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SOIL FERTILITY UNDER CONTINUOUS CULTIVATION IN NORTHERN NIGERIA. II. RESPONSES TO FERTILIZERS IN THE ABSENCE OF ORGANIC MANURES

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SUMMARY

Initial results of long-term trials in northern Nigeria indicate that deficiencies of potassium and trace elements, and soil acidity, may become important under continuous cultivation on some soils, in addition to the more common deficiencies of nitrogen and phosphorus.

Preliminary results of long-term trials to determine which soil factors might become limiting to crop production under continuous cultivation were reported in Part I of this paper (Heathcote, 1970). From these trials, carried out at Samaru with cotton, sorghum and maize as test crops, the results indicated that soil acidity, and a deficiency of one or more trace elements, were limiting factors with cotton and maize, and there was also some evidence of potassium deficiency with these crops. The conclusion was drawn that, in the short term, the effectiveness of organic manures in maintaining fertility under continuous cultivation was largely explicable in terms of these factors, but the need to extend the trials to embrace a wider range of soils and climates was recognized, and this paper reports the initial results of long-term trials at three sites, representing three soils in three climatic zones in the northern states of Nigeria in 1968 and 1969.

THE EXPERIMENTS

The trials were carried out on land that had initially been in cultivation for at least three years before the experiment, during which time it had received no fertilizer or manure except inorganic nitrogen and phosphorus. Soil and climatic data for the three experimental sites are given in Table 1. The soil figures, referring to the surface (0–6 in.) horizon, were based on samples taken from each site in 1968, before application of experimental treatments.

The trials tested the sixteen combinations of the treatments given below, two replicates of a 2^4 factorial design being used for each crop at each site. The same treatments were applied to each plot in each year, the experimental crops being rotated.

N_0—no nitrogen
N_1—3 cwt/acre Nitrochalk (21% N)

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K_0—no potassium
K_1—80 lb/acre potassium chloride (50% K)
L_0—no lime
L_1—lime added at rate calculated to raise the pH in the surface soil horizon (0–6 in.) to 6·0 in (2 : 1) m/100 calcium chloride
T_0—no trace elements
T_1—trace elements applied at the following rates
440 gm/acre H_3BO_3
70 gm/acre $CuSO_4.5H_2O$
70 gm/acre $ZnSO_4.7H_2O$
14 gm/acre $(NH_4)_6Mo_7O_{24}.4H_2O$

The trace elements were applied as a foliar spray in two applications about 4 and 6 weeks after planting, using 0·05 per cent Teepol solution as a wetting agent. Magnesium sulphate ($MgSO_4.7H_2O$) was included with the trace elements at Mokwa, applied to the soil before planting at the rate of 80 lb/acre.

Table 1. *Soil and climatic data for the three experimental sites*

Site	Latitude and longitude	Carbon (%)	Nitrogen (%)	pH in 2 : 1 m/100 $CaCl_2$	Cation exchange capacity (m.e./100 gm)	Exchangeable K (m.e./100 gm)	Exchangeable Ca (m.e./100 gm)	Mean annual rainfall (in.)	Duration of rains (days)
Kano	11° 58′ N 8° 51′ E	0·296	0·027	5·4	1·90	0·09	1·04	34	120–130
Samaru	11° 11′ N 7° 17′ E	0·580	0·040	5·2	2·96	0·20	1·89	44	140–150
Mokwa	9° 18′ N 5° 04′ E	0·538	0·038	5·8	2·42	0·06	2·00	44	165–175

Single superphosphate at 3 cwt/acre was applied annually as a basal dressing throughout the experiments. Crop varieties of the highest yield potential available, suitable for the site concerned, were used throughout. All crop residues were removed from experimental sites at the end of each season.

RESULTS

The main effects of each treatment on each experimental site are given in Tables 2–4, including data for total dry matter production as well as for the economic component of each crop, since the former may provide a more accurate measure of soil fertility. The 1968 sorghum crop at Kano was destroyed by insect attack after application of all experimental treatments except trace elements.

Nitrogen

Nitrochalk was included as a treatment in these trials to determine long-term crop responses to fertilizer nitrogen without introducing the possibly harmful effects of soil acidity associated with the continuous use of sulphate of ammonia, which has limited the value of many earlier long-term trials carried out in northern Nigeria.

In the case of maize, the application of Nitrochalk gave large and significant responses to all yield components measured in these trials. With sorghum, responses were in general much smaller and in one case grain yield was significantly reduced. The yields of seed cotton and groundnut kernels were not affected in the single trial carried out on each of these crops to date, although in each case yields of total dry matter were increased. The failure to obtain a response to nitrogen

Table 2. *Effects of treatments on yield components of experimental crops at Kano (lb per acre)*

Crop	Component	N	K	L	T	S.E.	Control yields
Maize, 1968	Grain	+834	+490	+23	−15	±140	225
	Total D.M.	+2960	+1452	+54	−186	±430	617
Maize, 1969	Grain	+999	+112	+114	−204	±111	131
	Total D.M.	+6310	+1334	+1304	+593	±493	1885
Sorghum, 1969	Grain	+792	+689	+247	−508	±162	737
	Total D.M.	+3725	+4147	+1493	−2587	±907	4590

N.B. The sorghum crop was destroyed by insects in 1968

Table 3. *Effects of treatments on the yield components of experimental crops at Samaru (lb per acre)*

Crop	Component	N	K	L	T	S.E.	Control yields
Maize, 1968	Grain	+248	+69	+51	−430	±77	1158
	Total D.M.	+1796	+457	+136	+332	±262	6891
Sorghum, 1968	Grain	+223	+258	+102	−46	±68	2113
	Total D.M.	+1590	+1024	+756	−20	±342	13668
Groundnuts, 1969	Kernels	−109	−97	−33	−17	±55	1413
	Total D.M.	−545	+183	+207	−269	±113	4774
Cotton, 1969	Seed cotton	+41	−1	−66	+217	±60	1341
	Total D.M.	+1723	+215	+89	−205	±108	3116

Table 4. *Effects of treatments on yield components of experimental crops at Mokwa (lb per acre)*

Crop	Component	N	K	L	T	S.E.	Control yields
Maize, 1968	Grain	+859	+276	+82	+220	±110	1929
	Total D.M.	+2545	+958	+202	+250	±209	5355
Sorghum, 1968	Grain	+244	−88	+156	+64	±118	1192
	Total D.M.	+2928	+1277	+364	+784	±832	19322
Maize, 1969	Grain	+1033	+381	+94	+30	±85	1334
	Total D.M.	+2010	+1572	−330	+147	±313	6706
Sorghum, 1969	Grain	−209	+135	+60	−51	±72	1398
	Total D.M.	+476	+3064	+486	+425	±645	15204

in the case of seed cotton was, however, due primarily to greater insect attack where this treatment was applied, while the large increase in total dry matter production may have been due in part to the physiological reaction of the crop to loss of fruiting points from this cause.

Potassium

The application of potassium gave significant increases in grain yield in five of the nine trials carried out on cereals, while total dry matter production was

increased in seven cases. This result is almost totally at variance with previous experience in the savanna areas of Nigeria and elsewhere in tropical Africa (Russell, 1968), although the possibility of incipient potassium deficiency was mentioned in Part I of this paper (Heathcote, 1970). The following points should be borne in mind in considering the discrepancy between the results outlined above and those of earlier trials in northern Nigeria.

The soils of the region are generally of low inherent fertility. The data for the three experimental sites (Table 1) show that the values of such criteria of fertility as organic carbon, nitrogen and cation exchange capacity are well below those that would be considered optimal elsewhere. Early fertilizer trials reflected these characteristics in a number of ways. In the first place, unimproved local varieties were often used, i.e. varieties well adapted to the conditions of low fertility in which they are normally grown, and with relatively low nutrient requirements. Secondly, the ability of the soil to buffer itself against an imbalance of cations brought about by heavy fertilizer applications may be limited; in the early trials, fertilizers were added at rates which would be considered low elsewhere, but which would not seriously upset this balance. The likelihood of potassium response may have been further reduced by the use of sulphate of ammonia in such trials, since Bache and Heathcote (1969) found that one effect of this fertilizer at Samaru was to reduce the levels of exchangeable calcium and magnesium in the soil, while hardly affecting that of potassium.

In the trials described in this paper, improved varieties of higher yield potential, suitable for each site concerned, were used whenever possible. Rates of fertilizer application were relatively high, and additions of calcium in particular were much greater than in the earlier trials, especially where calcium ammonium nitrate (Nitrochalk) and lime were added. There is some evidence, discussed below, that lime in particular may induce or aggravate potassium deficiency.

In addition, the soil's capacity to provide potassium may be inadequate under unfavourable climatic conditions, and the effect of potassium in raising sorghum grain yields at Samaru in 1968 may have been a result of the exceptionally early end of the rains in that year. This effect was not repeated in a trial on sorghum on an adjacent site in the following year, 1969, in which the rains were prolonged beyond the normal limit.

Lime

The total effect of lime was very small, with significant main effects in only two trials, in each case affecting only total dry matter production. A response to lime would not be expected from the crops grown, at the pH values of the experimental sites. Interactions between lime and other treatments are discussed below.

Trace elements

Responses to trace element applications occurred only at Samaru, where yields of seed cotton and maize grain were significantly increased. There was a small increase in the total dry matter of groundnuts, but sorghum yields were unaffected.

The depression in sorghum yields at Kano in 1969 was probably the result of spray damage on the young crop.

As discussed in Part I of this paper, there is considerable evidence that molybdenum deficiency is a major factor involved in these effects. In 1969, however, symptoms of boron deficiency were noted on cotton not receiving the trace element treatment, and it may be that both elements were simultaneously deficient.

Interactions of nitrogen and potassium

In trials where each treatment gave a significant main effect, the response to either was in most cases greater in the presence of the other, but this apparent interaction was only statistically significant in about half of the trials concerned.

Potassium and lime

Significant and positive interactions between these treatments occurred in four of the five trials on cereals at Kano and Samaru, and on the one cotton trial at Samaru. The effect of lime was generally to depress yields in the absence of potassium but to raise them in its presence, while any response to potassium was increased by the addition of lime (e.g. two examples in Table 5).

Table 5. *Interactions between potassium and lime treatments on trials at Kano and Samaru (lb per acre)*

	Sorghum grain, Kano 1969			Seed cotton, Samaru 1969	
	K_0	K_1		K_0	K_1
L_0	1155	1741	L_0	1450	1292
L_1	1061	2482	L_1	1359	1514
	S.E. ± 325			S.E. ± 85	

N.B. Data for Kano refer only to plots receiving Nitrochalk.

Lime and trace elements

Only one interaction between these treatments occurred, on maize grain at Samaru in 1968. The interaction (Table 6) was negative, providing further evidence that molybdenum deficiency is one factor involved in the response to trace element application.

Table 6. *Interactions between lime and trace elements on the yield of maize grain at Samaru in 1968 (lb per acre)*

	T_0	T_1	
L_0	1581	2253	
L_1	1876	2062	S.E. ± 108

DISCUSSION

In Part I of this paper it was concluded that, in the short term, the effectiveness of organic manure was due chiefly to its provision of plant nutrients. It was, however, emphasized that further long-term trials would be required to determine whether fertility could be maintained indefinitely through the use of fertilizers alone. It

should therefore be borne in mind that the trials reported in the present paper represent merely the initial results of what must necessarily be a long-term investigation. The results obtained to date, however, if generally applicable to the soils and climatic regions represented by the three experimental sites, indicate that accepted views on soil fertility and fertilizer usage, especially with regard to potassium, may have to be drastically altered in the light of changing farming practice. In this context, the increasing use of improved, high-yielding crop varieties has been particularly emphasized. It should, however, be borne in mind that other potential changes in farming practice—e.g. improved methods of cultivation, higher plant populations, and better control of pests and diseases—may also influence the rates and forms of fertilizer applications required for optimal yields in the future.

These trials were designed to determine only whether or not the factors tested were likely to be important in maintaining fertility, and provide no information on optimal rates of application where this has been shown to be the case. Nitrogen and potassium have given the largest and most consistent responses, and more detailed investigations on these would be justified. It is true that many trials involving nitrogen have already been carried out in northern Nigeria (Goldsworthy and Heathcote, 1963; Goldsworthy, 1967a and b), but these have been annual trials only and provide no information on long-term nitrogen requirements under continuous cultivation.

Responses to lime have been small and inconsistent, and it is doubtful whether more detailed investigations are justified on the present evidence. Trace element responses have been restricted to only one experimental site, but practical difficulties have been encountered in the application of this treatment, and in one case crop damage has resulted. The use of a 'fortified' superphosphate would be preferred in future years if and when a suitable product is available.

It is a valid criticism that these trials have been carried out at only three centres in so large an area as the northern states of Nigeria. However, the results obtained from even so limited a series should provide a useful guide to the design of further trials on the subject at other sites in the future.

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