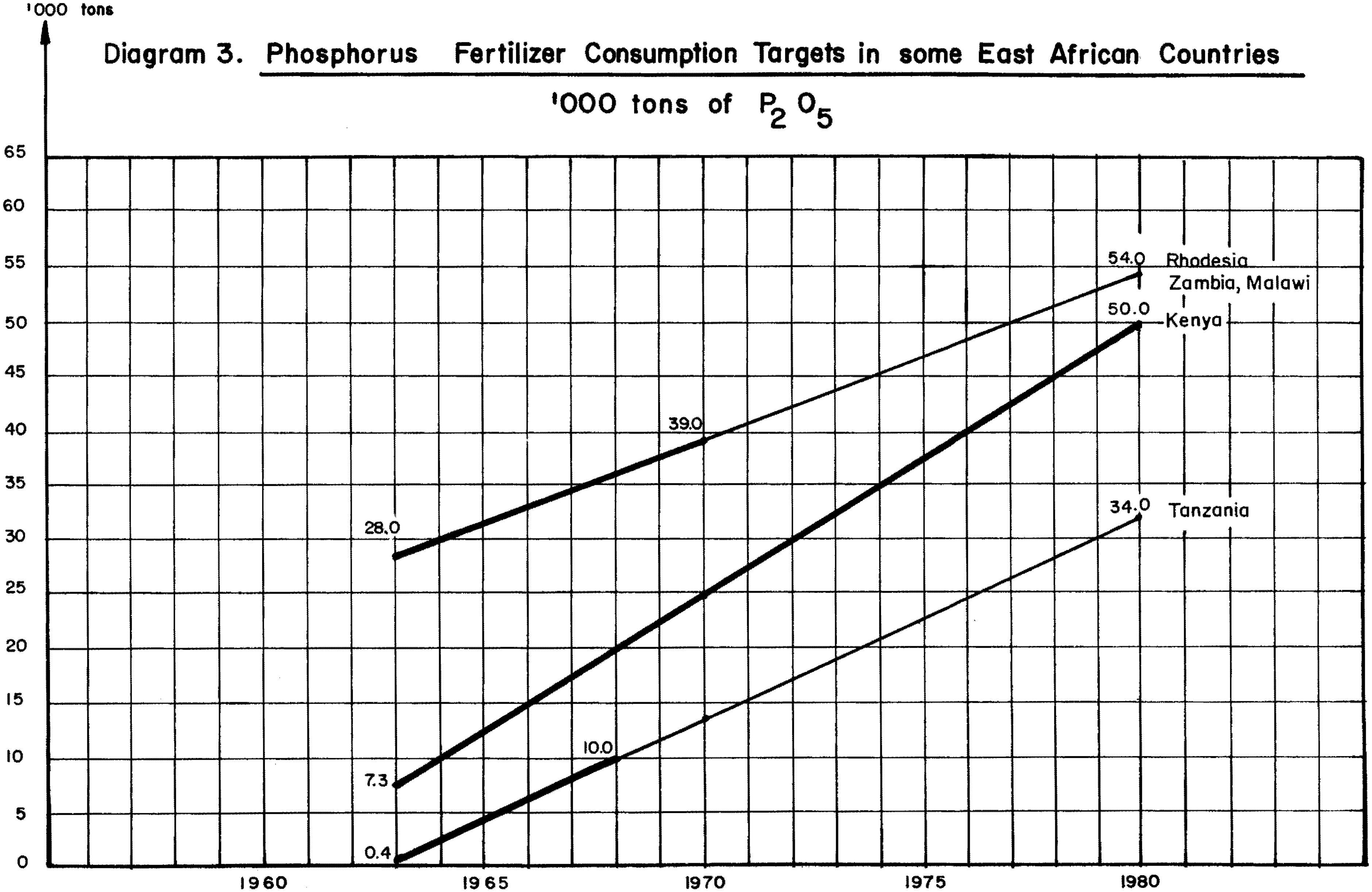
64. Thanks to existing super-phosphate plants, these three countries are using more phosphorus than the other countries in the sub-region. The expansion of the capacity of the plants permits an increase in phosphorus application, which can be seen on diagram 3.

Table 9. Phosphorus Fertilizer Consumption Targets to 1980

Country	Consumption in 1980 '000 tons of P_2O_5
Tanzania	34.0
Kenya	50.0
Rhodesia) Zambia) Malawi)	54.0
TOTAL	138.0

65. These five countries represent about 75 per cent of the present phosphorus consumption in the sub-region (Table 4 - Column Phosphorus 1963/64). Assuming the same yearly increment for the rest of the sub-region, we obtain 185 thousand tons as a target for 1980.

66. A potassium target can be obtained from the proportion between the elements: N: P_2O_5 : K_2O and amounts to 120 thousand tons of K_2O.



'000 tons
Diagram 3. Phosphorus Fertilizer Consumption Targets in some East African Countries
'000 tons of P2 O5
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1960
1965
1970
1975
1980
54.0
Rhodesia
Zambia, Malawi
50.0
Kenya
39.0
28.0
34.0
Tanzania
10.0
7.3
0.4

Diagram 4. East African Fertilizer Consumption

'000 tons of pure nutrients

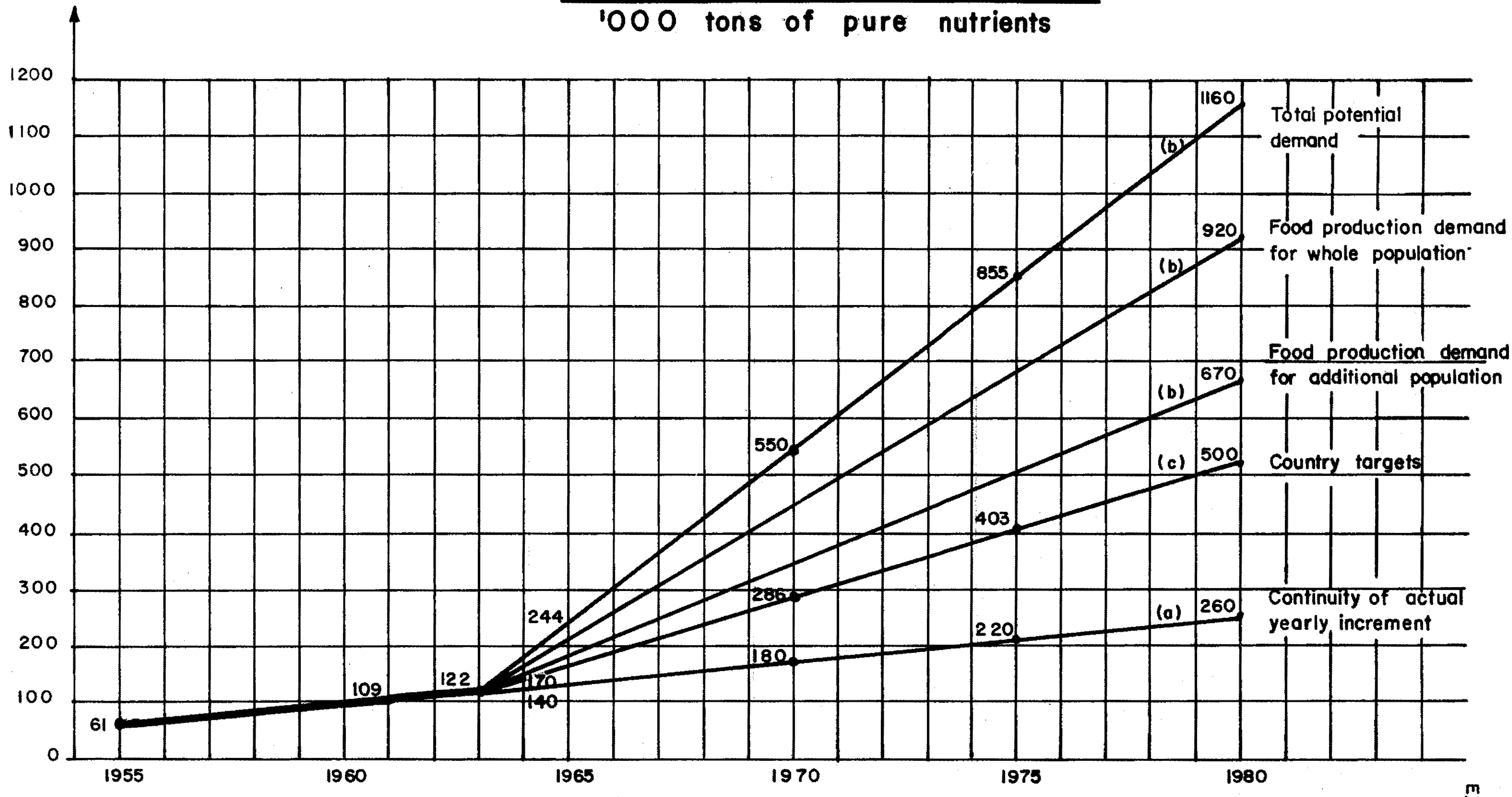


Table 10. Fertilizer Consumption Target for 1980

Specification	Consumption in 1980 '000 tons of plant nutrients
Nitrogen	215
Phosphorus	185
Potassium	120
Total	520

67. Let us now compare the results of our **deliberations.** Diagram 4 contains five lines:

(a) the lowest line represents the continuity of the actual yearly increment;

(b) the top lines show the potential demand at three variants;

(c) the middle line shows the targets of 6 countries extended to the whole sub-region.

68. Lines "b" and "c" should of course be drawn as the curves of a parabola rather than as straight lines; however, this kind of line drawing is justified as it would be impossible to be precise in any case, given such great differences.

Table 11. Comparison of Various Assumptions of Future Fertilizers Consumption

'000 tons of plant nutrients

Specification	1965	1970	1975	1980	Yearly increment
Continuity of actual yearly increment	140	180	220	260	8
Country targets	170	286	403	520	23
Total Potential demand	244	550	855	160	61

69. The last column of Table 11 shows the yearly increment of fertilizer application in the sub-region. It is interesting to note how great are the differences between the three figures in this column.

70. The yearly increment was calculated by dividing the difference between the final figures (1980) and the 1963 consumption by 17. This is the consequence of the straight line drawing. In reality the increment should be lowest at the beginning of the period of time under consideration and should increase in the later years of the period, until, in the final years, the highest value is reached. This presentation should be sufficient to illustrate the differences between the figures of the targets and those of the potential demand.

71. Table 12 shows the potential demand of fertilizer in the various countries in the sub-region. The demand was calculated according to the assumptions made in this paper. The footnotes under Table 12 explain the methods of calculation. Most questionable are the figures in column 8 dealing with the demand of fertilizer for cash crops for export. Plans for cash crop expansion to 1980 by countries do not exist. The assumption that the future consumption of fertilizer for cash crops alone will equal double the present over-all consumption figure seems inaccurate for some countries especially for those where fertilizer is presently used very little (Ethiopia, Somalia, Tanzania, Uganda, Mozambique, Madagascar). Therefore, the figures in column 9, which contain the total demand by countries, are more realistic than those in columns 5 - 8.

72. The last four columns give a picture of the demand by groups of countries and by plant nutrients. For each of those groups the same proportion of plant nutrients, namely, 40 N: 40 P_2O_5 : 20 K_2O, is assumed. As a whole this proportion reflects to some extent the pattern of fertilizer needs in the region under review although the present consumption shows more K_2O (Table 4 - 46 N: 46 P_2O_5 : 29 K_2O). In the future, however, the relative role of potassium will diminish in comparison to the roles of nitrogen and phosphorus. This is due

TABLE 12

Fertilizer Needs in 1980 by Countries

Country	Population (millions) a/			Fertilizer demand by 1980 (thousand tons)					Country target for 1980 '000 tons	Demand of Group of countries '000 tons			
	1960	1980	increment	Nutrition Improvement b/	Food Supply c/ for additional population	Food crops together d/	Cash crops for export e/	Total demand		NPK	N	P_2O_5	K_2O
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ethiopia	20.0	29.0	9.0	67.0	150.8	217.8	0.8	218.6	.	240.4	96.2	96.1	48.
Somalia	2.0	2.9	0.9	6.7	15.1	21.8	.	21.8	.				
Burundi	2.5	4.2	1.7	8.4	28.4	36.8	.	36.8	.				
Rwanda	2.7	3.5	0.8	9.0	13.4	22.4	.	22.4	.				
Kenya	8.1	13.6	5.5	27.1	92.1	119.2	22.4	141.6	100.0	407.7	163.1	163.1	81.
Tanzania	9.5	14.6	5.1	31.8	85.4	117.2	6.6	123.8	55.0				
Uganda	6.7	10.0	3.3	22.4	55.3	77.7	5.4	83.1	.				
Rhodesia	3.6	7.1	3.5	12.0	58.6	70.6	120.0	190.6	112.6				
Zambia	3.2	5.7	2.5	10.7	41.9	52.6	15.8	68.4	.				
Malawi	3.5	6.1	2.6	11.7	43.6	55.3	7.0	62.3	.				
Mozambique	6.5	9.1	2.6	21.8	43.6	65.4	6.8	72.2	.				
Madagascar	5.4	7.6	2.2	18.1	36.8	54.9	3.6	58.5	.	519.9	208.0	208.0	103.
Mauritius	0.7	1.1	0.4	2.3	6.7	9.0	42.0	51.0	.				
Réunion	0.3	0.5	0.2	1.0	3.3	4.3	12.6	16.9	.				
	74.7	115.0	40.3	250.0	675.0	925.0	243.0	1168.0	500.0	1168.0	467.2	467.2	233.
										100.0	40.0	40.0	20.

a/ Source: as in Table 13
b/ Figures of Column 2 multiplied by 3.35 kg. of fertilizer (consumption per year, per capita)
c/ Figures of Column 4 multiplied by 16.75 kg. of fertilizer (consumption per year, per capita)
d/ Figures of Column 5 + figures of Column 6
e/ The over-all consumption of fertilizers in 1963/64

to two factors: (1) production patterns (big role of grain, small of root plants) and (2) the high level of potassium in most soils of the region. It is assumed that the proportions of pure nutrients assumed in Table 12 will hold in 1980.

73. In some countries of the region under consideration (Kenya, Malawi and others) the present percentage of phosphorus is higher than 40 per cent of the total of plant nutrients consumed. However, as world fertilizer consumption develops, the relative role of nitrogen is becoming more and more important. For this reason it is assumed that nitrogen and phosphorus will in future be consumed in equal amounts and assigned them each the same proportion.

74. From among the three groups in the Table, the first is unlikely to achieve the estimated fertilizer consumption. The reason for this becomes obvious when one considers that the present consumption of fertilizer in Ethiopia and Somalia is almost zero. The figures for the other two groups are more realistic, as it is more probable that the countries belonging to them will be able to increase their fertilizer consumption to the extent that they will keep pace with the potential demand. This is especially true of Rhodesia, Mauritius, Kenya and Reunion.

75. The last three columns of Table 12 indicate the whole future requirement for nitrogen, phosphorus and potassium. However, this requirement should be defined according to the kinds of plant nutrient in each group. The case of potassium is rather easy. Most potassium is used as a muriate of potash (KCl) which contains 48 ÷ 62 per cent K_2O and about 47 per cent chlorine. Muriate is obtained by removing sodium chloride from sylvinite, a natural salt-potassium chloride. The high percentage of K_2O found in muriate is very convenient as it reduces the very high transport costs.

76. More difficult is the choice of a proper fertilizer containing nitrogen and phosphorus as there are many varieties of such fertilizers. A few of the most import nitrogen fertilizers are described in Table 13.

Table 13. Most Important Nitrogen Fertilizer

Specification	Chemical Formula	Percentage of Nitrogen	Most Important Features
Sodium nitrate	about 16	$NaNO_3$	Natural depositis (Chile)or synthetic neutral, highly soluble N in the form most readily available to plants, quick-acting fertilizer, subject to leaching.
Ammonium sulphate	20.5	$(NH_4)_2SO_4$	Increases soil acidity, resistant to leaching, contains about 23 per cent sulphur.
Calcium nitrate	17	$Ca(NO_3)_2$	Contains about 34 per cent lime (CaO), excellent on acid soils or for plants sucn as vegetables that utilize large quantities of calcium.
Calcium cyanamide	about 21	$CaCN_2$	Contains 70 per cent hydrated lime, resistant to leaching, may be toxic, can be used for weed-killing.
Urea	about 46	$CO(NH_2)_2$	Highest percentage of N, slightly increases soil acidity, is gaining importance in world use.
Ammonium nitrate	33	NH_4NO_3	Very soluble, but more resistant to leaching than sodium nitrate; N readily available to plants in two forms: ammonia and nitrate; high percentage of N; used for explosives.
Solutions of ammonia	20-50	NH_4OH	Increasing in world use, shipping in tank cars, introduced by piping systems into irrigation water and into mixed fertilizers.

77. Phosphatic fertilizers are obtained chiefly from phosphate rock, may be used either without any processing other than grinding or as super-phosphates. Ordinary (single) super-phosphates, which contain 16-20 per cent phosphoric acid (as P_2O_5) is made by treating phosphate rock with sulphuric acid. It is readily soluble in water and does not easily wash out of the soil, where it is held by the colloidal complex. Super-phosphate is neutral in reaction in the soil; it contains about 19-20 per cent calcium and also sulphur in amounts of 10-12 per cent which can be very important for some soils (Kenya and Zambia - see Chapter II of this paper). 1/

78. Concentrated super-phosphate (double and triple) is usually made by treating the rock first with sulphuric acid and then with phosphoric acid. This fertilizer contains 45-48 per cent phosphoric acid. It costs more to produce and is slightly more expensive per unit of acid than single super-phosphate, but its transportation costs are lower, which is most important to farmers. There is also another phosphatic fertilizer - basic slag, which contains 10-20 per cent phosphatic acid combined with a considerable amount of lime (30-50 per cent CaO). It is obtained as a by-product of steel manufacturing, principally in Europe, where iron ores have a high content of phosphorus which must be removed along with other impurities in order to produce high-grade steel. Basic slag is used entirely in straight application. Owing to its high basic effect, this fertilizer is useful on acid soils but is less satisfactory on alkaline soils.

79. The features of fertilizers presented above have to be taken into consideration if some decisions are taken in the field of industrial activity. On the other hand, agricultural characteristics are also very important. One has to remember that:

(a) A large part of the soil in the region under review shows strong sulphur deficiency in Kenya, Zambia and other countries.

1/ Sulphur is a plant nutrient, equal in importance to nitrogen, phosphorus, and potassium. Large quantities of sulphur are applied as a constituent of some fertilizers such as single super phosphate and ammonium sulphate.

(b) Most of the soils in the region are neutral or close to neutral, but in many places acid soils occur (Rhodesia).

(c) Transportation of fertilizer is a most important factor as it is very expensive. Therefore more concentrated fertilizers are advantageous.

(d) Higher concentration of fertilizers, however, requires better knowledge of fertilizer usage because when a nutrient is more concentrated, it becomes easier to harm the soil than to help it.

80. Problems of industrial production must also be taken into consideration. These include the investment cost per unit of fertilizer made, the production cost per unit, raw material availability and other factors.

V. HOW TO GET EAST AFRICAN FARMERS TO USE FERTILIZERS

81. If we consider that from 1961/62 to 1964/65 world fertilizer consumption has increased from about 7 million tons to over 30 million tons, an increase of fertilizer consumption in East Africa from 120 thousand tons to 1 million tons in 17 years does not seem to be impossible; but if we consider the factors that make it difficult for the farmers in this region to use fertilizers, we see that the level of 1 million tons of fertilizer will really be very difficult to reach. Limiting factors are as follows:

(a) The high cost of fertilizers (see Table 14). Transport charges represent a large proportion of the total cost of fertilizers. Transportation cost could only be reduced by bulk handling, which cannot be justified at the present rate of usage.

(b) The low value of many crops grown in the region, such as cassava, bananas and maize. Most of the non-export crops have a very low cash value and although most of these crops show marked responses (see Chapter II of this paper) to fertilizer application, the resultant increases in yield may not be sufficiently large to warrant applying fertilizer.

(c) The relatively low standard of crop husbandry for most East African crops. Fertilizers are not a substitute for good farming; rather, they must be regarded as an integral part of good farming practice.

(d) Very low basic yields of some crops, particularly food crops in such countries as Ethiopia, Madagascar, and Mozambique. Production of new varieties by the plant breeder could result in a gradual increase in basic yields.

(e) Lack of adequate supplies of fertilizers and an inadequate distribution system. This is perhaps the key problem in increasing fertilizer application.

(f) Lack of information on the kinds and amounts of fertilizer needed and on methods of application in specific circumstances.

It is relatively easy to introduce fertilizer to the big farm units where continuous cultivation is practiced, but the most important task is the introduction of fertilizers to small farmers. There are great possibilities for extension services to contribute to increasing fertilizer use in East Africa.

(g) Tenure systems that still exist in Ethiopia, Madagascar and certain other countries. Such systems tend to discourage the economic use of fertilizers.

(h) The lack of adequate seed, and of disease and insect control measures and other practices that are necessary if fertilizers are to have their best effect.

(i) Additional labour that is required to apply fertilizer at a busy time of the year. Adoption of fertilizer seed drill by mixed farmers could reduce the labour requirements involved in application of fertilizers.

(j) Reluctance on the part of farmers to accept new techniques. We can expect this to be gradually overcome by education, propaganda and demonstration systems.

82. All these impediments and obstacles will have to be overcome if fertilizer use is to become more common in East Africa. In this connexion government action is necessarily very important.

83. The following policies are most important and are possibly even required if modern agricultural methods are to be used to increase agricultural production.

(a) Provision for greatly expanded research and extension services to supply information to cultivators and to assist them in applying improved methods.

(b) Provision of practical field demonstrations with fertilizer, in combination with other means of extension and publicity (film shows, radio broadcasts, leaflets, articles and so on).

TABLE 14

Prices paid by farmer per 100 kg. of plant nutrient in selected countries, US Dollars in 1961/62*

Type of Fertilizer	Kenya a/ 1961/62	Reunion 1961	Rhodesia b/ and Nyasaland 1961/62	Germany Federal Republic 1961/62	United Kingdom
Nitrogenous Fertilizers					
Ammonium Sulphate	27.6	33.8	29.1	26.5	14.1 e/
Ammonium Nitrate	-	31.3	-	26.0	18.8 e/
Calcium Nitrate	-	59.4	33.1	32.0	27.7 e/
Sodium Nitrate	-	-	59.0	31.2	-
Calcium Cyananide	-	-	-	32.2	23.8 e/
Urea	25.6	24.6	25.5	-	-
Phosphate Fertilizers					
Superphosphates below 25% P_2O_5	18.8 d/	-	27.0	20.2	11.65 f/
25% of over	23.0	-	22.4	-	-
Basic Slag	24.4	-	30.3	13.8	-
Potash Fertilizers					
Potassium Sulphate	18.2	-	18.0	9.2	13.2
Muriate, 60% K_2O	11.6	-	12.6	7.1	10.5

* Source: Fertilizers, an annual review of world production, consumption and trade, 1962 FAO, Rome.

a/ November - October, f.o.r. Mombasa; reduction offered for purchases in large quantities.

b/ April - March, 1959/60 through 1961/62, f.o.r. Salisbury

c/ Net of subsidy of 10%

d/ f.o.r. factory Tuybo

e/ Net of subsidy of $11.48

f/ Net of subsidy of $9.24

(c) The development of an effective pricing and distribution system for farm products and farm supplies that they must have in order to make use of modern methods.

(d) An effective distribution system for fertilizers, possibly combined with a subsidy system which would cover transportation costs to very distant regions and make the price of fertilizer equal for every farmer.

(e) The development of a system of farm credit for cultivators which would provide adequate protection against uncontrollable risks, such as severe drought in some regions.

VI. SUMMARY

84. The sub-region under consideration has good possibilities for agriculture expansion. At present only 6.4 per cent of the total area is cultivated. Vast areas are used as grassland for livestock. In Uganda, Rwanda, Burundi and Kenya, rainfall distribution differs from one rainy season to the next, changing the farming pattern from only one crop a year to two. Most of the area is highland and variations in altitude and temperature, as well as in rainfall, are a major climatic feature, dividing the whole area into six sub-regions and zones.

85. The soils in the sub-region range from desert and sub-desert types, through sandy soils, acid, red and yellow and reddish-brown soils in the highlands around Lake Victoria to alluvial soils, together with dark clay, poorly drained and difficult to work, in the lowlands - all in the same zone. In the Eastern Plateau, alluvial soils are found as well as yellow, deep and friable forest and sandy soils, dark clay and red and yellow tropical forest soils of varying usages. In the highlands, very productive volcanic soils occur and black, brown or dark red forest soils. Thus on the whole, there is a mosaic of many different types of soils.

86. The fertility of East African soils is in general low, with the exception of the highlands soil. The organic matter content and exchange capacity are low to very low. The pH of the top soils is 5.0 where rainfall is heavy to 7.5 in drier areas. Nitrogen and phosphorous content is usually very low and in some parts of the sub-region such as Kenya, the phosphorous content is extremely low. The potassium content is higher, and in many places potassium application gives no positive response. In Kenya, Zambia and some other countries there is a widespread deficiency of sulphur. Yield levels differ very much from low in African agriculture to high and even very high in European settlement areas.

87. With the exception of Burundi, Rwanda, the Ethiopian highlands and Kenya, the density of population is not high, and shifting cultivation and land grazing are widespread over vast, sparsely populated areas of the sub-region. Shifting cultivation means that only a small part of the

arable land is cultivated. In those parts of the sub-region where the population is dense, it is also expanding very rapidly; and some means must be found to eliminate forest fallow and of utilizing the land more productively. To accomplish this, many factors have of course to be taken into account, but one of the most important is fertilizers. Additional amounts of plant nutrients must be applied in order to obtain the higher yields needed to increase human food consumption and improve nutrition. Fertilizers will be required not only to raise yields rapidly and to get maximum results from improved varieties of seeds and from other modern agricultural practices but also to prevent further deterioration of soil fertility.

88. Experiments have been carried out in the sub-region for many years and the results obtained, mostly from experimental stations, lead to the conclusion that nitrogen and phosphorous are the most necessary fertilizers. A first dose of about 40 kg. per ha of nitrogen and about 40 kg. per ha of P_2O_5 give the highest economic returns. The dosages depend on soil type, crop grown and other factors. The application of potash is indispensable only in certain areas, as in most parts of the sub-region potash gives no positive response. In some regions the addition of sulphur as well as of some minor elements is absolutely necessary.

89. In 1961/62 fertilizer consumption in East Africa exceeded 100,000 tons of pure nutrients. This amounts to 3.0 kg. of fertilizer per hectare of arable land or 1.5 kg. per capita. However, consumption, especially consumption per hectare of arable land, varies greatly from country to country in the sub-region. For instance, the highest consumption occurs in Mauritius - (233 kg/ha), Reunion - (105 kg/ha), and Rhodesia (33,3 kg/ha), while the lowest is in Ethiopia and Somalia, where almost no fertilizer is used.

90. Considering the population growth and the necessity for improvement in nutrition and for the expansion of export crops, it is assumed in this paper that by 1980 the demand for pure soil nutrients may be over 1 million tons. Of this total 40 per cent should be nitrogen, 40 per cent phosphorous and 20 per cent potassium.

91. Development of fertilizer consumption will not be possible unless applied research, intensive extension and, most important of all, an improved system for distributing fertilizers to the farmers are introduced. Good distribution system would include such items as supply, credit, marketing facilities and probably subsidies.

ANNEX I.

THE RESULTS OF EXPERIMENTS CARRIED OUT IN SOME COUNTRIES IN THE SUB-REGION

Kenya

Prior to 1952 the major efforts in fertilizer and soil fertility studies in Kenya were the "Highland Fertilizer Scheme" and the "African Fertilizer Scheme". These studies were confined to the main cereal producing areas of the Kenya Highlands and to the north western parts of the African area of Nyanza Province. The major fertilizers used were super-phosphates, soda phosphate, rock phosphate and sulphate of ammonia. Information on the effect of fertilizer on crop growth elsewhere in Kenya was obtainable only from the results of a limited number of unco-ordinated trials which district agricultural staff had been able to carry out. Study of the effects of fertilizer composition on plant growth had been confined to the comparison of different phosphatic fertilizers as sources of phosphorous and the only comparison of importance had been between superphosphate and soda phosphate.

In 1952 fertilizer studies were extended to new areas in Nyanza, Central and Coast Provinces. These were on sulphate of ammonia, superphosphate and muriate of potash. Because of its favourable price particular interest was featured on the use of Uganda rock phosphate, with the primary intention of comparing its long-term cumulative effects with those of the quick acting phosphates. From 1952 to 1959 the number of fertilizer trials was increased and the range of fertilizers expanded. The phosphatic fertilizers used were single and double superphosphates, Uganda rock phosphate, guano, soda phosphate, basic slag, fused magnesium phosphate, and in the latter part of the period, di-ammonium phosphate. The nitrogenous fertilizers were sulphate of ammonia, urea, sodium nitrate, calcium nitrate, calcium cyanamide, and ammonium sulphate nitrate. Muriate of potash was the potassium fertilizer with a small amount of potassium sulphate. A large number of the trials continued with evaluating the effectiveness of the various phosphatic fertilizers, both for immediate and residual responses. Here double super-phosphate generally found most favour, although in a few cases for pyrethrum, legumes and grassland, basic slag and soda phosphate were almost equally effective.

The largest number of trials are, however, on application of N, P, and K, and generally take the form of mixtures of double super-phosphates sulphate of ammonia and muriate of potash. It is already well known that response of phosphate is widespread and can be expected for most crops. Response to nitrogen, although wider spread than was apparent from earlier experiments, is much less reliable and obviously depends greatly on time of application and prevailing climatic conditions. In the records of experimental work it is difficult to find real evidence of a response to potassium and in fact there are numerous statements that application of potassium was actually responsible for a depression of yield. The figures shown below (Table 1 and 2) are taken from the "Annual Report of the Senior Soil Chemist (E. BELLIS), Kenya, 1961."1/

That report provides a summary to 1961 of the investigation begun in 1953 into the effects of limiting on some important soil types in the Kenya Highlands and on the crops grown on them. Experiments were laid down at four sites; Kaptagat, Eldoret, Molo and South Kinangop. The first three are reddish brown loams and the last a grey Kaolinitic loam. The pH of the soils was approximately 5.0. Fertilizers were applied each year of the wheat cycle. Double super-phosphate at nil (DS_0), 100(DS_1), 200(DS_2) and 400 lb (DS_3) per acre was applied at planting. At Eldoret the 400 lb. dressing was omitted. Differential sulphate of ammonia (N) and muriate of potash (K) applications each at 200 lb. per acre were made when the plants were about knee high. At Molo and Kinangop the N and K were combined. At Eldoret only the K and N+K treatments were given, the N alone being omitted. Wheat was grown on three of the sites and barley on Kinangop except for the last year of the cereal cycle when wheat was planted.

The yields of cereals for each site are given below as mean annual yields in pounds per acre. The figures in brackets give the number of seasons over which the means were obtained.

1/ L.A. WHELAN, Lime Trials, Annual Report of the Senior Soil Chemist, Nairobi, 1961.

TABLE 1[a]

Responses of cereals to Super-phosphate. Pounds per acre[b]

Site		lb. of double superphosphate				L.S.D.[c]	
		o	1oo	2oo	4oo		
		DSo	DS_1	DS_2	DS_3	5%	1%
Kaptagat	(4)	890	1,327	1,316	1,327	70	93
Kinangop	(4)	672	1,099	1,186	1,173	73	106
Molo	(2)	607	1,169	1,571	1,487	289	421
Eldoret	(5)	308	569	642	–	62	83

b/ Pound per acre x 1.13 equals kg. per ha (1 lb. - 0.454 kg, 1 acre = 0.40 ha).

c/ LSD means least Significant Difference with the probability 95 per cent (5 per cent) and 99 per cent.

The responses to phosphate were highly significant at all site but varied in magnitude from year to year. At Kaptagat the maximum response was obtained with the small application, indeed in 1954 the higher applications caused a significant (P .01) progressive decrease in yield, DSo 1,863 DS_1 2,479, DS_2 2,154 and DS_3 1,929, probably due to the severe lodging on the DS_2 and DS_3 plots making harvesting difficult. At Kinangop and Eldoret the maximum responses were obtained at the DS_2 level but in 1955 the heaviest application DS_3 decreased the yield significantly (P .05) DS_2 1,326 lb., DS_3 1,055 lb.

TABLE 2

Responses of cereals to K or NK mixture. Pounds per acre

					L.S.D.	
		Nil	K	NK	5%	1%
Kaptagat	(4)	1,148	1,277	–	40	54
Eldoret	(5)	438	530	550	62	83

The responses to potash at Kaptagat and Eldoret were highly significant. The interaction between response and years was also highly significant there being no significant response at either centre during the last two years of the cycle. In 1953 at Kaptagat the incidence of stern and leaf rust was much less where potash had been applied.

There was no indication of response to N from the mean annual yields at any site. The straw from the 1954 seasons at Kaptagat and Eldoret was ploughed back on a plot basis and the straw from half of each plot of the Kinangop 1955 season was also ploughed back. The following crop at Kaptagat gave an indication of a response to N, an increase from 686 to 1,144 lb. at Eldoret the mean yields for the following crop were:-

O	K	NK	L.S.D. 5%	L.S.D. 1%
408	485	561	95	128

There was highly significant response to the NK mixture.

Some very interesting figures (Table 3) were given in Kenya Fertilizers Working Party Report, Ministry of Agriculture Nairobi, 1963.

TABLE 3

Some Responses to Fertilizer in Kenya[a/]

Crop	Fertilizer	Application per acre	Cost of Fertilizer Applied at Nakuru in Shillings	Increase yield per acre	Value of increase in shillings per acre
Potatoes	D.S.[b/]	3/4-1½ cwt.[d/]	26 to 52	14 bags	210
	S.A.[c/]	1 - 1½ cwt.	22 to 33	10 bags	150
Maize	D.S.	Residual e/	-	410 lbs.	73
	S.A.	Residual e/	-	600-700 lbs.	107 to 124
Beans	D.S.	Residual e/	-	190-260 lbs.	
Maize	D.S.	1 cwt.	34	680 lbs.	121
	S.A.	2 cwt.	43	700 lbs.	124

Source: a/ T.C.I. RYAN and R. KEMPTON, The Economic Aspects of Using Fertilizer, Kenya Fertilizer Working Party Report, Appendix E/3, Ministry of Agriculture, Nairobi, 1963.

b/ D.S. is Double Superphosphate

c/ S.A. is Sulphate of Ammonia

d/ 1 cwt. = hundred weight = 112 lbs., 1 bag is 200 lbs.

e/ Residual nutrient from the potato experiment.

TABLE 3 (Cont'd.)

Some Responses to Fertilizer in Kenya[a/]

Crop	Fertilizer	Application per acre	Cost of Fertilizer Applied at Nakuru in Shillings	Increase yield per acre	Value of increase in shillings per acre
Wheat	D.S.	1/½ cwt.	52	900 lbs.	211
Barley	D.S.	3/4 cwt.	26	450 lbs.	77
Rice	D.S.	1-2 cwt.	34 to 61	275-595 lbs.	55 to 119
	S.A.	1-2 cwt.	22 to 43	230-560 lbs.	44 to 112
Tea	S.A.	4 cwt. over one cycle	87	111-395 lbs.	363 to 1647
Pineapples	S.A.	2,000 lbs.	389	4-7 tons	582 to 1019
		10 cwt.	217	5-6 tons	728 to 874
		1,500 lbs.	290	10 tons	1456
Coffee	S.A.	2 cwt.	43	1.2-1.5 cwt.	418 to 522
Sisal	S.A.	14 cwt. over 1st 4 years	303	0.8 tons fiber	62
Pyrethrum	D.S.	150-300 lbs.	46 to 92	333-780 lbs. over 3 years	931 to 2183
Sugar	S.A.	280 lbs. 6 cwt.	54 to 130	6.8-17 tons cane	320 to 800
	D.S.	1 cwt.-240 lbs.	34 to 74	1.8-10 tons	
Sorghum	D.S.	1-2 cwt.	34 to 69	300-670 lbs. grain	
	S.A.	1-2 cwt.	22 to 43	190-990 lbs. grain	
Tomatoes	S.A.	2 cwt.	43	2.7 tons	484
Strawberries	S.A.	2500 lbs.	483	10 tons	2720
	Urea	1140 lbs.	437	9 tons	2300
Sunflower:					
Giant	D.S.	150 lbs.	79	230 lbs.	
Dwarf	S.A.	1½ cwt.		390 lbs.	

Source: a/ T.C.I. RYAN and R. KEMPTON, The Economic Aspects of Using Fertilizer, Kenya Fertilizer Working Party Report, Appendix E/3, Ministry of Agriculture, Nairobi, 1963.

Based on the figures given in Table 3, gross value responses and net value response were calculated and are shown in Table 4.

TABLE 4

Some Responses to Fertilizer in Kenya

Crop	Fertilizer	Mean Gross value c/ Response	Mean Net value d/ Response
Potatoes	D.S.a/	5.4	4.4
	S.A.b/	5.4	4.4
Maize	D.S.	3.5	2.5
	S.A.	2.9	1.9
Wheat	D.S.	4.1	3.1
Barley	D.S.	3.0	2.0
Rice	D.S.	1.8	0.8
	S.A.	2.4	1.4
Tea	S.A.	12.1	11.1
Pineapples	S.A.	2.1-5.0	1.1-4.0
Coffee	S.A.	10.9	9.9
Sisal	S.A.	0.2	0.8
Pyrethrum	D.S.	15.8	14.8
Sugar	S.A.	6.1	5.1
	D.S.	5.1	4.1
Tomatoes	S.A.	11.2	10.2
Strawberries	S.A.	5.6	4.6
	Urea	5.2	4.2

a/ Double Superphosphate

b/ Sulphate of Ammonia

c/ Gross value response means gross increase in value of output per unit cost of fertilizer.

d/ Net value response means net increase in value of output (gross increase-cost of fertilizer) per unit cost of fertilizer.

Some co-efficients are very high (sulphate of ammonia applied to tea, coffee, tomatoes; double-superphosphate to pyrethrum and so on). Some of them do not justify the application (sulphate of ammonia on sisal). As a whole, however, the picture is very clear and promising; the average net response to fertilizer is sufficiently high to make its application profitable.

Thanks to experiments which have been carried out for many years, it is possible to make some recommendations for fertilizer usage in different parts of Kenya for the most important crops of that country (see Aneks, Fertilizer Recommendations for Wheat, Malting Barley, Maize and Grassland, given be E. Bellis in "A Guide to Fertilizer Use in Kenya)".

Tanzania

On the hilly sandy soil of UKIRIGURU most soil treatment bring handsome rewards. There have been high responses to phosphorous applications. In most seasons, there have been valuable nitrogen - phosphorous interactions. The heavier dressings of phosphorous with top-dressing nitrogen, allowing for variations in application, have given average responses of the order of 560 kg. seed cotton per hectare per season. This tends to be slightly better than the responses to 15 ton/ha of cattle manure applied once in every three seasons but does not have the long continuing residual benefit.1/

A complex experiment with sisal was started in 1949. The treatments comprise dressings of lime, nitrogen, phosphate and potash in every combination and each at three rates, viz., non, moderate and heavy dressings, all but the lime having been applied annually. Each plot was cut separately as it became ready and the most forward ones were cut

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1/ PEAT, Y.E. and BROWN, K.J., The yield responses of rainfrown cotton at UKURIGURU, in the lake province of Tanganyika, I. The use of organic manure, inorganic fertilizers and cotton-seed ash, Empire Cotton Growing Corporation, Western Regional Centre, Department of Agriculture Ukuriguru, Tanganyika.

for the first time when the sisal was two years old. A consequence is that complete yield data is only available for the first cutting. First cut yields showed small responses to nitrogen, phosphate and lime but none to potash; there was no difference between moderate and heavy dressing of nitrogen. Interactions between the fertilizers were not significant. There is clear evidence, however, that nitrogen has hastened growth because out of fifty-four plots receiving this fertilizer fifty-three have been cut twice and five three times, the latter yielding between five and six tons of fibre per hectare up to date. Such yields are comparable with results previously obtained on virgin land. Of the twenty-seven plots without nitrogen fifteen had been cut only once by the end of the year.1/

The results from a fertilizer trial with maize on volcanic loam at Arusha are of considerable interest, and are shown in the following table:-

TABLE 5

Results of a Fertilizer Trial on Maize in the Arusha District a/

	Bags (200 lbs.) per acre b/
Nil	18
NPK	18.2
NK	19.8
N	19.9
P	20.5
NP	20.7
K	21.2
PK	21.4

Source: a/ East African Agricultural and Forestry Research Organization, Fertilizer Trial, 1953.
b/ 1 bag = 200 lbs.

Nitrogen as ammonium sulphate and phosphate as double superphosphate were applied at 160 lb. per annum and muriate of potash at 80 lb. per

1/ Sisal Research Station, Milingano, Ngomeni Annual Report for the Year 1952.

annum both separately and in combination (quantity of commodity). The most interesting and unexpected result was the significant response to potash which gave a 17 per cent increase over the control yield. Phosphate alone also gave a significant increase which is of interest on this volcanic soil. The poor results from NPK, NK & N are difficult to explain but may have been due to damage to the roots by a high concentration of soluble salst shortly after application.[1]

Fertilizer Field Trials on African-grown cotton

Phosphate was applied at the rate of 90 lb/acre before throwing up the ridges. Sulphate of ammonia was applied at the rate of 200 lb/acre to one half of each plot on the ridge. The results are tabulated below:

TABLE 6

Results of Fertilizer Trial on Cotton
(lb. of cotton/acre[a])

(a) Effect of fertilizer in increasing yield of cotton in pounds per acre grouped by control yields

Control Yield	No. of plots	P	NP	N by Subtraction
Under 300	44	+ 127	+ 216	+ 89
300-400	41	+ 162	+ 242	+ 80
400-500	40	+ 144	+ 321	+177

(b) Summary

Total No. of plots	Yields of control	P Effect of by Subtraction	Significant Difference
125	335	+145	53

Source: a/ Summary of Experimental Work, Lake Province 1955 Annual Report of the Department of Agriculture 1955, Part III.

[1] East African Agricultural and Forestry Research Organization Fertilizer Trials, 1953.

From the results obtained it appears that both N and P give a substantial increase in yield. Low yields on many of the plots may be attributable to termite damage particularly on the red soils.

Maize Factorial Fertilizer Trial

Fertilizers were applied at the following rates:

Nil and 125 lb. of double superphosphate per acre.

Nil and 125 lb. of muriate of potash per acre.

Nil and 200 lb. of sulphate of ammonia per acre.

The principal results are presented in Table 7.

TABLE [a]

Fertilizer	Yield (lb/acre)
Nil	1,608
N	2,112
P	1,631
K	1,682
NP	2,182
NK	1,937
PK	1,671
NPK	2,018

Main Effects	Significant difference
N = + 373	P = .05...... = 240
P = + 83	P = .01...... 322
K = − 97	P = .

Only sulphate of ammonia gave useful increases in yield. Interactions were not significant.[1]

a/ Source: WAMI Sub-station, Annual Report of the Department of Agriculture 1957, Part II.

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Work carried out by the Tanganyika Agricultural Corporation has shown that the application to maize of 1 cwt. each of single superphosphate and sulphate of ammonia gives a high return. Higher rates of application of sulphate of ammonia and phosphate were tested.

TABLE 8

The Effect of High Rates of Application of Sulphate of Ammonia and Superphosphate on Maize Yields[a/]

Lb. per Acre

Superphosphate lb. per acre	Sulphate of Ammonia, lb. per acre				
	100	200	300	400	Mean
100	1,708	2,087	2,175	2,511	2,120
200	1,883	2,175	2,000	2,234	2,073
300	2,146	2,175	2,671	2,321	2,328

Source: a/ Annual Report of the Department of Agriculture, 1958, Part II (Research).

Taking the cost of sulphate of ammonia at 31 shilling per 100 lb. and of maize at 17 shillings per 100 lb., a response of 182 lb. of maize per acre is necessary to pay for the fertilizer. The results obtained suggest that applications greater than 200 lb. of sulphate of ammonia per acre are not likely to be economic.

Uganda

The poor sandy soils of Katakwi gave 61 per cent and 60 per cent over-all increases on a mean control yield of 1,433 lb. per acre of the finger millet crop and 57 per cent increase on a mean control yield of 1,567 lb. per acre for broadcast phosphate, placed phosphate and nitrogen respectively.[1/] In the trial at Severe head increases of 30 per cent, 11 per cent and 23 per cent were given by these respective treatments and at Bulopa, as the result of a wet growing season, nitrogen increased a mean grain yield of 1,527 lb. per acre by 35 per cent . Responses on the red soils of the Southern districts were small.

1/ Annual Report of the Department of Agriculture, for the year ended 31 December 1954, Uganda Protectorate.

Single superphosphate gave an average of 92 per cent increase on a 433 lb. per acre crop of cotton with both dressings (15 cwt and 30 cwt/acre) applied four years previously.[1/] The best treatment was superphosphate at the lower rate, which gave 108 per cent increase on a 433 lb. crop. Nitrogen as sulphate of ammonia at 2 cwt. per acre applied to this crop at planting produced an over-all increase of 23 per cent, but at double this rate the response showed a decrease of 7 per cent.

A trial at Kawanda on a permanent grass lay showed that grass will respond well to sulphate of ammonia. A nearly four-fold increase in green matter was obtained from dressing up to 80 lb. per acre of nitrogen, and a pasture which was previously useless, produced very valuable dry season grazing (November and December).[2/]

Evidence was obtained at Serere that potassium and lime are of value but are probably not economic to apply.[3/] The role of sulphur in crop production was further studied in an extensive experiment on finger millet. Sulphate of ammonia gave yield increases of 25-50 per cent while nitrogen without sulphur gave increases of only 0-20 per cent, all on a 1,490 lb. per acre control crop.

The beneficial effect of the mineral nutrients contained in elephant grass was proved in a cotton experiment on the old soil structure plots.[3/] Increase was obtained of 157 per cent from ash and 83 per cent from its equivalent in nitrogen, phosphorous and potassium fertilizer, with and without lime and trace-elements, on low control yield of 313 lb. per acre seed cotton.

Trials with inorganic fertilizers were carried out on more than 400 farmers' plots of millet, throughout Teso and Bukedi districts. An average yield increase of 400 lb. per acre of grain was obtained, but the range was great and only about 50 per cent of the farmers could be expected to make additional profits by using the fertilizer.

1/ Annual Report of the Department of Agriculture, for the year ended 31 December 1954, Uganda Protectorate.

2/ Annual Report of the Department of Agriculture for the year ended 31 December 1955, Uganda Protectorate, pp.153-155.

3/ Annual Report of the Department of Agriculture for the year ended 31 December 1956, p.30 Uganda Protectorate.

During the year, five fertilizer experiments on coffee, including one of growth substance sprays, were started. At Kituza Research Station responses of coffee to nitrogenous fertilizers have been economic.1/

In trials on farmers' fields, an application of only 98 lb. per acre of sulphate of ammonia when the finger millet crop was 6 inches high gave very considerable responses. At Bugusege a trail with sulphate of ammonia begun in 1956 on very old coffee, has shown remarkable increases in parchment production at all levels of application of the fertilizer. Yields were very much higher than previously, and a 50 per cent increase from an application of 80 lb. nitrogen took place on a basis yield level of 1,200 lb. of parchment per acre.

Malawi

Physical responses of dark fired tobacco to fertilizers have been investigated for the past 12 years. In general there has been a gradually increasing response, as cultivation has progressed, originally to nitrogen and latterly to nitrogen and phosphate combined. The inter-action of these two nutrients has reached a stage where applications of nitrogen alone to phosphate deficient soils has in fact reduced yields. In a series of trials cultivating in the production of response curves the responses have been as follows in yields. There has been no clear pattern to date with quality responses and no responses of any sort to potash applications. Results obtained from 3 years' work are given below:

1/ Annual Report of the Department of Agriculture for the year ended 31 December 1959, pp.23-24, Uganda Protectorate.

TABLE 9

Results of Fertilizer Trials on Dark Fired Tobacco in Malawi[a/]

Superphosphate 19% P_2O_5 lb.	Sulphate of Ammonia lb./acre	Yield lb. of acred leaf/acre	Response lb/acre
Nil	Nil	670	-
	150	800	+ 130
	300	850	+ 180
	Nil	800	-
250	150	1,020	+ 220
	300	1,080	+ 280
	Nil	800	-
500	150	1,020	+ 220
	300	1,200	+ 400

a/ Information received from the Tobacco Research Office, Agriculture Research Chitedze, Lilouqwe, Malawi, 1964.

The economic aspects of these results can be obtained by converting the yield response obtained at each level using the cost of fertilizer averaged at 3d. per lb. and the average price paid for tobacco since 1959 as 17d. per lb. An economic response to the fertilizer application should be more than one fifth the weight of fertilizer applied.

At 250 lb. Supers and 150 lb. S/A the cost of fertilizer is approx. £5. The response over nil fertilizer is 350 lbs. cured leaf approx. £24. Applying 150 lb./acre S/A alone at approx. £2 the return is 130 x x 17d. approx. £ but extra 150 lb. S/A alone at £2 the return is only 50 x 17d. = £3 and this only under good standards of cultivation.

At 500 lb. Supers + 150 S/A the response is not as economic as 250 Supers + 150 S/A. This is in line with the theory of the response to either of the two nutrients being limited by the amount of each present. The combined application of 150 lb/acre S/A and 250 lb/Supers (19 per cent) is considered the tobacco optimal at present for village cultivators.

Recommendations on Chitedze[1/] soils are in the region of 200 lb/acre 'C' Compound ($5N-15P_2O_5-12K_2O$) and 200 lb/acre sulphate of ammonia or calcium ammonium nitrate. This is designed to give a good quantity of nitrogen and phosphate with a basement dressing of potash in case responses do occur. The choice of Sulphate of Ammonia or Calcium Ammonium Nitrate depends mainly on the pH levels of the soil.

Fertilizer experiments with tea have been in action at Swazi since the mid-thirties. Since 1950 more complex experiments have started. Summary of these experiment is given below.

Nitrogen (Sulphate of Ammonia)[2/]

In practically every country where tea is grown nitrogen is reported as having beneficial effects not only on leaf yields as such but on the vigour and size of the bush as a whole. Whenever nitrogen has been included in experiments with mature tea in Malawi (Cholo and Mlanje), beneficial responses in yield have been recorded within the season of first application and these benefits also persisted with a diminishing response for two or three seasons after nitrogen fertilizing ceased. In Mlanje 1 lb. of nitrogen (equal to 5 lb. sulphate of ammonia approximately) has returned a long-term average of 4.5 lb. of made tea per season but responses in Cholo might be less. The experiments there are not old enough to yield precise information. With mature unshaded tea in both districts there has been no falling off in benefits up to the maximum rate used which is equivalent to 120 lb. N per acre (600 lb. sulphate of ammonia approximately).

1/ Chitedze, Agricultural Research Station, Lilongwe, Malawi.

2/ Fertilizers for Nyasaland Tea, Department of Agriculture, Nyasaland, 1958.

With unshaded mature tea, responses to nitrogen appear to vary with seasonal differences and management method. In wet seasons nitrogen is more effective than in dry ones. It becomes more effective in the unpruned years than in the season following prune and at Thornwood it is appearing that an annual application of 40 lb. N per acre (200 lb. sulphate of ammonia approximately) is insufficient to support two or three year pruning cycles to their full potential.

In summary, nitrogen is the quickest rewarding fertilizer that is applied to unshaded tea and should at present form the basis of fertilizer policy.

Phosphate (Superphosphate) and Potash (Muriate of Potash)

Neither of these nutrients have caused measurable effects on yields or bush growth at Swazi where they have been under experiment for six consecutive years with mature unshaded tea. But in the face of Far Eastern experience and Malawi inconclusive evidence, dressings of phosphate and potash are to be recommended for the time being as an insurance policy.

Sulphur (contained in Sulphate of Ammonia and Superphosphate)

Adequate supplies of sulphur are particularly important for newly planted and young tea in Nyasaland, otherwise "yellows" symptoms might be developed, and if the deficiency is not cured quickly, at worst, death can result and, at best, a serious check is given to development. The deficiency can be easily prevented by applying regular dressings of sulphate of ammonia and although young tea does not appear to respond to the nitrogen, it does respond to the sulphur content. Sulphur alone in the form of flowers of sulphur can be used, but the quantities per bush are so small as to make handling difficult on a commercial scale.

According to the information obtained from the Senior Agricultural Research Officer in Agricultural Research Station, Chitedze, Malawi, the most important nutrient required in Malawi is Nitrogen. Other nutrients may be needed to balance the nitrogenous dressings if rates are high, but in regions where no response to nitrogen is expected, no response is expected to any other fertilizer either.

By far the most economic short-term dressing of fertilizer is a low rate of nitrogen 20 - 40 lb/acre.N. This will hold true over the whole country for non-leguminous crops with the following exceptions.

1) Recent alluvium newly cultivated
2) Karonga lake shore
3) Lower river clays
4) Acid soils completely ruined by over cultivation which need very careful rehabilitation.

In certain areas soil phosphorous is becoming increasingly a limiting factor. Soils of Central and Northern Regions of high inherent fertility are the heavier basement complex. Here phosphorous as well as nitrogen is required. The sandier soils of Central and Northern Regions do not appear to the short of phosphorous yet, nor do the majority of the Souther Region soils inspite of the intensity of cropping there. Tobacco, cotton, potatoes, maize and young grass seeds are the crops most likely to require phosphorous. It has been rare in the past to get legumes responding markedly to phosphorous, and the greatest responses have been to single superphosphate on sandy soils on which gypsum has proved equally effective.

Soil potash levels so far tested appear to be on the whole high, and very few responses to potash have been obtained in trials.

Sulphur may be necessary for groundnuts on certain soil types, if these are newly opened to cultivation and as yet unfertilized. Gypsum is used for this purpose. However, if Sulphate of Ammonia and single superphosphate are used from time to time, the problem need not arise. These fertilizers are considered to be most efficient forms of N and P under present circumstances.

Farmyard manure in Malawi is of very variable and usually poor quality i.e. the supplies of available and total nutrients are low. Very frequently manure will give no benefit in the year of application, and it may even reduce yields of maize. However if applied at 2-4 tons/acre together with 20-40 lb/acre N it makes an excellent manurial treatment for maize, tobacco and potatoes, and crops will benefit from the residues for a further two or three years. More detailed recommendations are given in Annex.

Zambia

Livestock nutrition in Zambia largely depends on feed available from the natural grasslands. Hyparrhenia veld is more or less open grasslands with scattered trees and shrubs. Plot trials measured the effect of fertilizers on Hyparrhenia veld.[1/] N was the only nutrient limiting growth, and N fertilizer markedly increased the herbage yield and crude protein per cent. The herbage response was linear up to the highest rate used, 189 lb. N/acre, with a calculated N recover of approximately 35 per cent. Split fertilizer applications were only advantageous in one year out of three. The effect of N fertilizer steadily decreased at successive harvests after application, and the residual effect in a following season was transient. N fertilizers did not alter the botanical composition of the veld.

B. J. Coxe showed quite recently the responses to nitrogen, phosphate and potash when applied to cotton.

TABLE 10

Results of Fertilizer Trials on Cotton in Zambia[a/]

a) The Effect of nitrogen[2/]

Total	lbs.N/acre	Yield increase: lbs. seed cotton/acre	Yield increase: lbs. cotton per lb. N
1961	42	159	3.8
1962-1/	30	82	2.7
	60	245	4.1
2/	30	145	4.8
	60	307	5.0
1963-1/	30	226	7.5
	60	322	5.4
2/	30	346	11.5
	60	648	10.0

1/ C.A. Smith, Studies on the N. Rhodesia Hyparrhenia Veld. IV the effect of nitrogen fertilizer and defoliation Mount Makulu Research Station, Northern Rhodesia.

2/ B.J. Coxe Review of Experiments on the Fertilization of cotton in the Southern Province, Magos Regional Experimental Station, August 1964 (paper not published).

The price of a pound of N at the farm gate is one shilling and four pence and the price of seed cotton six pence per pound. This means, 2.7 lbs. of seed cotton per lb. of N is the minimum required yield increase (16/6). Most of the trials showed larger increases.

b) The effect of phosphate

Trial	lbs. P_2O_5 /acre	Yield increase lbs. seed cotton/ acre	lbs. seed cotton lb. P_2O_5
1961	38	363	9.6
1962	30	266	8.9
	60	394	6.6
1963-1/	30	226	7.5
	60	322	5.4
2/	30	245	8.2
	60	395	6.6

The price of a pound of P_2O_5 at the farm gate is one shilling and twopence (seed cotton - sixpense). The minimum required yield increase would therefore be 2.3 lbs. of seed cotton per lb. of P_2O_5 applied. All trials showed bigger increases.

The field experiments with maize 1/ in which a sulphur deficiency was discovered were in fact designed to compare the efficiency of different nitrogenous fertilizers. The treatments were: 3 levels urea, 3 levels sulphate of ammonia, 3 levels calcium ammonium nitrate, 3 controls, in a rendomized block layout with 3 replications (the three levels of introgenous fertilizers were equivalent to 40, 80 and 120 lb.N/acre). Three important conclusions could be drawn from these experiments:

1/ Responses to sulphur-fertilization in N.Rhodesia, J.B.M. Vogt, Agricultural Chemist, Mount Makulu Research Station - Ministry of Agriculture, P.O. Box 7, Chilanga near Lusaka, N.Rhodesia (A paper to be presented to VTH Simposio Internazionale di Agrochimico "Lo Zolfo in Agricultura" to be held in Palermo-Catania from 16th to 21st March 1964).

(1) The statistical analysis of the yield figures from the main experiment showed that the differences between the sulphate of ammonia treatment and the other treatments were very highly significant.

(2) A comparison between the yield figures from the observation trial and the main experiment showed that the addition of sulphur makes urea a fertilizer of the same effectiveness as sulphate of ammonia and gave a more than five-fold yield increase over the urea used alone. This confirmed a severe sulphur deficiency in this soil.

(3) Although the optimum level of sulphur needed further investigation, the observation trial indicated that it lies at or lower than 25 lb. per acre.

In the annex there are some general fertilizer recommendations for extension workers for the 1964/65 season.

RHODESIA

The state of fertility and of the nutrient position in the soil, weather conditions, planting dates, weed control, pests and diseases, and other factors all play a part in determining yields. In a survey of this nature, however, factors such as these cannot be measured, and Table 11 sets out the relationship between expenditure on fertilizer and average yield as found in the sample. The last column shows the amount available to the grower. On balance, those spending small amounts on fertilizers received the smallest margine and those who were fertilizing at a high level had the greatest room for manoeuver. The Southern Rhodesia lowest expenditure group consists mainly of farms outside the main maize-producing areas, but which returned high yields and therefore high incomes per acre during these seasons. The fall in the margin in the second-lowest expenditure group for Northern Rhodesia in 1956-57 is solely the result of a poor crop for the one producer falling in the group that year, and cannot be regarded as representative. Similarly, in 1957-58 the Northern Rhodesia results were very seriously affected by the poor season. The high margin in the £6 and-over per acre expenditure on fertilizer is very largely due to one large efficient producer who was fortunate in having reasonable rainfall that season. The two middle groups had fertilized at a rate commensurate with a far higher yield than they actually obtained that season.

It is clear on the Rhodesia evidence, which has the advantage of being from a large sample, that there is an unbroken rise in the average return per acre as expenditure on fertilizer increases, and although in the higher ranges the rate of increase diminishes, there was still room on the cost-price relationships of the three years for increased usage of fertilizer over and above what was in fact applied. The same pattern can be safely attributed to Northern Rhodesia, where the deviation from the steady rise is due to variations within the small groups.1/

Fertilizer is a major factor influencing yields and consequently costs and returns. Attention has already been drawn to the low rates of fertilization on maize in the tobacco rotation and in regions with an unreliable rainfall. The extent to which variation in the levels of fertilization generally influence production costs, yields and returns is shown in Table 12 and in Table 13.

1/ Maize Production costs on some European Farms in Northern and Southern Rhodesia for the 1955-56, 1956-57 and 1957-58 Crops; Final Results for the Three Years, Economics and Markets Branch, Federal Ministry of Agriculture.

TABLE 11

The Influence of Expenditure on Fertilizers on Yield of Maize and Returns[a/]

1955/56[b/]

Expenditure on Fertilizers £ per acre	Farms	Average Expenditure on Fertilizers per acre			Average	Margin on Gross Return over Expenditure on Fertilizers per acre		
		£	s.	d.		£	s.	d.
N. Rhodesia								
0-2	6		18	10	7.51	14	12	9
2-4	11	2	15	6	10.96	19	19	4
4-6	2	5	1	9	15.55	27	3	7
6 and over ..	2	6	18	6	10.94	15	15	6
S. Rhodesia								
0-2	10		10	10	7.83	15	14	1
2-4	16	3	0	6	12.92	23	15	8
4-6	16	4	17	6	14.96	26	3	4
6 and over ..	5	9	14	4	18.65	28	19	8
1956/57[c/]								
N. Rhodesia								
0-2	5	1	11	4	9.33	17	1	10
2-4	1	3	9	8	6.67	9	17	2
4-6	7	5	0	9	12.92	20	16	1
6 and over..	3	9	14	8	20.96	32	3	9
S. Rhodesia								
0-2	9		11	7	9.18	17	15	7
2-4	8	3	14	2	10.58	17	9	0
4-6	22	5	2	8	14.30	23	9	4
6 and over...	11	8	2	10	16.74	25	6	8
1957/58[d/]								
N. Rhodesia								
0-2	2		11	0	5.25	10	17	9
2-4	4	3	5	6	3.64	4	5	10
4-6	6	4	10	9	4.39	4	11	4
6 and over..	4	11	5	9	15.98	21	17	6
S. Rhodesia								
0-2	5		19	7	8.41	16	9	3
2-4	6	3	1	9	12.38	22	11	9
4-6	17	5	2	11	12.33	20	9	0
6 and over..	20	8	11	2	15.42	23	8	10

Source: a/ Maize Production Costs on some European Farms in Northern and Southern Rhodesia for the 1955-56, 1956-57 and 1957-58 Crops, Final Results for the Three Years, Economics and Markets Branch, Federal Ministry of Agriculture.

b/ All maize valued at £2.1s.6d. per bag

c/ All maize valued at £2 per bag.

d/ 1 bag = 200 lbs.

TABLE 12

Average Costs and Margins by Expenditure on Fertilizer

Expenditure on Fertilizers £ per acre	Farm	Acreage per Farm	Yield of maize per acre	£ per/acre				
				Value of Output	Total Cost of production	Net Return Production	Cost of Fertilizer	Margin over fertilizer cost
1	2	3	4	5=6+7	6	7	8	9=5-8
	No.	Acres	Bags					
0-2	2	88	10.43	19.97	9.00	10.97	-	19.97
2-4	18	232	10.97	20.98	11.75	9.23	2.76	18.22
4-6	22	270	15.50	29.64	17.60	12.04	5.25	24.39
6-8	19	259	18.20	34.81	18.72	16.09	7.15	27.66
8-10	10	421	19.93	38.12	23.54	14.55	8.85	29.27
10 and over	5	324	22.15	42.38	23.50	18.88	11.24	31.14

Source: a/ Maize Production Costs on some European Farms in Southern Rhodesia for the 1962-63 Crop, Interim Report on the results for 1962-63, Economics and Markets Branch Ministry of Agriculture, Southern Rhodesia.

Similarly to Table 11, this table shows an unbroken rise in the average yield per acre as expenditure on fertilizer increases. The increase in yield is greatest between the group with an average expenditure of £2.76 per acre and the next group spending an average of £5.25 on this item. Thereafter the yield per acre continues to increase with additional expenditure on fertilizer but at a decreasing rate.

The relatively low margin received by the "£8-10" group was not due to the high cost incurred on fertilizers, which was more than justified by the high yield obtained, but resulted from high expenses for other items. This group of 10 farms averaged the highest cost per acre.

The column "Gross Margin over Fertilizer Cost" in Table 13 shows the amount available to the grower out of which he must cover all expenses other than fertilizer and out of which his profits must be obtained. On balance, those spending least on fertilizer achieved the smallest margins. If the first group of two farms is discarded as being typical, the last column in the Table shows that extra cost incurred on fertilizer was consistently exceeded by the extra returns obtained.

It is obvious that increased fertilizer dressings up to a cost of between £12 and £15 per acre appear to have improved both yield and quality. At higher levels than this, both yield and quality were depressed. It is interesting that the same pattern emerged in the 1961-62 survey.

Table 13 gives analogous figures for Flue-cured Virginia Tobacco grown in Rhodesia[a/]

TABLE 13

Effect of Expenditure on Fertilizers on Gross Margins

Expenditure on Fertilizers £/acre	Number of Growers	Acreage per grower	Per Acre										Per Pound			
			Yield	Fertilizer costs			Total income			Gross Margin over Fertilizer Costs			Fertilizer Costs	Total Income	Gross Margin over Fertilizer Costs	Gross Margin over Fertilizer Costs
	No.	Acres	lb.	£	s.	d.	£	s.	d.	£	s.	d.	d.	d.	d.	
3-6	14	86	784	5	9	1	130.	16.	9	125	7	8	1.67	40.04	38.37	22.7
6-9	63	88	824	7	17	6	141.	13.	9	133.	16.	3	2.29	41.27	38.98	17.0
6-12	110	82	878	10	10	9	157	9	9	146.	19	0	2.88	43.07	40.19	14.0
12-15	47	91	1,018	13	2	11	187	4	0	174	1	1	3.10	44.13	41.03	13.2
15 and over	14	79	912	15	18	3	166	1	1	150	2	10	4.19	43.71	39.52	9.4

Source: a/ The cost of production of Flue-cured Virginia Tobacco on some farms in the south-western area of the Rhodesias for 1962-63 crop, Report on a survey carried out by the Economics and Markets Branch Rhodesian Ministry of Agriculture for the Rhodesia Tobacco Association.

So far it had been proved that nitrogen and phosphorous are to be needed for good grass growth in Rhodesia.[1] Nitrogen is needed in large quantities, and where amounts of up to about 120 lb. of N per acre per year are used, the responses are for practical purposes proportional to the amount applied. Smaller and less consistent responses are obtained with phosphate fertilizing and these are normally recorded only where phosphate is applied in combination with nitrogen. In the past the phosphorus has been applied almost exclusively in the form of super-phosphate and it is of possible significance that substantial quantities of calcium and sulphur were also added to the soil.

Mauritius

In the factorial NPK experiments[2], sugar cane was harvested in 1950 in fourth ratoons, and the following results were obtained:

1. Application of 30 kilograms of nitrogen produced an increase of 37 per cent in yield of cans. A supplementary dose of 30 kilograms produced an additional increase of 15 per cent.

2. No individual response to phosphate application was observed.

3. In two trials cane responded significantly to potash application.

4. Average sugar analyses for five crops in this series of experiments show a marked decrease in sugar content of canes receiving increased applications of nitrogen. Phosphate and Potash do not seem to have marked effects on sugar content.

1/ Improved pastures contributed by D.L. Barnes Federal Department of Research and Special Services.

2/ Annual Report of the Department of Agriculture, 1950, P.25 Colony of Mauritius, 1957.

In 1952 the experimental crops of the NPK trials were harvested in sixth ratoons.1/ The whole series showed that there was always a response to nitrogen fertilizers, that the response was higher in the older ratoons, and that the depressing effect of nitrogen application on sucrose content decreased with the age of the cane. On small planters' lands responses to phosphate and potash applications were generally obtained, but on estate lands there was usually no response to these fertilizers except in the sugar-humid region.

Fertilizer experiments with different levels of nitrogen in the form of sulphate of ammonia applied to different grasses were carried out in 1961-1962.2/ The yield of each grass was greater on plots which received 150 pounds of sulphate of ammonia per acre of each cut than from those plots receiving 50 to 100 pounds per acre. In some instances an application of 200 pounds of sulphate of ammonia per acre at each cut gave the highest yield, particularly for elephant grass. Three levels of phosphate in the form of single superphosphate, potash in the form of sulphate of potash and lime showed no significant differences in yields.

1/ Annual Report of the Department of Agriculture, 1952, p.5 Colony of Mauritius 1953.

2/ Annual Reports of the Department of Agriculture for the years 1961 and 1962. Colony of Mauritius 1962, 1963.

ANNEX II

TABLE 1

FERTILIZER Recommendations for Wheat, Malting Barley, Maize and Grassland in Kenya

Soil	Locally	Crop	Available P_2O_5	Recommended Dressings lbs. per acre	N
Seasonally wet greyish loam over murram copper dark clay	Much of Kinangop Plateau, Ol Plain and Mau, Londiani,	Wheat and malting barley	40-60		
		Grassland			
	Sotik and Nanyuki vleis	At sowing	65		
	Sotik and Kipsigis vleis	Maize	45		
	Remarks: Surface drainage and application of phosphates are essential for successful crop growing on these soils.				
Dark brown, reddish brown or orange-brown loams at high elevation on both sides of the Rift Valley.	Land above 8,000 ft. between Thomson's Falls and Nakuru, Northern Aberdares and Mau, Holo and Tinderet areas.	Wheat and malting barley	40-60		
		Grassland			
		At sowing	60		
		Established	60	and	35
	Timau	Malting barley	20		
	Nanyuki	Wheat	40		
Brown and dark brown loams over dark tuff subsoils or ash.	Land above 7,000 ft. between Nakuru and Rongai River.	Wheat	40		
		Maize	40	and	Try 20 after first weeding
		Grassland			
		At sowing	45		
		Established	45	and	35

Remarks: The response of wheat here is variable and occasionally will be barely economic: farmers who obtain satisfactory return from recommended dressings should try higher rates of application to their wheat. A strong local preference exists for mineral phosphatic fertilizers such as hyper-phosphates as these are considered safer to use in dry years and for fortifying the phosphatic fertilizer with copper.

TABLE 1 (Cont'd)

FERTILIZER Recommendations for Wheat, Malting Barley, Maize and Grassland in Kenya

Soil	Locally	Crop	Available P_2O_5	Recommended Dressings lbs. per acre N
rown-red to red loams.	The slopping undulating country between Elgeyo Escarpment and the Uasin Gishu Plateau as near Kipkabus.	Wheat	125	
		Grassland		
		At sowing	80	
		Established	65-70	and 25-30
			Remarks:	Soda phosphate here may be superior to the superphosphates.
range-brown loams with increasing amounts of ironstone concretions in the subsoil and over-lying soiled rock or murray at 2-3 ft.	Most cultivated uplands of Uasin Gishu Plateau.	Wheat	40-70	
		Maize immediately after Wattles	30-35	
		Elsewhere	30-35	followed by 40 at knee height
		Grassland		
		At sowing	65-70	
		Established	65-70	and 45
Reddish loam to coarse sandy loam over red loam to fine sandy loam; soil sets hard during drought.	Elgon North and South Nyanza, Nandi, West Suk and North West Uasin Gishu.	Maize	45	followed by 20-25 at knee height on unmanured land.
	Remarks: As much maize land as possible should be manured at the rate of 7½ tons per acre instead of receiving fertilizer.			

NOTE: The recommendations for maize both immediately after wattle and elsewhere are here based largely on the results of work undertaken by the Research Division of the Plateau Wattle Company. This courtesy in providing the information is much appreciated.

Soil	Locally	Crop	Available P_2O_5	Recommended Dressings lbs. per acre N
	Trans Nzoia red plains soils Central Trans Nzoia	Maize	25	followed by 20-45 at knee height
		Grassland		
		At sowing	45	
		Established	45	and 20-45
	Remarks: Grass-clover mixtures benefit from 170 lb. gypsum per acre in the seed bed and later as top dressing in addition to the phosphate and nitrogen application.			

TABLE 1 (Cont'd)

FERTILIZER Recommended for Wheat, Malting Barley, Maize and Grassland in Kenya

Soil	Locally	Crop	Available P_2O_5	Recommended Dressings lbs. per acre N
	Machakos and Kitul	Maize	45	
	Remarks: Timely planting is essential and best responses are obtained with long-term maize provided the maize is taken after a season of bare fallow and provided effective water conservation measures are adopted. Nevertheless, under the prevailing uncertain rainfall conditions in these districts it is more satisfactory to use a short-term maize such as Taboran even following a bare fallow and to forego some loss of response to fertilizer application in order to secure the greater certainty of getting a crop if rainfall is short which will go with using the short-term maize.			
Deep red and dark red friable fine textured soils.	Central Province, South and Central Nyanza, Kipsigis	Maize following well fertilizer or manured potatoes		20-25 at knee height
		Maize or unfertilized and unmanured land	45	
	Endebess Plain and Foothills	Wheat	No firm recommendations available.	
		Maize	30-35 followed by 20-45 at knee height	
Deep dark brown and black friable clay loams.	Elgon Mountain, Kinangop Forest, Nandi, Lessos, Xerita, Kiberìcho and Karatina areas.	No firm recommendations available. Crops grow well on these soils and in these localities without fertilizers.		
Reddish-brown to greyish-brown coarse sandy loams to coarse sandy clay loams of considerable depth.	Lighter sandy soils of Chorengani Hills, Nzoia Valley, Hoeys Bridge, Turbo, Lugari and Moiben areas.	Wheat	45	
		Maize	30-35	followed by 20-50 at knee height.
Reddish-brown to yellowish-brown loams over reddish- or brownish-subsoils.	North Nyanza, South Nyanza, Nandi, Machakos Hills.	Maize	45	

TABLE 1 (Cont'd)

FERTILIZER Recommendations for Wheat, Malting Barley, Maize and Grassland in Kenya

Soil	Locally	Crop	Available P_2O_5	Recommended Dressings lbs. per acre N
Deep brown bracken infested friable loams of low fertility	Central Province	Maize	65-70	
	Remarks: Unless this land is limed with agricultural lime at the heavy rates which laboratory studies show to be necessary for its amelioration, maize like most other crops will not grow on the poorest sites. 50 lb. per acre K_2O is also beneficial.			
Light grey sands and loamy sands with pale brown or pale yellow sandy subsoils.	Elgon, Nyanza, North Nyanza	Maize	20-25 at knee height on unmanured land.	
	Remarks: As much land as possible should be manured at the rate of 7½ tons per acre.			
	Mackakos, Kitui.	Maize	20-25 on unmanured land as soon as the crop is established.	
	Remarks: Manure at 7½ tons per acre should be well-dug in or ploughed in during land preparation on as much land as possible.			
Red and grey sands with red or yellow subsoils.	Coastal Hills and Plains	Maize	45 and 10-15 in seed bed following 10-15 after a period of persistent rain.	
	Remarks: The crops should be grown on ridges and as much maize as possible should be given 3 tons of manure per acre per annum, placed in the base of the ridge. On the Coastal Plain, responses are less reliable than on the Hills and farmers here need to try fertilizers for themselves before using them extensively.			

TABLE 1 (Cont'd)

FERTILIZER Recommendations for Wheat, Malting Barley, Maize and Grassland in Kenya

Soil	Locally	Crop	Available P_2O_5	Recommended Dressings lbs. per acre N
Uniform black clays and black cotton soils.	Songhor, Muhoroni	Maize	45	and 20-50 at knee height
		Grassland		
		At sowing	45	
		Established		20-25
	Remarks: Provision of adequate surface drainage is essential for satisfactory growth and response to be obtained. As the sulphur status of these soils is low, sulphate of ammonia is the recommended nitrogenous fertilizer particularly for grassland: 2 cwt. per acre gypsum should be given to grassland to encourage leguminous constituents in the award.			
	Kano Plains	Maize		
	Remarks: Fertilizing here is justified only where average rainfall exceeds 45 inches.			
	Laikipia, Nanyuki, Athi Plains.	Grassland		
		Established		20-25
	Remarks: Rainfall is unreliable; to fertilizer, responses are erratic. Ranchers should try nitrogenous fertilizers on their grazing and see if there are worthwhile responses before using them extensively.			

TABLE 2

Fertilizer Factors and Percentage Content of Manurial Constituent in some Commonly Used Nitrogenous, Phosphatic Potassic and Compound Fertilizers

	N*	P	K	Total	Nitrogen as N Ammonium	Nitrogen as N Nitrate	Phosphate as P_2O_5 Total	Phosphate as P_2O_5 Water Sol.	Phosphate as P_2O_5 Cit. Sol.	Potash as K_2O	Total Lime as CaO	Total Sulphur as SO_3	Equivalent Acidity as $CaCO_3$
Sulphate of Ammonia	5	–	–	20.5–21	20.5–21	–	–	–	–	–	–	59	110
Calcium Ammonium Nitrate	5	–	–	20.6	10.3	10.3	–	–	–	–	10–20	–	0
Ammonium Sulphate Nitrate	4	–	–	26	19.5	6.5	–	–	–	–	–	29	85
Urea	2½	–	–	42–46	42–46	–	–	–	–	–	–	–	75
Nitrate of Soda	6½	–	–	15.5	–	15.5	–	–	–	–	–	–	Basic
Double, Triple and 42% Super-phosphate	–	2½	–	–	–	–	40–50	40–42–18	–	–	17–20	0–3	0
21% "T.I.C.A.F." Super-phosphate	–	–	–	–	–	–	?	21	–	–	25–30	28–31	0
Soda phosphate	–	7+	–	–	–	–	24–26	–	18–22	–	–	0	0
Hyperphosphate	–	10	–	–	–	–	27.5	–	12.5	–	47	0	0
Seychelles Guano	–	10	–	2	–	–	20–25	–	11.13	–	?	0	0
Uganda Rock Phosphate	–	–	–	–	–	–	20–27	–	2–4	–	?	0	0
Basic Slag	–	7‡	–	–	–	–	?	–	18–20	–	47	1	Basic
Nuriate of Potash	–	–	1½	–	–	–	–	–	–	48.62	0–3	0–7	0
Sulphate of Potash	–	–	2	–	–	–	–	–	–	48–52	0–3	39–48	0
Di-ammonium phosphate	5½	2	–	18.5	18.5	–	48	48	–	–	–	–	0
10:30:10	10	3½	10	10	7.5	2.5	30	30	–	10	–	–	0
10:30:0	10	½	–	10	7.5	2.5	30	30	–	–	–	–	0
and ot er compounds similarly													

NOTE: * The N factors apply only to crops which can use effectively all the N in the fertilizer, be it ammonium or nitrate.

\+ P Factor for soda phosphate in Kipkabus area is 5. Farmers in this area should use the factor 5 instead of 7.

‡ P factor for basic slag for pyrethrum is 5. Farmers using basic slag on pyrethrum should use the factor 5 instead of 7.

ANNEX III

Fertilizer Recommendations for Maize, Groundnuts, Potatoes and Cotton in Malawi

A. Maize

Nutrient	Soil type and region	Optional dressing lb. N/acre	Maximum Size of Response lb gram/acre
1) Nitrogen			
	Northern Region SCL* Plateau	40 - 60	1200 - 2000
	Northern Region SL/LS Plateau	20 - 40	1000 - 1600
	Central Region Plateau SCL/SC	20 - 40	600 - 800
	Central Region Plateau SL/LS	40 - 60	600 - 1200
	Central Region Lakeshore SCL/SL	40 - 60	1000 - 1800
	Southern Region SCL	20 - 40	400 - [illegible]00
	Southern Region SL/LS	40 - 60	

Nutrient	Region	Ot.dressing P_2O_5	Max.response
2) Phosphorus			
	Northern Region SCL Plateau	40	1000
	Northern Region SL/LS Plateau	40	600
	Central Region Plateau SCL/SC	40	600
	Southern Region Pediments SCL/SL	40	800

3) Potash No response expected

Types of fertilizer recommended: S/A, Single superphosphate; 16:8:4 if one must have a compound for regular use

B. Groundnuts

1) Gypsum or Single supers.	Sandy soils along border of N. Rhodesia - if no S/A or Supers applied before.	100 lb/acre gypsum	400
		200 lb/acre supers	400

Elsewhere residues from other fertilized crops only.

C. Potatoes

The best general recommendation is 5 tons F.Y.M. + 200 lb/ S/A this will raise yields of Blight resistant varieties by 3-4 tons/acre total crop, Alternatively fertilizer giving about 40-60 lb. N, 20 lb. P and 20-30 lb. K per acre. The K recommendation is guesswork.

D. Cotton

On alluvial soils, 20 lb N and 10 lb P_2O_5 to balance the tendency of the nitrogen to greatly increase vegetative growth. Response up to 500 lb/acre seed cotton.

On basement complex soils 40 lb/N and 40 lb P_2O_5, which will give a response of up to 800 lb/acre seed cotton.

On black cotton soils - nil.

Texture

The texture of a soil refers to the proportions of the various particle-size fractions of which it is composed. There are three main fractions, which are internationally defined as follows:

Clay : particle sizes less than 0.002 m.m.

Silt : particle sizes 0.02 m.m.

Sand : particle sizes 0.02 - 2.0 m.m.

Anything coarser than 2 m.m. is classed as gravel and is not included in the soil analysed.

The textural classes commonly found in the former Federation of Rhodesia and Nyasaland, soils contain the following proportions of clay, silt, and sand:

Heavy Clays	(HC)	More than 50% clay
Clays	(C)	30-50% clay; less than 50% sand or silt
Clay loams	(CL)	20-30% clay: less than 50% sand or silt
Sandy clays	(SC)	30-50% clay: more than 50% sand
Sandy clay loams	(SCL)	20-30% clay: more than 50% sand
Sandy loams	(SL)	More than 20% silt + clay: more than 50% sand
Loamy sands	(LS)	15-20% silt + clay : 80-85% sand
Sands	(S)	Less than 15% silt + clay : more than 85% sand.

Other textural classes are: loams, silty loams, silty clay loams, and silty clays, but they are almost unknown in Rhodesia and so are not included.

ANNEX IV

The Fertilization of Maize in the Southern Province of Zambia
General Recommendations for Extention Workers for the 1964/65 Season

The following fertilizer recommendations have been drawn up from analysis experiments carried out in the Province over the past few years:

1. Nitrogen — Straight nitrogen can be applied either as sulphate of ammonia, calcium ammonium nitrate or urea and should be worked into the soil. This is particularly important when using urea. On heavy soils all the nitrogen can be applied at planting time but on lighter soils a split application of nitrogen is recommended (e.g. one third at planting and two thirds at 4 weeks).

2. Phosphate — All phosphate should be banded two inches to the side and two inches below the seed at planting time.

3. Potash — No responses to potash have been recorded in the southern Province but if potash deficiency is suspected then D Compound 8 - 16 - 8 should be applied instead of P. Compound 10 - 20 - 0.

4. Sulphur — Deficiency of this element has been detected at Kalomo but the following recommendations include sufficient sulphur to overcome this deficiency.

Finally it cannot be over emphasized that fertilizer is no substitute for early planting, good plant populations and clean weeding.

Recommendations for the 1964/65 Season Sandveldt Soils in Choma and Kalomo

HYBRID VARIETIES SR. 13 AND SR. 52

Maize after Maize Expected yield		Fertilizer required/acre
20 bags/acre		1. 150-200 lbs. P. Compound plus 275 lbs. Calcium ammonium nitrate (C.A.N.)
	OR	2. 150-200 lbs. P Compound plus 275 lbs. sulphate of ammonia (S/A)
	OR	3. 150-200 lbs. Single superphosphate plus 350 lbs. C.A.N.
	OR	4. 150-200 single supers plus 350 lbs. S/A.
30 bags/acre		1. 200-250 lbs. P Compound plus 400-500 lbs. C.A.N.
	OR	2. 200-500 lbs. Single supers plus 500-600 lbs. C.A.N.

OPEN POLLINATED VARIETIES - HICKORY KING

Maize after Maize Expected yield		Fertilizer required/acre
10 bags/acre		1. 100 - 150 lbs. P. Compound plus 150 lbs. C.A.N.
	OR	2. 100 - 150 lbs. P. Compound plus 150 lbs. S/A.
	OR	3. 100 - 150 lbs. Single Supers and 200 lbs. C.A.N.
	OR	4. 100 - 150 lbs. Single Supers and 200 lbs. S/A.
15 bags/acre		1. 150 - 200 lbs. P. Compound plus 275 lbs. C.A.N.
		2. 150 - 200 lbs. P. Compound plus 275 lbs. S/A.
		3. 150 - 200 Single Supers plus 350 lbs. C.A.N.
		4. 150 - 200 lbs. Supers and 350 lbs.S/A.

N.B.: Where maize is grown after tobacco hybrid varieties should receive 100 lbs. P Compound/acre plus 450 - 500 lbs. C.A.N./acre.

Soils in Monze - Magoye - Mazabuka

A. HYBRID VARIETIES SR 13 and SR 52

Maize after Maize

Expected Yield		Fertilizer Required/acre
20 bags/acre		1. 200 lbs. P Compound plus 200-25 lbs. C.A.N.
	OR	2. 200 lbs. P Compound and 200-250 lbs. S/A.
	OR	3. 200 lbs. Single Supers plus 300-350 lbs. C.A.N.
	OR	4. 200 lbs. Single Supers plus 300-350 lbs. S/A.
30 bags/acre		1. 300 lbs. P Compound and 350-400 lbs. C.A.N.
	OR	2. 300 lbs. Single Supers and 500-550 lbs. C.A.N.

Maize after Green Manure

Expected Yield		
20 bags/acre		1. 200 lbs. P. Compound and 100 lbs. C.A.N.
	OR	2. 200 lbs. P. Compound and 100 lbs. S/A.
	OR	3. 200 lbs. Single Supers plus 200 lbs. C.A.N.
	OR	4. 200 lbs. Single Supers and 200 lbs. C.A.N.
30 bags/acre		1. 300 lbs. P. Compound plus 150 lbs. C.A.N.
	OR	2. 300 lbs. Single Supers plus 300 lbs. C.A.N.

Maize after cotton (Cotton fertilized with 200 lbs. or more P. Compound/Accre)

Expected Yield		Fertilizer required/acre
20 bags/acre		1. 150 lbs. P. Compound and 225-300 lbs. C.A.N.
		2. 150 lbs. Single Supers plus 300-350 lbs. C.A.N.
30 bags/acre		3. 200 lbs. P. Compound plus 400-500 lbs. C.A.N.
		4. 200 lbs. Single Supers plus 500-550 lbs. C.A.N.

B. OPEN POLLINATED VARIETIES e.g. HICKORY KING

Maize after Maize

Expected Yield		Fertilizer required/acre
10 bags/acre		1. 150 lbs. P. Compound and 125 lbs. C.A.N.
	OR	2. 150 lbs. Single Supers and 200 lbs.S/A.
15 bags/acre		1. 200 lbs. P. Compound and 200 lbs. C.A.N.
		2. 200 lbs. Single Supers and 300 lbs.S/A.

Maize after Green Manure

Expected Yield		Fertilizer required/acre
15 bags/acre		1. 200 lbs. P. Compound plus 100 lbs. C.A.N.
	OR	2. 200 lbs. Single Supers plus 100 lbs.S/A.
20 bags/acre		1. 300 lbs. P. Compound and 150 lbs. C.A.N.
	OR	2. 300 lbs. Single Supers plus 300 lbs.S/A.

Maize after Cotton (Cotton Fertilized with 300 P. Compound/acre)

Expected Yield		Fertilizer required/acre
10 bags/acre		1. 100 lbs. P. Compound and 150 lbs. C.A.N.
		2. 100 lbs. Single Supers and 200 lbs.S/A
15 bags/acre		1. 150 lbs. P. Compound and 225 lbs C.A.N.
		2. 150 lbs. Single Supers plus 300 lbs.S/A.

FERTILIZER RECOMMENDATIONS FOR THE 1964/65 COTTON CROP IN ZAMBIA

Trials to date indicate that the following levels of nitrogen and phosphate will give economic increases in the yields of seed cotton:

A. Nitrogen - 40 - 60 lbs. N. per acre

B. Phosphate - 40 - 60 lbs. P_2O_5 per acre

It is recommended that both the nitrogen and phosphate should be placed 4" deep and 4" to the side of the crop at planting. Great care must be taken not to allow the fertilizer to fall too near the seed, as there is a real danger of fertilizer burn.

A suitable fertilizer dressing would be:

200 - 300 lbs. P. Compound (10-20-0)

plus 150 - 200 lbs. Calcium Ammonium Nitrate.

The higher level of nitrogen should be used on the heavier soils.

ANNEX V

The Efficient Use of Fertilizers and Lime, Rhodesia

1. Introduction

Fertilizer recommendations are made by the Chemistry Branch on the assumption that the soil sample has been correctly taken according to the official instructions issued and that it is thoroughly representative of the land for which the recommendations are required. Unless information to the contrary is supplied, it is also assumed that the soil is physically in good heart, a condition that it is impossible to assess by examination or analysis of soil samples.

Recommendations are adjusted for each individual soil to ensure a balanced and adequate supply of plant nutrients which will make possible the attainment of good, economic yields, under the average climatic conditions for the area concerned.

On the Fertilizer Recommendation sheet the amounts of N, P_2O_5 and K_2O required for the crop are shown first; then follow suggestions regarding the commercially available fertilizers that may be used to provide these nutrients in a suitable form, and the method and time of application; and finally the lime requirement of the soil, if any, is given.

The purpose of this pamphlet is to discuss the methods of application that may be recommended, in relation to particular crops; to give information about the use of alternative forms of certain fertilizers; and to explain some aspects of the problem of soil acidity and the alternative forms of liming material available commercially.

2. Methods of Application of Fertilizer

(a) Broadcast before ploughing or before ridging

This is advised when it is desirable that some fertilizer should be applied at the time of preparation of the land in order to raise the fertility of very poor soils.

On soils which are very deficient in phosphate a broadcast application of fertilizer phosphate, in addition to a localized application at the time of planting, ~~is often beneficial. This~~ broadcast application should be turned in as deeply as possible.

On soils where substantial amounts of mature plant residues are turned in, a broadcast application of fertilizer, nitrogen may be required in order to compensate for microbial fixation of nitrogen during the decomposition of the residues.

Also, on poor soils requiring very heavy fertilizer applications, it is sometimes desirable to localize only a part of the fertilizer and broadcast the remainder in order to prevent burning of roots with very heavy concentrations of fertilizers.

(b) Initial application

This represents the fertilizer normally required at planting, which should be given according to the method best suited to the crop concerned and the equipment available.

For tobacco and other transplanted row crops the fertilizer is best applied in bands, preferably on either side of the plants and slightly below the root crowns.

For large seeds such as maize, beans and groundnuts, and also for cotton, the fertilizer may be banded to the side of, out of contact with, and preferably slightly below, the seed, or it may be broadcast and deeply turned in.

With small seeds such as the small grains, the fertilizer may be drilled with the seed, or again, it may be broadcast and disced in.

For pastures, lucerne, and other perennials the fertilizer should be broadcast and deeply turned in. With very fine seeds a small amount of fertilizer may often be mixed with the seed for ease in drilling; where this is done the bulk of the fertilizer should, nevertheless, be broadcast and turned in, except on fertile soils where the total required is small.

For potatoes the fertilizer is preferably banded to the side of the seed, but if suitable equipment for this is not available, it may be placed in the furrow with the seed.

For vegetables the fertilizer may be broadcast and well turned in or, if preferred, a suitable method of side-band placement may be used.

(c) Top-dressing

For crops of long growing period and for late-planted crops, especially on sandy soils, it is preferably to supply part of the nitrogen required in the form of a top-dressing in order to minimize possible leaching losses and also to enable it to be applied over the active feeding root zone at the right time.

For tobacco the top-dressing should be applied two to three weeks after planting; it may be applied in a ring around the plant some 6 in. from it. After the fertilizer has been applied the land should be ridged up again as soon as possible. The fertilizer does not suffer any loss from exposure, but care must be taken to see that it is not washed away by rain and it is considered that some form of light cultivation or incorporation of the fertilizer with the surface soil is desirable.

For maize and many other tall-growing crops on light soils the top-dressing should be given four to six weeks after planting; it should be side-dressed between the rows well to the side of the plants. Urea should always be well worked in. With other forms of nitrogen this is not necessary on lands of normal topography, but it may be done with advantage if cultivation is in any case required for weed control.

On heavy soils the top-dressing may be given at any convenient time up to six weeks. There is, however, experimental evidence that for early planted crops on such soils pre-planting applications of nitrogen are as effective as top-dressing and that broadcasting is as efficient as band-placement. The total nitrogen requirement may, therefore, safely be broadcast in one operation and, if convenient, it may be given with the phosphate at the time of ploughing.

For small grains, and grasses grown for seed, the top-dressing may be applied when the crop is 4 to 6 in. high. It should preferably be applied when the plants are dry in order to avoid leaf injury.

For pastures, in the year of establishment, the top-dressing should not be given until the grass has become firmly established or, in the case of creeping grasses, until some measure of soil cover has been achieved. In subsequent years the top-dressing should normally be given at the onset of the general rains, although the nitrogen may be split between applications timed to stimulate new growth at the required times.

For potatoes the top-dressing should be given two to three weeks after emergence.

For lucerne and other perennial legumes the annual top-dressing should be given with the commencement of the growing season.

Most Rhodesian soils are deficient in boron for lucerne production, and borax should be applied with the annual top-dressing, at rates of from 20 lb. per acre on sandy soils to 40 lb. per acre on heavy soils.

For cotton the top-dressing may be given at the early squaring stage.

For vegetables and fruit trees the times of application are described in detail on the special report forms used for these crops.

3. Alternative Forms of Nitrogenous and Phosphatic Fertilizers

Several alternative forms of straight nitrogenous and phosphatic fertilizers are obtainable. They are not all equally suitably in all circumstances, although often one may be substituted for another, provided that the correct method of application is employed. It is not practical to specify on the Fertilizer Recommendations sheet in every case all suitable alternatives with the necessary comments on how they should be used. Therefore, as a guide to which alternatives are suitable in a particular case, notes are given below on the characteristics of the alternative forms and any precautions that must be observed in their use.

(a) Nitrogenous fertilizers

Of the various forms available in Southern Rhodesia only nitrate of soda and calcium ammonium nitrate are suitable for top-dressing tobacco. With nitrate of soda the response is slightly more rapid, but at the higher rates of application leaching losses are greater and there is more risk of root-burn.

For other field crops, calcium ammonium nitrate, sulphate of ammonia and urea are equally suitable for pre-planting or top-dressing applications on most soils, provided that they are used correctly. For pastures, calcium ammonium nitrate or sulphate of ammonia is probably more suitable.

Calcium ammonium nitrate has the advantage that it does not acidify the soil. It also contains half its nitrogen in the nitrate form, which is probably an advantage for horticultural crops. Care is necessary, however, to avoid contact with foliage or localized heavy concentrations over the root-zone, because of the risk of fertilizer-burn.

Sulphate of ammonia acidifies the soil quite strongly. This is an advantage on alkaline soils, but on acid soils it makes more frequent or heavier liming necessary. To compensate for the effect, approximately 150 lb. of lime are required for every 100 lb. of sulphate of ammonia used. When this is taken into account, it will be found that sulphate of ammonia is actually more expensive than calcium ammonium nitrate on acid soils, although per unit of nitrogen is slightly cheaper.

Urea is converted to ammonium carbonate by micro-organisms in the soil and this provides ammonia-nitrogen for the use of plants. When used as a top-dressing, urea should therefore be applied somewhat earlier than the other nitrogenous fertilizers. Several other precautions should also be taken.

(1) Urea should not be localized in large amounts near the seed, because certain substances, temporarily formed during its conversion to nitrates may have a toxic effect at high concentrations. This danger does not exist if the urea is broadcast at any level of application likely to be used in practice.

(2) It is strongly recommended that urea should not be used on recently limed lands, owing to the risk of the formation of toxic products of decomposition in localized pockets of temporarily high pH. If the lime can be applied while the soil is still moist at the end of the rainy season, urea may be broadcast as a pre-planting dressing for the next summer crop; but if the lime has to be applied later, it is advisable to use an alternative form of nitrogen.

(3) If urea is applied as a top-dressing, it should be well worked into the soil because there is some danger of loss of ammonia by volatilization if a dry spell occurs before it has been absorbed by the soil. (This danger does not exist with calcium ammonium nitrate or sulphate of ammonia.)

(4) Urea is very susceptible to leaching before it has been converted to ammonia and it is therefore not suitable for use of light soils immediately prior to flood irrigation.

Urea acidifies the soil slightly and approximately 100 lb. of lime for every 100 lb. of urea is required to compensate for the effect. (If one takes into account the higher nitrogen content of urea, this means that urea has one-third the acidifying effect of sulphate of ammonia per unit of nitrogen.)

(b) Phosphatic fertilizers

Phosphatic fertilizers are classified according to their solubility, because this largely determines their availability to plants and therefore the conditions under which they will be most effective. There are three main types:

(1) Water-soluble

The superphosphates and the phosphate in standard fertilizer mixtures are in this category. They are suitable for all crops under all soil conditions, but they are especially suitable for crops that have a high phosphate requirement in the early stages of growth (e.g. tobacco) or over a relatively short period (e.g. potatoes). For such crops, suitably placed applications of water-soluble phosphates are recommended. Water-soluble phosphates are also the only form suitable for use on neutral or alkaline soils.

(2) Water-insoluble, but mainly citric-soluble

The only example of this type generally obtainable in Rhodesia is basic slag. Although not as readily available as water-soluble phosphates, it is likely to be as effective as superphosphate on acid soils for all crops except those with special requirements, mentioned above. (It is not possible to be precise about the suitable pH range. At calcium-chloride pH values below 5.5 basic slag should be definitely satisfactory, and possibly up to 6.0.)

Basic slag is unique among fertilizers in that it is also a liming material. It has a neutralizing value equivalent to that of an equal weight of pure limestone (calcium carbonate), and its use therefore provides a convenient indirect means of applying small maintenance dressings of lime to medium-acid soils.

(3) Predominantly citric-insoluble

The rock phosphates and bone meals are in this class. They are the least readily available of all phosphatic fertilizers, but they are satisfactory on acid soils for crops that take up their phosphate over a fairly long period. (Contrary to long-standing beliefs, however, they are no better in this respect than water-soluble forms of phosphate, except possibly on very sandy soils, and their merit should be assessed purely on a cost basis; for example rock phosphate is suitable as a pre-planting application for perennial crops on acid soils, and per unit of P_2O_5 it is considerably cheaper than super-phosphate.)

On the more acid soils (calcium-chloride pH below 5, and possibly even up to 5.5), rock phosphate is likely to be adequately available for crops such as maize, unless the soil is particularly deficient in available phosphorus. It is important, however, that this form of phosphate should be very finely ground, and that it should be broadcast and thoroughly incorporated with the soil as deeply as possible.

(c) Sulphur content of fertilizers

Another factor that should be borne in mind in choosing the type of fertilizer is the amount of sulphur it contains, since this is one of the elements essential for plant growth.

Sulphate of ammonia, single superphosphate, and the standard fertilizer mixtures, all contain appreciable amounts of sulphur in one form or another. When any one of these materials is used at normal rates of application, the amount of sulphur supplied should be adequate to maintain the sulphur reserves of the soil. On the other hand, calcium ammonium nitrate and urea contain no sulphur at all, and double super-phosphates very little. If, therefore, a combination of the latter fertilizers is used exclusively, it may be only a matter of time before the sulphur reserves are depleted and sulphur deficiency appears.

As yet, sulphur deficiency is not common in Southern Rhodesia, although it has been reported fairly widely in Northern Rhodesia. However, recent experiments at the Grasslands Research Station have indicated that deficiency may occur rapidly on virgin sandy soils when fertilizers containing no sulphur are used.

It is therefore recommended that a combination of calcium ammonium nitrate or urea and double superphosphate should not be used on virgin soils, especially sands, or on soils that have received very little sulphur-containing fertilizers in the past. On such soils, if calcium ammonium nitrate or urea are to be used, single superphosphate or a fertilizer mixture should be chosen as the source of phosphate; or, alternatively, if double superphosphate is preferred, then sulphate of ammonia should be used as the nitrogenous fertilizer.

(d) The choice of fertilizers for mixing on the farm

When it is intended to mix fertilizers before application, the physical characteristics of the alternative forms should be taken into account in making one's choice. In general, physically stable and homogeneous mixtures will be obtained only when powders are mixed with powders and granules with granules and when the densities of the ingredients are not too widely different.

Calcium ammonium nitrate and double superphosphate are granular and may be mixed with each other or with compound fertilizers. Nitrate of soda, sulphate of ammonia, and muriate and sulphate of potash are powdered or finely crystalline and may also be mixed with each other, but not satisfactorily with granular materials.

Urea and basic slag are in classes by themselves. Urea is granular, but by far the "lightest" of all the fertilizers, while basic slag is very finely powdered and by far the "heaviest". Farmers are advised not to attempt to mix urea with a powdered or crystalline fertilizer, or basic slag with a granular fertilizer, because serious segregation during application will almost certainly occur.

4. <u>Soil acidity and the Need for Lime</u>

Lime is not a fertilizer in the ordinary sense. Its main function is not to supply plant nutrients, although it does this indirectly, but to adjust soil acidity. For most crops a slightly acid soil is desirable, but if the soil becomes too acid pronounced, infertility may result, mainly because the availability of certain elements (chiefly aluminium and manganese) may increase to toxic levels. Usually such infertility first appears in patches, which rapidly spread, if the condition is not corrected.

(a) Methods of applying lime

The effect of lime is mainly confined to the soil with which it is in direct contact. It is desirable, therefore, to incorporate lime thoroughly with the soil throughout the plough-zone, since its primary function is to amend soil conditions and not to satisfy the nutrient requirements of plants.

This is particularly important when the pH is in the critical range and correction of acidity is urgently necessary. In such cases mere ploughing-under of lime is not satisfactory, because it may bury the lime without mixing it with the soil above, and, as a result, the soil may remain too acid for crops in their early stages of growth. To overcome this, the lime should be thoroughly disced in, preferably after ploughing. It is also desirable in such cases to apply the lime while the soil is still moist at the end of the rainy season prior to planting, in order to allow time for it to react with the soil and correct the acidity.

If, however, lime is applied as a maintenance dressing before the pH reaches the critical range, the method of application is less important, provided that the lime is mixed with the soil and not merely buried. Maintenance dressings may be applied when convenient in the rotation, preferably before legume or wheat crops, if these are included, or when grass leys are ploughed in. Because of the greater latitude permissible in the case of maintenance dressings, and also to avoid any risk of the pH approaching the level where fertility may be affected, maintenance of the pH ($CaCl_2$)* in the range 5.0 to 5.5 should be regarded as an essential feature of sound soil management.

When soils are very strongly acid (calcium-chloride pH below 4.5) and the total lime requirement is consequently large, it is preferable to split the application, applying half immediately (to ensure that the pH is raised above the critical level) and the remainder early in the subsequent rotation. This practice should always be followed when corrective applications precede one of the more acid-tolerant crops, such as potatoes or tobacco. Maintenance applications, on the other hand, should be made in the rotation and not immediately before planting potatoes or tobacco. If, however, the calcium-chloride pH is below about 4.8, it is considered desirable to make an immediate application of half the total lime requirement, even for such crops.

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* pH ($CaCl_2$) means pH measured in a suspension of soil in calcium chloride solution instead of water. It is, on an average, about 0.7 units lower than the pH measured in water as in the past.

(b) Choosing a liming material

Under the regulations governing the registration and sale of agricultural liming materials in Southern Rhodesia,* five categories of material are recognized, which contain the following active ingredients:

- Ground limestone: calcium carbonate with a negligible amount of magnesium carbonate.
- Ground magnesian limestone: calcium carbonate with a moderate amount of magnesium carbonate.
- Ground dolomite: calcium and magnesium carbonates in approximately equivalent proportions.
- Ground liming slag: mainly hydrolysable silicates of calcium and magnesium.
- Ground mixed lime: mixtures of oxides, hydroxides, and carbonates, of calcium and/or magnesium.

The purity of the material is described by its "neutralizing value" which is the weight of pure calcium carbonate that has the same neutralizing effect as 100 lb. of the material. Recommended liming rates are always stated in terms of pure calcium carbonate, that is material with a neutralizing value of 100. So, if a farmer wishes to use a material with a neutralizing value appreciably above or below 100, he should decrease or increase his recommended liming rate proportionally. Similarly, by comparing the neutralizing values of different materials in relation to their prices and transport costs, he can decide which is the most economic to use.

With a few exceptions, this is the most important factor in choosing a liming material - more important in fact than its type. Where, however, costs are more or less equal, the following may be used as a guide:

- On heavy soils (clays and clay loams) in medium-rainfall zones, ground limestone, ground magnesian limestone, or ground liming slag is suitable.

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* Federal Government Notices No. 86 of 1961 and No. 43 of 1963.

- On all soils in high-rainfall zones, and on sandy soils in medium-rainfall zones, ground magnesian limestone is most suitable, or ground liming slag if it contains an appreciable amount of magnesium. Alternatively, ground dolomite may be used, but since this material contains a large amount of magnesium, it is probably not desirable to use it repeatedly for maintenance applications, but to alternate with ground limestone, ground magnesian limestone, or ground liming slag.
- On soils derived from the magnesium-rich rocks (serpentine and pyroxenite) of the Great Dyke and similar local intrusions elsewhere, ground limestone only should be used and not a type containing any appreciable quantity of magnesium.

Ground mixed lime may be used satisfactorily instead of the other types, taking into account the magnesium content of the particular material available. Since, however, it usually contains the more soluble hydroxides and oxides, it should be applied sufficiently in advance of planting to avoid any danger of root-burn or temporary, localized high pH values.

ANNEX VI

CHEMISTRY BRANCH, DEPARTMENT OF RESEARCH AND SPECIALIST SERVICES,
FEDERAL MINISTRY OF AGRICULTURE

Fertilizer Recommendations for Intensive Market-Gardens

For crops grown on a field scale, specific fertilizer recommendations for individual crops are normally given. But in the case of market gardens, where a wide range of crops is usually grown in an intensive rotation, it is more convenient to recommend a basic fertilizer treatment, designed to raise the individual soil to a satisfactory initial level of fertility, followed by standard dressings of the fertilizers considered most suitable for specific market-garden crops on the soils analysed.

(a) Basic Treatment

When beds are prepared in new ground, and the first time existing beds are prepared for replanting, broadcast and turn in thoroughly the following dressings:

Dressing	Rate (lb. per acre)			
	Lab.No.	Lab.No.	Lab.No.	Lab.No.
Agricultural limes				
Double superphosphate (38%)				

(b) Regular Planting Dressings

In addition to regular dressings of compost or manure, apply the following fertilizer dressings and incorporate them thoroughly with the soil before planting each crop:

Potatoes, Celery, Asparagus:

700 lb/acre	Compound C	5.15.12
600 lb/acre	Compound S	6.18. 6
400 lb/acre	Compound M	9.12. 9

Tomatoes:

600 lb/acre	Compound V	4.18.15
600 lb/acre	Compound S	6.18. 6
300 lb/acre	Compound D	8.16. 8

Peas, Sweet-potatoes:

500 lb/acre	Compound C	5.15.12
400 lb/acre	Compound S	6.18. 6
250 lb/acre	Compound M	9.12. 9

Brassicas, Beet and Chard, Carrots, Onions, Lettuce, Flowers:

500 lb/acre	Compound D	8.16. 8
400 lb/acre	Compound M	9.12. 9

Beans, Cucurbits:

300 lb/acre	Compound D	8.16. 8
250 lb/acre	Compound M	9.12. 9

For perennial flowers the dressing recommended above should be repeated annually at the commencement of the growing season. For roses it should be given after pruning in July, and for carnations towards the end of the rains (early March).

(c) Regular Top Dressings

For the crops listed below sulphate of ammonia or calcium ammonium nitrate, at the rate of 150 lb. per acre (½ oz. per square yard), should be sprinkled in the rows or round the plants at the times stated.

Potatoes:	Once, 2-3 weeks after emergence.
Tomatoes:	Once when first fruits are marble-sized, and thereafter at 3-weekly intervals while picking*.
Cabbages and Cauliflowers:	Twice, at 3-weekly intervals after transplanting.
Chard:	At monthly intervals while picking.

* The experience of many commercial growers indicates that quality may be improved if top-dressings of sulphate of potash are also given regularly while picking at the rate of ¼ - ½ oz. per square yard.

Celery:	Twice, at monthly intervals after transplanting.
Asparagus:	Once after cutting starts, and again 3 weeks later.
Peas:	Once before first pods set.
Onions:	Once after bulbs start to form.
Cucurbits:	Once after first fruit is formed, (but not for water melons).
Flowers:	At monthly intervals while flowering.

No additional nitrogen should be necessary for the following:

Sweet potatoes, water-melons, lettuce, beetroot, carrots, parsnips, radishes, turnips, and beans.

(d) Special top dressing

The following vegetables have a high boron requirement:

Beetroot, chard (spinnach-beet), cabbage, cauliflowers, kohlrabi, celery, turnips, parsnips and radishes.

To meet this need, borax should be dissolved and watered on before, or shortly after, planting, at the following rates:

On very sandy soils .... 3/4 oz. per ten square yards.
On loamy soils .... 1 oz. per ten square yards.
On clayey soils .... $1\frac{1}{2}$ oz. per ten square yards.

These rates must not be exceeded, and borax must not be reapplied to the same bed within a year.

Cauliflowers are sensitive to a deficiency of molybdenum. If signs of "whip-tail" (unevenly-formed, whip-like leaves) develop on beds that have been correctly limed, sodium or ammonium molybdate at the rate of 8 grains per ten square yards (enough to cover a "tickey") should be dissolved and watered on with the borax. If the soil is acid, the effect of liming should first be tried before resorting to the use of molybdate.

NOTES: (1) Where double superphosphate (granular) has been recommended, single superphosphate (powdered) may be used instead at twice the rate.

(2) 300 lb/acre = 1 oz./square yard.

ANNEX VII

Below are shown prices of compounds and straight fertilizers at the store-houses of the companies in Salisbury

COMPOUNDS

	N Nitrogen	P_2O_5 Phosphate Water Soluble	K_2O Potash	Price per ton £	s.	d.
A[a]	2 0.5 Nitr. 1.5 Amm.	18 18.3.Cit.Sol 19.0 Total	15 15 Sulph.	27.	0.	0.
B[a]	4 1.0 Nitr. 3.0 Amm.	18 18.3.Cit.Sol 21 Total	15 15 Sulph.	28.	19.	0.
G[a]	1 0.25.Nitr. 0.75.Amm.	20 20.3.Cit.Sol 21 Total	15 15 Sulph.	27.	8.	0.
K[a]	2 0.5.Nitr. 1.5 Amm.	18 18.3.Cit.Sol 19.0 Total	15 11 Sulph. 4 Chlor.	26.	9.	0.
H[a]	3 0.75.Nitr. 2.25.Amm.	18 18.3.Cit.Sol 19.0 Total	15 11 Sulph. 4 Chlor.	27.	9.	0.
V[a]	4 1.0.Nitr. 3.0.Amm.	18 18.3.Cit.Sol 19.0 Total	15 11 Sulph.	28.	10.	0.
C[a]	5 1.25.Nitr. 3.75.Amm.	15 15.3.Cit.Sol 16.0 Total	12 9 Sulph. 3 Chlor.	25.	17.	0.
S	6 1.5.Nitr. 4.5.Amm.	18 18.3.Cit.Sol 19.0 Total	6 6 Sulph.	26.	8.	0.
D	8 8.0.Amm	16 18.3.Cit.Sol 17.0 Total	8 8 Chlor.	26.	1.	0.
P	1 10.0.Amm.	20 20.3.Cit.Sol 21.0 Total	0	27.	15.	0.
M	9 9.0.Amm.	12 12.3.Cit.Sol 12.8 Total	9 9 Chlor.	24.	2.	0.
Z	16 1.0.Nitr. 15.0.Amm.	8 8.2.Cit.Sol 8.5 Total	4 4 Chlor.	25.	16.	0.

Most of the above fertilizers will be available in 50 lb. packs at an extra charge of 30/- per ton.

a/ These compounds contain 7 Pounds fertilizers borate per ton.

The six first compounds on the list (A, B, G, K, H, V) are usually applied to tobacco, the last four (D, P, M, Z) to general crops.

STRAIGHTS

N NITROGEN	NITR. per cent	AM. per cent	TOTAL per cent	PRICE PER TON £	s.	d.
+ Calcium Ammonium Nitrate	10.5	10.0	20.5	21.	5.	0.
Sulphate of Ammonia	-	21	21	20.	16.	0.
Urea	-	46	46	37.	10.	0.
Nitrate of Soda	16	-	16	28.	18.	0.

+ Price quoted is for 125 lb. Plastic packs. Price in 100 lb. Jute/Polythene is 22/6d. per ton additional. One will try to meet the actual demand but must reserve the right to supply in either pack - at the price for that pack.

P_2O_5 PHOSPHATE	WAT. SOL. per cent	CIT SOL. per cent	TOTAL per cent	£	s.	d.
Double Superphosphate	38	39	40	30.	14.	0.
Single Superphosphate	19	19.7	20.5	15.	13.	0.
Basic Slag	-	16	18	15.	13.	0.
Raw Rock	-	9.4	37.0	15.	13.	0.

K_2O POTASH	SULPH. per cent	CHL. per cent	TOTAL per cent	£	s.	d.
Muriate of Potash	-	60	60	23.	14.	0.
Sulphate of Potash	50	-	50	23.	7.	0.
+ Ground Dolomite 12 per cent Mg. Neutralizing value 100				4.	12.	0.
High Grade Fertilizer Borate				2.	18.	0.
				per 112 lb. Bag.		