Contribution to the agropedological knowledge of the solonetzic Tropical Grey Earths of the Accra plains, Ghana

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Summary

Some 200 square miles of tropical grey earths cover the gently undulating Accra plains in the south eastern corner of Ghana and another 125 miles of similar soils occur on the Ho-Keta plains east of the river Volta. The soils show a solonetzic profile morphology and have a limited water storage capacity. Thus during the rains they tend to be waterlogged and in the dry season desiccation is severe.
The annual rainfall varies between 25 and 45 inches distributed in a double peaked pattern. May and June are the wettest months and a less developed maximum occurs in October. The grey earths carry a short grass community with scrubs growing on randomly distributed termite mounds. The soils are not cultivated but they provide the major grazing areas on the Accra plains.
Agricultural development is subject foremost to applications of nitrogenous and phosphatic fertilizers the choice of which is determined solely by the cost per applied unit of N and P_2O_5. Considerable improvement of the stock carrying capacity of the grasslands may be expected from annual applications of artificials. The production of arable crops with a growing period of 3 to 4 months holds promise.

1. Side details

The Accra plains form a triangle bounded by the Akwapim scarp in the north-west, the Guinea coast in the south and the lower part of the Volta river in the east. With the exception of Akwapimian outliers in the western part and a number of inselbergs and isolated hills in the north-east the plains lie below the 250 ft contour.
A review of weather and climate in Ghana has been given by WALKER (1957). Total annual rainfall on the Accra plains increases from Accra eastward and varies between 25 and 45 inches. The wettest months are May and June when more than half of the yearly total may fall. A second less developed maximum occurs in October. Though July and August are relatively dry the weather is dull with much overcast. In the driest month January total rainfall is generally less than one inch.
The vegetation of the Accra plains has been described by TAYLOR (1952) as "The coastal scrub and grassland zone". The grey earths carry grasses growing to a height of 2 ft. The basal cover seldom exceeds 25 %. A scrub vegetation flourishes on randomly distributed termitaria that are relatively well drained. The soils are not cultivated and sparsely populated. Cattle grazing is practised on an open range in herds of 100 heads or more and at a density of approximately one animal per 30 acres. Grass fires are of regular occurrence during the dry season.

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Information on the geology of the Accra plains has been supplied by KITSON (1928) and by JUNNER and BATES (1945). BRUECKNER (1955, 1956 a, b) has offered an acceptable explanation for the occurrence of a stone line and fragments of laterite in the grey earths. Postulated were three climatic cycles covering the pleistocene. These were correlated with the pluvials and interpluvials of Mortelmans (BRAMMER, 1958) in Central Africa and also with the glacials and interglacials of the Northern Hemisphere. During each cycle an arid period resulted in a desert pavement of coarse material (stone line) through physical desintegration and the wind and water removal of finer grained particles. In a subsequent warm and humid period the stone line and underlying formations were affected by intense chemical weathering proceeding downward while at the same time, resulting from the activity of soil fauna (primarily termites) the stone line became buried under a layer of earth. A final semi-arid period in each cycle lead to the complete or partial removal of earth and stone line by erosion, which process was counteracted simultaneously by the cementation of these layers through impregnation of predominantly ironoxides (laterite formation).
A reconnaissance soil survey of the Accra plains has been carried out by BRAMMER (1958). Details of the tropical grey earths recognized as solonetz soils, have been given by BRAMMER and DE ENDREDY (1956), by STEPHENS (1953) and by the author (HAGENZIEKER, 1957). On the Accra plains the grey earths cover some 200 square miles. Another 125 square miles of similar soils occur on the Ho-Keta plains east of the river Volta.

2. Experimental methods

Soil fertility has been studied exclusively by means of field experiments. These were conducted from 1953 until 1957 on the Agricultural Research Station Nungua in the south-west corner of the Accra plains.
In all experiments plant numbers were kept constant. Thus covariance analyses of plant numbers with treatments have not been necessary.
Tests of significance have been carried out by means of variance ratios and t tests. Effects and F ratios which lie between the calculated and tabular values corresponding with 5 and 1 % levels of probability are indicated by a single asterisk. Similarly those exceeding values corresponding with P : 0,01 are designated by two asterisks. Subscript numbers are used to denote the degrees of freedom associated with standard errors (S) and variance ratios (F). Thus F 15/30 indicates a variance ratio with numerator and denominator associated with respectively 15 and 30 degrees of freedom.
In lattice square designs the effective error variance adjusted for row and column effects, has been compared with the treatment variance computed from the sum of squares of treatment totals that were also adjusted for row and column effects. This results in an approximate but fairly reliable F value (COCHRAN and COX, 1950).
Response curves that are statistically accounted for may be evaluated by means of polynomial and multiple regression equations. In view of the variability between results of identical treatments in different experiments and the relatively sparse numbers of observations graphs drawn from such equations are not considered of greater value than the presented free hand curves.

3. *Description of the tropical grey earths*

The grey earths are associated with and overlie acid gneisses and shists of the

Dahomeyan series. Muscovite and biotite are of common occurrence and of the feldspars plagioclase is dominant.

Invariably soil profiles differ considerably even if not more than yards apart. In the fully developed profile more or less weathered rock is overlain by sandy clay on top of which rests loose quartz sand. Embedded in the base of the sandy clay is a stone line of iron stained subangular quartz gravel, laterite fragments and iron pisoliths. Generally the lower boundary of the stone line is even whereas the upper boundary shows an irregular wavy pattern. Thus in profile pits the stone line may show a thickness varying between a few inches and some 6-feet.

The surface 3 inches of the sand is coloured dark grey by organic matter. Below, to a depth of 6 to 8 inches the colour is brownish grey when there is a gradual change to the buff grey of the non humic sand. Humus stains the top few inches of the yellowish grey sandy clay horizon to a brownish grey.

The sandy clay horizon is sharply defined. Upon drying the hard and compact upper layer cracks into prismatic blocks of approximately 6 inch in diameter and one foot in depth. Superficial humus staining may extend along the tops and sides of the prisms. When wetted the hard pan becomes cloddy and plastic. Further down the sandy clay dries out less hard and is more plastic when wet. On exposure to air the material oxidizes to a red hue.

Iron mottling may be observed in the lower 6 inches of the sand and to a similar depth in the toplayer of the sandy clay. Invariably root channels are iron stained.

Development of the sand and sandy clay horizons is associated with the gently undulating topography. Slopes are generally less than 2 %.

In the upper slope members of the grey earth catena the sand may reach a thickness of 3 to 4 feet, whereas the sandy clay horizon is weakly developed or absent. Down slope the sand horizon becomes thinner while simultaneously the sandy clay increases more rapidly in depth. Near the valley bottom the thickness of the sand horizon is no more than a few inches and the sandy clay reaches down to 12 feet or more before hitting rock. The stone line appears less developed in the lower members of the catena.

No concretions are found in the sand. Halfway down slope hard dolomitic and partly silicified carbonate concretions appear in the sandy clay. Further towards the valley bottom these increase in number and size, up to a maximum diameter of 2 inches. In localized spots the concretions may constitute more than 50 % of the solum. Throughout the sandy clay there occur small and soft concretions of iron and manganese oxides and hard grains of goethite.

The sandy clay is impervious. Excessive rain saturates the sand resulting in early run off and lateral drainage immediately above the sandy clay horizon. More prolonged lateral movement of water takes place through the stone line. The sand is subject to severe water erosion.

The profile morphology indicating highly dispersible clay and humus suggests the presence of substantial amounts of sodium. This conclusion is confirmed by the results of soil analyses.

The clay content of the sand is usually much less than 10 %, contrasting sharply with the sandy clay that shows values around 30 %. The silt content of some 5 % remains fairly constant throughout the profile as are the approximately equal percentages of fine and coarse sand.

The exchange capacity of the clay varies between 50 and 70 m.eq/100 g. Capacities in the sand horizon are lower than 10 m.eq/100 g and in the sandy clay horizon

these vary between 15 and 20 m.eq/100 g. Humus contributes but little to the exchange capacities. Maximum contents of up to 1,5 % and 1,0 % are found respectively in the humic top soil and in the upper layer of the hard pan. Ca and Mg constitute more than 80 % of all metals adsorbed. Ca/Mg ratios fluctuate from unity to 2,5. K contents are about 5 % and one % of all bases adsorbed in respectively the sand and the sandy clay. The Na content of the sand is low but increases rapidly to between 10 and 15 % of the exchange capacity in the upper layers of the hard pan. Further down in the sandy clay horizon this value increases to a maximum of 30 %. The occurrence of sodium salts, predominantly chlorides, is confined to the more plastic layers of the sandy clay, below the upper hard pan.
Soil reactions in the sand horizon and in the hard pan layer fluctuate around pH : 6,0. Further down in the sandy clay the pH rises to a maximum of 8,5 due to the presence of bicarbonates.
C/N ratios are highest in the humic top soil : to maximum values between 15 and 20. The ratio decreases to below 10 with depth, sometimes reaching a second maximum in the upper part of the humic stained hard pan. Contents of total P seldom exceed 100 p.p.m. and usually are considerably lower.
The presence of sodium is satisfactorily explained by the occurrence of plagioclase in the parent rock. Chlorides are thought to be derived from fossil seawater held in the rocks since Tertiary and Quarternary marine invasions.

4. Soil fertility in general

Early observations on simple trials indicated positive responses to be expected from applications of nitrogenous and phosphatic fertilizers. These indications were confirmed by the results of more elaborate experiments two sets of which are reproduced in TABLES 1 and 2. Both experiments were conducted on land that had not been cropped previously. One month before planting the grass sod was ploughed under. Single superphosphate was broadcast shortly before planting and disced in. Sulphate of ammonia and sulphate of potash were applied as top dressings. As even tobacco known for its high potash demands, did not respond to applications of sulphate of potash it appears unlikely that the soil supply of potash is inadequate for initial optimum production.
The extreme phosphate deficiency was demonstrated dramatically in the experiment on sorghum. No responses were obtained from sulphate of ammonia in the absence of superphosphate. Identical to the "nil" treatment when both fertilizers were absent plants failed to grow taller than 6 inches and showed severe P deficiency symptoms.
Dressings of superphosphate in the absence of sulphate of ammonia resulted in fully developed plants showing N deficiency symptoms that yielded proportional to the rates of application. Highest yields were recorded if both sulphate of ammonia and superphosphate were applied.
Similar responses obtained to applications of urea, triple superphosphate and other sulphate free nitrogenous and phosphatic fertilizers render the hypothesis of sulphur deficiency unlikely. The absence of responses to foliar and soil applications of ammonium molybdate, borax and the sulphates of iron, magnesium, manganese and zinc make the prevalence of other than acute nitrogen and phosphate shortages equally improbable.
The natural grasslands also respond to dressings of nitrogenous and phosphatic fertilizers. Results of a factorial experiment testing the absence and presence of sulphate of ammonia and single superphosphate each applied at a rate of 2 cwts per acre

TABLE 1. Effects on tobacco of sulphate of ammonia (SA), single superphosphate (SS) and sulphate of potash (SP). Yields of flue cured leaf in lbs per acre

	Rates of application in cwts per acre						
SA	SP			Mean	SS		
	Nil	0,5	1,5		0,5	1,0	2,0
0,5	665	679	672	672	599	607	810
1,0	793	782	789	788	723	853	789
2,0	987	924	936	949	847	967	1031
Mean	815	795	799		723	809	877
SS							
0,5	715	721	733	723			
1,0	823	806	797	809			
2,0	907	857	867	877			

		l.s.d.		F2/6	F4/6
	S6	P 0,01	P 0,05	N : 17,74**	NP : 1,36
Body of tables	57	301	198	P : 5,46**	NK : 0,01
Means	33	174	115	K : 0,10	PK : 0,01
				NPK: confounded	

TABLE 2. Effects on sorghum of sulphate of ammonia (SA), single superphosphate (SS) and sulphate of potash (SP). Yields of grain in lbs per acre

	Rates of application in cwts per acre				
SA	SS				
	Nil	0,7	1,4	2,8	Mean
Nil	nil	540	700	870	527
0,5	nil	690	1190	1290	792
1,0	nil	760	1270	1590	905
2,0	nil	920	1170	1870	990
Mean	nil	727	1082	1405	

		l.s.d.		F3/30	F9/30
	S30	P 0,01	P 0,05	N : 28,02**	NP : 6,54**
Body of table	76	300	220	P : 251,05**	
Means	38	150	110		

are presented in TABLE 3. The experiment also incorporated the absence and presence of a discing treatment, meant to increase the efficiency of the superphosphate dressing.

Contrary to results obtained with arable crops positive responses to dressings of sulphate of ammonia in the absence of superphosphate were recorded. However, combined with an application of superphosphate responses were significantly higher. Discing did not result in the anticipated effect. Responses to sulphate of ammonia lasted longer than to superphosphate but this result may not be generalized nor can a reliable statement be made about the time interval between dates of application and the last cut showing responses. In other experiments effects lasted from 30 to 64 weeks after the dates that the fertilizers were applied.

4.1. Nitrogen

Residual responses to dressings of nitrogenous fertilizers in the previous year proved negligibly small though consistent and proportional to rates of application. This is illustrated by the results of an experiment on millet (*Pennisetum typhoides*), repro-

TABLE 3. Effects on grass of sulphate of ammonia (N), single superphosphate (P) and discing (H) at the time of fertilizer application. Yields of green grass in cwts per acre

Factorial effects	Number of cut				Combined effects of cuts 1, 2 & 3
	1	2	3	4	
	Numbers of weeks between dates that fertilizers were applied and cuts were made				
	8	25	56	76	
N	22**	8**	5*	nil	35**
P	9**	2*	1	nil	12**
H	-4*	nil	1	1	-2
NP	7**	1	nil	-1	8
NH	1	-1	-1	-2	4
PH	1	-1	-3**	nil	-3
NPH	-1	nil	nil	1	-1
Mean	29	14	24	16	67
S21	1,7	0,7	1,2	1,2	2,1

Combined treament effects of cuts 1, 2 and 3		
(1)	45	—
n	75	30**
p	51	6
h	49	4
np	99	54**
nh	74	29**
ph	50	5
nph	89	44**

S21 : 30

l.s.d.	
P 0,01	P 0,05
12	9

duced in TABLE 4. Basal dressings of triple superphosphate at rates of 3 cwts per acre were given in the year that sulphate of ammonia was applied and in the succeeding season.

Nitrogen losses caused by leaching and lateral drainage may be expected in the upper slope members of the grey earth catena that have a well developed sand horizon. Consequently responses to seed bed applications of nitrogenous fertilizers are smaller than to top dressings as may be seen from the results of an experiment on millet that are presented in TABLE 5. A basal dressing of triple superphosphate was applied at a rate of 3 cwts per acre.

In down slope members of the grey earth catena that have an ill developed sand horizon and where leaching and lateral drainage is limited differences in responses to seedbed applications and topdressings of nitrogenous fertilizers are unlikely. Results of an experiment on millet, reproduced in TABLE 6 confirm the expectations. Triple superphosphate was applied as a basal dressing at a rate of 3 cwts per acre.

TABLE 4. Residual responses to applications of sulphate of amonia (SA) applied in the previous year. Yields of green millet in cwts per acre

Rates of SA in cwts per acre			
Nil	0,5	1,5	2,5
88	96	103	116

	l.s.d.		
S36 : 7,0	P 0,01	P 0,05	F6/36 : 1,68
	27	20	

TABLE 5. Effects on millet of seed bed applications and topdressings of sulphate of ammonia (SA). Yields of green millet in cwts per acre

Time of application	Rates of SA in cwts per acre				
	Nil	0,5	1,5	2,5	Mean
Seed bed	55	80	138	155	124
Topdressed		77	154	187	139
Mean	55	79	149	171	

	S36	l.s.d. P 0,01	l.s.d. P 0,05	F6/36 : 74,13**
Body of table	5,8	21	16	
Means	4,1	15	11	
	3,3	12	9	

TABLE 6. Effects on millet of seed bed applications and topdressings of sulphate of ammonia (SA). Yields of green millet in cwts per acre

Time of application (T)	Rates of SA in cwts per acre (N)			
	1,5	3,0	4,5	Mean
Seed bed	194	208	282	228
Topdressed	175	225	285	228
Mean	184	217	283	

	S55	l.s.d. P 0,01	l.s.d. P 0,05	
				T — F1/55 : < 0,01
				N — F2/55 : 31,55**
Body of table	12,7	47	35	NT — F2/55 : 1,01
Means	10,4	38	29	
	9,0	33	25	

4.2. Phosphorus

The effects on virgin land of alternative phosphatic fertilizers were compared with those of single superphosphate. The testcrop millet received a basal topdressing of sulphate of ammonia at a rate of 6 cwts per acre. In each replication 4 "nil" plots received no phosphate fertilizers in the first season. The experiment was planted to millet in the following year to compare residual effects of the phosphatic materials with current dressings of superphosphate that were applied to 3 of the 4 "nil" plots of the previous season. Again a basal dressing of sulphate of ammonia at a rate of 6 cwts per acre was given. Results are shown in FIG. 1 and further relevant detail is reproduced in TABLE 7.

TABLE 7. Statistics relevant to data of FIG. 1. Standard errors, confidence limits and least significant differences in cwts of green millet per acre

First year

F15/30 : 79,55**

	S30
a Phosphate absent	7,0
b „ present	14,1

	P 0,01	P 0,05
c.l. a	19	14
b	39	29
l.s.d. a	55	41
a—b	43	32

Second year

F15/30 : 28,97**
S30 : 13,8

	P 0,01	P 0,05
c.l.	38	28
l.s.d.	54	40

Current and residual responses of the same magnitude were obtained from applications of all phosphatic materials tested. Apparently the chemical form of phosphate in the fertilizer is of no consequence to its effect. Optimum rates of application appeared to be in the order of 0,8 to 1,0 cwt of P_2O_5 per acre. Residual effects expressed in P_2O_5 equivalents to current responses are presented in TABLE 8. The data are interpolated from the curves of FIG. 1.

FIGURE 1

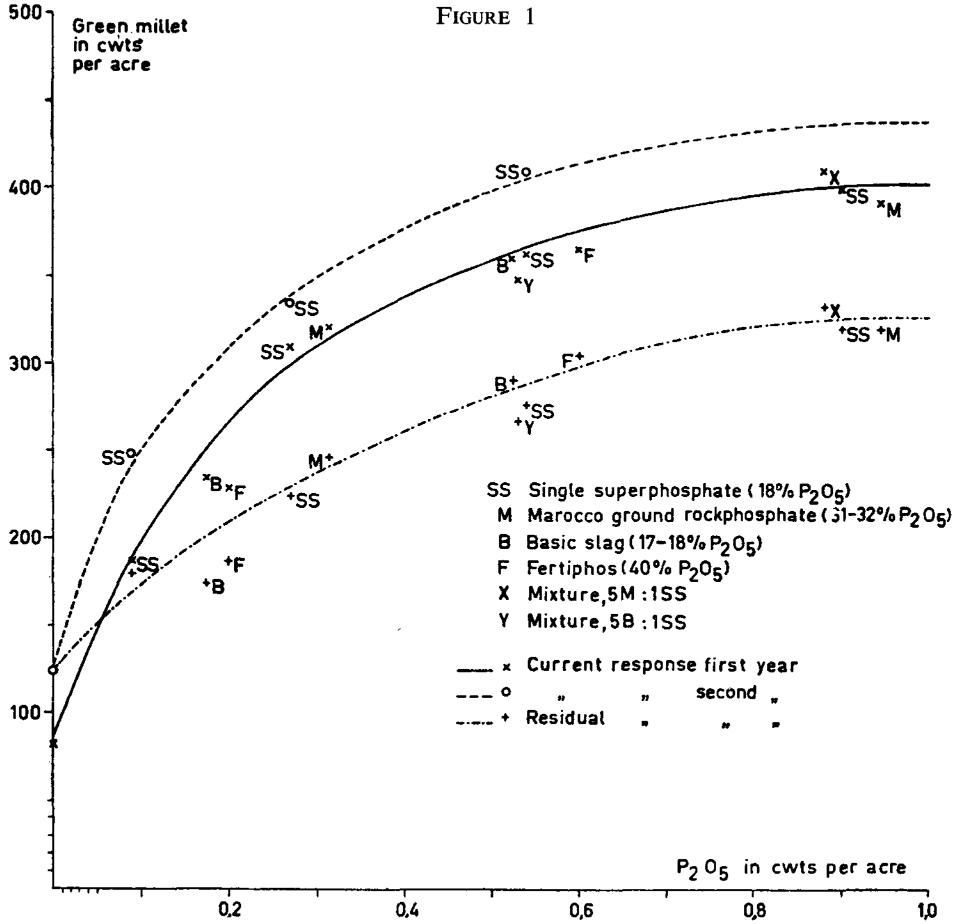

TABLE 8. First year residual effects to applications of phosphatic fertilizers expressed in P_2O_5 equivalents to current responses

a	0,2	0,4	0,6	0,8	1,0
b	0,05	0,11	0,18	0,23	0,23

a. Rates of P_2O_5 applied in the preceeding year.
b. Rates of P_2O_5 applied in the current year associated with yields of equal magnitude resulting from residual effects of corresponding rates of P_2O_5 in the previous year.

Optimum dressings yielded residual effects that were of the order of one quarter of the current response in the succeeding year. At sub-obtimal rates of application residual effects were proportionally smaller.

Removal of phosphates by a crop grown in the previous season does not appear to have a substantial effect on residual responses to phosphatic fertilizers. This is illustrated by the results of an experiment on millet that are depicted in FIG. 2 and of

which relevant detail is given in TABLE 9. In each replication rates of single superphosphate were applied in a double set of plots of which one was cropped to millet and the other was left bare fallow. A third set of plots also left bare fallow did not receive superphosphate. In the following year the whole experiment was planted to millet. Superphosphate was applied only to the "nil" plots of the previous year. In both seasons the crop received a basal dressing of sulphate of ammonia at a rate of 6 cwts per acre.
The curve for residual effects shows the combined response of fallowed and cropped in the previous year. Both curves have been extended by broken lines to presumed optimum responses at 0,8 to 1,0 cwt of P_2O_5 per acre. Owing to the steepness of the response curve for current effects in the section that corresponds with the lowest

FIGURE 2

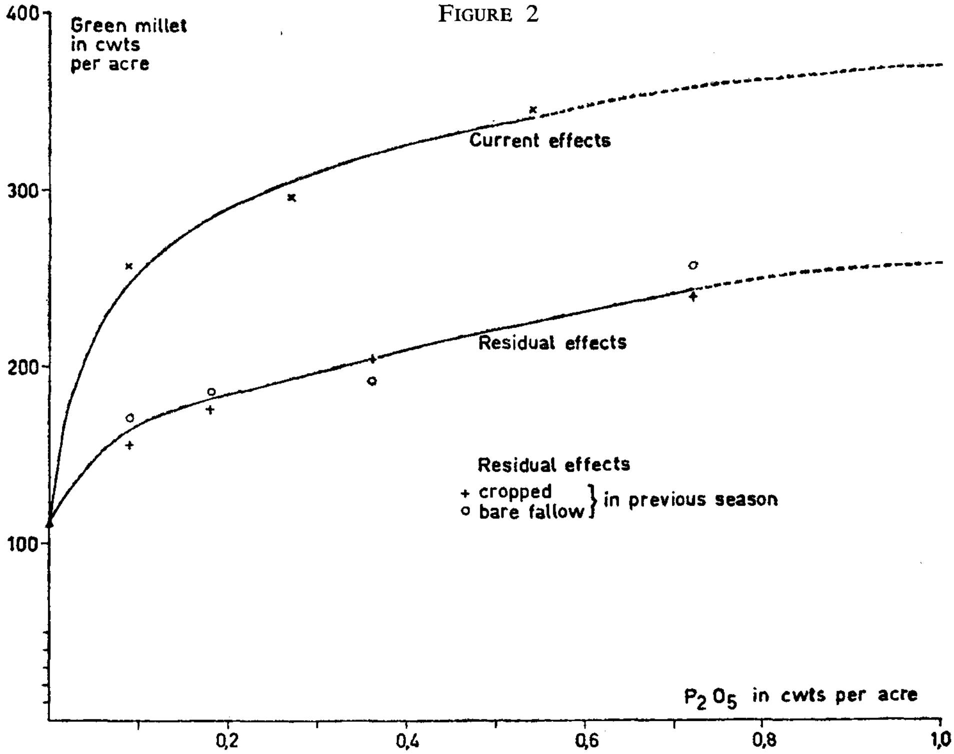

TABLE 9. Statistics relevant to data of FIG. 2. Standard error, confidence limits and least significant differences in cwts of green millet per acre

S33 : 15,2			F11/33 : 18,46**
	P 0,01	P 0,05	
c.l.	41	21	
l.s.d.	59	30	

application rates of superphosphate, residual effects expressed in fertilizer equivalents to current responses were only of the order of half those shown in TABLE 8.
Three methods of application of superphosphate were compared in an experiment on millet:

I : broadcast and ploughed under;
II : drilled with seed;
III: spaced 12 inches below the seedrow.

Sulphate of ammonia was applied as a basal dressing at a rate of 6 cwts per acre. Results are presented in TABLE 10. No significant differences were found between the application techniques. In general slightly bigger responses were obtained from broadcast than from placement in the seedrow and from subsoil drilling.

TABLE 10. Effects on millet of application methods and rates of single superphosphate (SS). Yields of green millet in cwts per acre

Method of application	Rates of SS in cwts per acre				Mean
	Nil	1	2	3	
I	40	106	145	194	148
II		125	116	172	138
III		113	142	159	138
Mean	40	115	134	175	

	S27	l.s.d. P 0,01	l.s.d. P 0,05	F9/27 : 15,82**
Body of table	10,7	42	24	
Mean	6,2	31	18	

4.3. Rates of application

Application rates of fertilizers required for optimum production are subject to rainfall and climatic conditions. These vary considerably from year to year and are quite unpredictable. As besides the grey earths are a group of soils of rather heterogeneous profile morphology only general statements can be made. Of course requirements differ also with the type of crop.
For non irrigated arable production annual phosphate requirements are unlikely to exceed the equivalent of 1,0 cwt of P_2O_5 per acre in combination with optimum dressings of nitrogenous fertilizers. The latter fluctuate around the equivalent of 1,25 cwt of N per acre yearly for the production of maize and millet fodder.
In the case of maize and sorghum grain optimum requirements are lower; some 0,8 cwt of N per acre. This equally concerns the production of tobacco when nitrogen supply is a dominant factor controlling quality. Annual phosphate requirements of the natural grassland would appear to be no more than the equivalent of 0,5 cwt of P_2O_5 per acre again combined with optimum rates of application of nitrogenous fertilizers equivalent to 1,25 cwt of N per acre.

5. Conclusions

The hypothesis that the short grass formation covering the grey earths is man made must be rejected. The floristic composition of this formation may undergo changes when fire and grazing are checked but the physiognomic appearance is not expected to alter. Equally, insufficient rainfall is not a factor preventing crop production. Any form of agricultural development on the grey earths is subject foremost to applications of nitrogenous and phosphatic fertilizers. The choice of these materials is decided only by the cost per applied unit of N and P_2O_5.

Improvement of the stock carrying capacity of the natural grassland is a primary objective. Dressings of nitrogenous fertilizers though resulting in positive responses when applied singularly are more effective when combined with applications of phosphatic fertilizers. Through annual dressings the acre yield of rainfed grass may be raised from 75 to 200 cwts. Higher yields still are to be expected under irrigation when fertilizer requirements will also be higher.

The construction of small dams to impound drinking water for cattle is essential. Fodder crops may be grown during the rains to provide silage for supplementary feeding in the dry season. Millet (*Pennisetum typhoides*) yields of 20 tons of green matter per acre are quite common.

Arable production requires a rigid system of soil erosion control combined with adequate drainage. "Broadlands" developed by HILL have proved effective. These cambered beds follow the contour and are constructed to convenient widths of 24 to 36 feet by up and down slope ploughing from an open drainage furrow.

Excellent yields may be harvested from rainfed crops with a growing period of 3 to 4 months, when N and P deficiencies have been corrected. No responses to nitrogenous fertilizers are obtained in the absence of an application of phosphatic materials.

Grain yields of maize and sorghum exceeding one ton per acre are no exception and correspondingly high yields have been obtained from groundnuts and soya beans. Tobacco is a promising and most rewarding cash crop.

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REFERENCES

BRAMMER, H. 1958 Report on the Reconnaissance Soil Survey of the Accra Plains. Report Ghana Dept. Soil and Land Use Survey.

BRAMMER, H., and A. S. DE ENDREDY 1956 The tropical Grey Earths of the Accra Plains, Gold Coast. Paper submitted to *Int. Congr. Soil Sc. - Paris, 1956.*

BRUECKNER, W. 1955 The Mantle Rock (Laterite) of the Gold Coast and its Origin. *Geol. Rundschau.* Bd 43, Heft 2, 307—327.

—— 1956a On Structural Irregularities in the Mantle Rock of the Gold Coast. *Journ. W. Afric. Sc. Assoc. 2,* 1 : 87—97.

—— 1956b Laterite and Bauxite Profiles of West Africa as an Index of Rhythmical Climatic Variations in the Tropical Belt. Paper Submitted to *Int. Geol. Congr. - Mexico City, 1956.*

COCHRAN, W. G., and GERTRUDE M. COX 1950 Experimental Designs.

HAGENZIEKER, F. 1957 A Contribution to the Agropedological knowledge of two soils of the Accra Plains. Report Univ. College of Ghana, Faculty of Agric.

JUNNER, N. R., and D. A. BATES 1945 Reports on the Geology and Hydrology of the Coastal area East of the Akwapim Range. Gold Coast Geol. Survey Dept., Memoir No. 7.

KITSON, SIR A. E. 1928 Provisional Geological Map of the Gold Coast and Western Togoland. Gold Coast Geol. Survey Dept., Bull. No. 2.

STEPHENS, I. 1953 A Petrographic study of a tropical Black Earth and Grey Earth from the Gold Coast. *Journ. Soil Sc. 4,* 2: 211—219.

TAYLOR, C. J. 1952 The Vegetation zones of the Gold Coast. Gold Coast Forestry Dept., Bull. No. 4.

WALKER, H. O. 1957 Weather and Climate of Ghana. Ghana Met. Dept., Note No. 4.