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Gypsum application to improve soil-water relationship in poorly drained soils of the Chemelil sugar zone

by

R.A.Leyder

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M I N I S T R Y   O F   A G R I C U L T U R E

N A T I O N A L   A G R I C U L T U R A L   L A B O R A T O R I E S

REPORT ON LABORATORY INVESTIGATIONS IN RELATION TO THE USE OF GYPSUM TO IMPROVE THE SOIL-WATER RELATIONSHIPS IN THE POORLY DRAINED SOILS OF THE CHEMILIL SUGAR ZONE.

(re-edited 1978)

R.A.Leyder
Nairobi, July 1969

I. Introduction.

The investigations were started as a result of a meeting held at the provincial headquarters in Kisumu on 20th February 1967.
The meeting had been convened to discuss the urgent problems in the sugarcane area of the Chemilil outgrowers, where cane was badly droughting following the failure of the short rains 1966.

During the meeting the Senior Sugar Officer, Mr C.Hill, stressed that droughting was most severe on the dark swelling clay soils of the Luo Land Unit, in which the soil-water relationships were notoriously poor. Lack of internal and external drainage created waterlogged conditions under which the cane roots could not develop. In addition, lack of water penetration limited effective water storage, resulting in an insufficient moisture reserve to carry the crop through drought periods such as the prevailing one.
Based on the results of field experiments, carried out in the past on similar soils of the Miwani and Muhuroni estates, the Senior Sugar Officer recommended the application of 2 tons of gypsum per acre which, he was sure, would improve the internal water relationships in these soils, since part of the unfavourable characteristics was due to soil dispersion, caused by high sodium levels.

A report of a preliminary investigation by Mr S.N.Muturi and the author was presented at the meeting. During the investigation several soil pits in contrasting sites with respect to crop performance had been examined, and samples had been taken for chemical analysis. The outcome of the analyses seemed to suggest that droughting was associated with rel. higher levels of exchangeable sodium in the soil. The levels as such however, did not appear particularly high in view of the experience on sodium affected soils elsewhere in the world.
It was then decided to carry out more investigations on this matter, before drawing any further conclusions.

An extensive soil sampling of the outgrower area was carried out by Mr W.Wapakala and the author in April/may 1967. Observations were made as far as the auger procedure used allowed for. The field observations agreed very well with those of the Songhor report (1). The results of analysis showed that the exchangeable sodium percentages (ESP) were generally in the order of 3 to 7.5 and only a few exceeding 10.
On these samples and on samples subsequently sent by the Senior Sugar Officer, which were taken from outgrower's blocks to be planted in 1968, further investigations described in this report, were carried out.
The aim of these investigations was: a) to find in the laboratory a confirmation of the beneficial effect of gypsum application and b) to work out

The swelling and shrinking characteristics of the soil are caused by the predominance of montmorillonite type minerals in the clay fraction.
The exchangeable sodium level in the soil increases with depth, although levels of more than 8 are rarely found.
In the Luo Land Unit a pale yellowish-brown structureless layer is frequently encountered at a depth of 4 feet or below. This layer with a thicknes of only a few inches is of volcanic origin (X-ray amorphous) and hardly differs chemically from the over- and underlying clay. Physically there is a difference in that its water transmitting properties are reasonable to good.

The drainage measures as practiced in the Chemilil outgrower's zone is designed to lead the surface water off in order to prevent erosion.. The drains are very wide and shallow and surround the sugarcane cooperative blocks.
There are several examples to be given to demonstrate that such surface drainage alone is not sufficient. One example is a part in the Ang'ogo block which unit as a whole suffers from bad drainage as well, but the condition of the sugarcane is particularly bad at the foot of the (faint) slope which runs roughly parallel to the main road to Kisumu. Examination of the soil profile during the wet season revealed that at about 2 feet, the soil was impervious and that water had accumulated above this depth, causing waterlogging in the relatively free draining topsoil. It could easily be seen that most of this water had come down laterally from the slope. This adverse condition can easily be prevented by properly spaced drains, laid across the slope.

With low permeability of the soil there is the problem of water penetration necessary to build a sufficient water reserve to carry the crop through the dry seasons of the prevailing climate. The recommendation of the Senior Sugar Officer to apply gypsum on the poorly draining soils points towards this aspect of the soil-water relationships.

III. Experimentation.

1. The old permeability test.

The existing permeability test at the N.A.L. had largely been adopted from the Handbook 60, USDA Dep. Agriculture.

The test measures the permeability or hydraulic conductivity under constant head of a 50 grs ground soil sample (0-2mm), packed into a brass cylinder Ø 1.4", length 6". The packing is done by dropping the loaded cylinder 20 times over a height of 1" onto a rubber stopper. Readings are taken at certain intervals as mm/24h, but the figure given in appendix 2 represents the reading after 2? hours.

To a limited number of samples 25 ml of 0.02N gypsum solution was given and after standing for 1 hour, the usual water percolations were carried out. This gypsum treatment is equivalent to 1 me% Ca or roughly 2 tons per acre-foot of soil.

Comments.

The results, as presented on the bottom lines of the soil data sheets of appendix 2 show that a large proportion of the samples tested gave very low to zero readings. No relationship at all was established with the permeability figure and ESP. It was found that for those soils, pre-treated with gypsum the permeability was much higher at first, but upon further leaching with water the permeability decreased to low levels or to zero readings. On some soils a low permeability was maintained where without gypsum treatment, the permeability would have fallen to zero.

The above test was further discarded because it was considered to be not sensitive enough to distinguish between the effects of normal swelling of a montmorillonitic soil and any additonal adverse effect due to additional swelling and aggregate breakdown associated with high sodium levels.

III-2 Constant Percolation Rate of 0.1-2mm aggregates.

To overcome the stated disadvantages of the previous test the following modified procedure was adopted, which owing to lack of enough sample material was done on rather small amounts of soil sample.

15 grs of soil sample, fraction 0.1-2mm aggregates were weighed into 3.5cm glass filterfunnels with por. no 1 sintered glass bottoms. The soils were packed in a standardised way, covered with a filterpaper disc and subjected to continuous water percolation under constant head until a constant percolation rate was attained. Demineralised water was used. The constant percolation rate (CPR), was expressed as mm/24 hours.

When tried out on a rather large batch of samples, the test seemed to bring out a more differentiated pattern of soil behaviour towards water percolation.

III-2.1 In table 1, samples from a field experiment which was conducted in Miwani by the Senior Sugar Officer, were tested in the same way.

Only the top and second foot were investigated. For the sake of demonstration, 4 percolation rate readings at intervals 15 min-17h-24h-24h- are given; the reading of the 4th day represents constant percolation rate (CPR).

Table 1. Percolation Rates* (method III-2) of Soil Samples taken from a Gypsum Rates Field Trial in Miwani.

Measurement taken		Gypsum treatment in tons per acre							
		0		1		2		3	
Day	Hour	0-12"	12-24"	0-12"	12-24"	0-12"	12-24"	0-12"	12-24"
1st	15.45	0	0	0	0	0	0	0	0
	16.00	404	0	509	69	nm	117	nm	133
2nd	09.00	349	6.7	322	22	nm	63	nm	63
3d	09.00	182	0.6	228	5.0	nm	40	nm	32
4th	09.00	157	[illegible]	213	2.7	200	35	180	28
ESP of field sample		6.2	7.2	4.3	5.0	4.0	5.4	3.3	5.0

* mm/24h. nm= not measured because of too high percolation rate.

Comments: It should be borne in mind that the percolation rates as presented in the table do not depict field rates. They only give a relative value ~~to~~ of the intrinsic behaviour of the soil sample towards water percolation.

The percolation rates decrease over the four days, until the constant percolation rate (CPR) is attained. This decrease may be ascribed to a slow swelling of the montmorillonitic soil and to a washing out of the free gypsum electrolyte.

The improvement in CPR of the 12-24" layer from 0 to 28 is highly significant, and may be considered as permanent.

The topsoil (0-12") is to start with in a much better aggregated condition,- probably due to the effect of organic matter-, but the drop from very high percolation rates to a level of 157 to 213 mm/h is due to both swelling and electrolyte effect.

For the 12-24" layer, the improvement in CPR is accompanied by a drop is ESP level from 7.2 to 5.0 in the 3tons /acre treatment. (3 tons/acre corresponds theoretically to approx. 1.8 me%). The additional removal of sodium may be due to a leaching out during the percolation.

III-2.2 The effect of gypsum treatment of the soil on its water transmitting properties has been tried in the laboratory on a few selected samples from different blocks in the area which are known to be very poor in this respect.
Following the method as outlined in III-2, the soil samples were first slowly leached with increasing quantities of gypsum solution (7.5ml of 0.02N gypsum solution for each m.e./100grs of soil). Percolation under constant head was continued with demineralised water until CPR was attained. To give an impression of the time required to arrive at this state, the length of the continuous

percolation (LP) before reaching CPR was recorded in hours.
Two heavy textured strongly swelling vertisol samples from an entirely different area (Mwea, near Embu) were included for the sake of comparison.

Table 2. Effect of Gypsum Treatment on the Constant Percolation Rate (CPR) of some soils of the Chemilil Outgrower's Area. A laboratory test.

a.

Lab.no	Gypsum treatment: no gypsum CPR	no gypsum LP	1 me/100gr CPR	1 me/100gr LP	2 me/100gr CPR	2 me/100gr LP	3 me/100gr CPR	3 me/100gr LP	10 me/100gr CPR	10 me/100gr LP
Kano Pl.										
9862	0.05	138	2.7	138	20	138				
9980	0.0	138	45	138	75	138				
*8522	0.0	142	0.0	142	3.8	142	7.3	142		
10643	0.0	65	0.0	65			7.5	187		
Mwea.										
759	19.3	143			32	143				
771	4.5	143			5.6	143			82	142

CPR in mm/24h; LP= hours of continuous percolation.

b. Physico Chemical Data of the same Soils.

Lab.no	Location	Depth (inch)	%Clay	CEC (me%)	ESP	$\%CaCO_3$
Kano Pl.						
9862	Nyalenda I	12-24	71	60	5.4	0
9980	Wasweta	12-24	66	54	4.8	0
8522	Sanda	12-24	58	41	6.1	0
10643	Ang'ogo	12-24	65	58	7.5	0.8
Mwea						
759		12-24	85	80	4.4	0
771		24-36	79	70	15.0	4.0

* A separate subsample, treated with 2 me/100gr gypsum has been carried through 4 weeks of uninterrupted percolation to leave no doubt as to the permanency of the improvement.

Note I. The samples which gave zero CPR readings under the no gypsum treatment showed visible signs of dispersion.

Note II. At CPR, the treated samples were free of gypsum electrolyte as tested with $BaCl_2$.

Comments.

The results are very interesting. All Kano Plain soils react strongly upon gypsum application: the CPR values attain satisfactory levels at 2 me/100gr gypsum treatment for the first three soils; Ang'ogo is of poorer structure stability, but gypsum treatment at the rate of 3 me/100gr improves the CPR from 0 to 7.5 mm/24h.

The Mwea soils behave somewhat differently. These soils showed more swelling than the Kano Plain soils. Yet for Mwea 759 the CPR with no gypsum applied is rel. good. Addition of gypsum at the rate of 2 me/100gr improves the CPR somewhat.

The soils discussed so far have low ESP values, in the range of 4-7.5.

Mwea 771 has in contrast an ESP of 15, at which level the soil is classified as sodic (or alkali). All the same the CPR at zero treatment is not zero as with the Kano Plain soils. Increasing gypsum applications give strong increases in the CPR. The general impression for this soil is that in the range of ESP 0-15, the CPR decreases more gradually than for the Kano Plain soils.

NOTE: It appeared that at CPR the soils were free of Sulphate as tested with $BaCl_2$.

I-2.3.

The soil with the poorest CPR values in the previous experiment, Ang'ogo, was selected for an investigation of artificially established ESP levels on the the aggregate stability and water transmitting properties as expressed by the CPR.

A bulk sample of 500 grams was slowly leached with $CaCl_2$ (10 liter of 1N solution) and subsequently leached with water until the soil was free of Chloride, as tested with AgCl. After removing most of the exccess water by suction, the soil was dried for 2 weeks at 40°C and carefully ground to pass a 2mm sieve; after removing the finest particles by sieving through a 0.1mm sieve, 15 grams of the soil containing aggregates of 0.1-2mm size were packed in filterfunnels in the usual way.

0 - 5 - 10 - 20 - 30 - 40 - 50 mls of 0.02N NaCl was slowly leached through the subsamples (in duplicate) and followed by the usual water percolations. A similar set in duplicate was treated with the sodium - chloride solutions, but in stead of water percolations, exchangeable sodium was determined by washing out the sample with 70% ethanol until just cl-free and displacing the adsorbed cations by NH_4-acetate, 1N, pH 7.0. Na was measured on an EEL-flamephotometer.

Table 3. Effect of increasing ESP-Levels* established on a poor Permeability Kano Plain Soil on the Constant Percolation Rate.

Ang'ogo 12 - 24 inches depth

Exch. Na (me/100g)	0	0.57	1.14	2.38	3.32	4.46	5.20
ESP	0	0.99	1.98	3.95	5.51	7.40	8.63
Const. Percolation Rate (CPR)	180	230	200	74	19	3.1	1.5

*after having previously saturated the exchange complex with Calcium.

Comments:
The effect of the increasing ESP levels on the CPR is evident above ESP 2; the CPR rapidly deteriorates to a very low figure of 1.5 at ESP 8.6.
In the original soil the CPR was already zero at ESP 7.5. The somewhat better behaviour of the soil in this respect in the above experiment is ascribed to the Ca-saturation of the exchange complex before imposing the ESP levels.

II.3 A modified percolation procedure on 0.1-2 mm aggregates.

The percolation procedure used in the previous chapter is time consuming and restricts the number of samples that can be tested in one batch, since the samples are continuously leached under constant head, for several days. As the reduction of percolation was ascribed to swelling and slow desintegration of the soil aggregates upon contact with water of low electrolyte concentration, rather than by the water passage (the concentration of the soil solution being already low), a procedure was adopted whereby the actual time of water passage was limited and interrupted by long intervals during which the soil was kept wet.

15 grs of soil sample were packed in the same way as before into glass filter funnels. The water percolations were carried out as follows: After a 15 minutes free run of water under constant head, a measurement of the percolation rate was taken over the next 10 minutes (I) and a second measurement after the subsequent 30 minutes (II). The water supply was then interruped for 24 hours during which time the samples were kept wet. A percolation of 30 minutes was given and the samples were again set aside for 24 hours. A final reading of percolation rate was then taken over a period of 30 minutes.(III)
In this way 4 batches of 24 samples could easily be handled within 50 hours.

It was found that the last reading (III) was virtually the same or only slightly

higher than the Constant Percolation Rate of the previous chapter.
The ratio of the readings III/I gives a measure of the reduced percolation
rate due to swelling and aggregate breakdown of the soil.

The above "test" has been carried out on a large number of soil samples from
outgrower's blocks in the Chemilil area, not yet under sugarcane (1968).
The results are presented in appendix 3.
A study of the results reveal considerable difference in behaviour for
the various soils. The initial percolation rate (I) varies considerably but
also the magnitude of the drop in percolation rate over the subsequent 48 hours
is highly variable. Plotting the rate of reduced percolation rates (III/I)
against the ESP value of the soil does not bring out any relationship, although
it can be said that at ESP values of 8 and higher, the last reading (III)
and therefore also III/I is likely to be 0. The failure to detect any
correlation between III/I and ESP is probably due to several factors which will
be discussed in chapter VI.

I-4 <u>Laboratory Stability Test.</u>

Where the previous tests showed the effect of both swelling and any possible
aggregate breakdown, another test was employed to characterize the aggregate
breakdown only, as an increase of the aggregate fraction < 50 microns (μ) over
that of a Calcium treated soil. A pipette method was employed, but with more
sample material available, the use of a hydrometer is advisable. Also a
soaking period of 72 hours in stead of 24 hours would probably be more realistic.
The choice of the increase in fraction < 50μ is arbitrary, and possibly a
smaller size fraction might even be more indicative. However the test as
employed may be considered to be useful.

<u>A.</u> 10 grams of air dried soil consisting of particles in the range of 0.1-2mm
were soaked for 24 hours in 400 ml dem. water, contained in wide neck cylindrical
bottles, 6 cm in diameter and 12 cm in height. After 24 hours of standing
the bottles were shaken gently in an end over end fashion, 40 times in 60 seconds
Immediately afterwards, a 25 ml pipette was lowered into the suspension
and a sample was taken after 30 seconds at a depth determined by the
temperature of the suspension, derived from a monograph so as to pipette
the fraction < 50 μ. For the actual pipetting, 15 seconds were taken.
The suspension sample was dried at 105°C and weighed. The weight was
expressed as a percentage of the air dry soil:

$$\% \text{ fraction} = \frac{400}{\text{vol. pipette}} \times \frac{\text{weight fraction} \times 100}{\text{weight of air dry soil}}$$

B. After the pipette sampling, 25 ml of 4% Na-hexametaphosphate was added to the suspension . The bottle was shaken for 30 minutes at 80 movements per minute in a shaking machine, left standing for 16 hours and shaken again for 30 minutes. The same pipette sampling as desribed under A was then carried out. A blank was carried along in duplicate consisting of 375 ml demineralised water to which 25 ml of Na-hexametaphosphate was added.

The calculation is the same as before with the only difference that the weight of the Blank has to be substracted from the weight of fraction.

C. A 10 gram subsample of the same soil as used for A and B was weighed into a 3.5cm diameter filter funnel with sinterd glass bottom, por.no 1, and carefully leached with 100 ml 0.5N $CaCl_2$. The sample was then leached with dem.water until Cl-free and transferred to the wide neck dispersion bottles in which it was left soaking for 24 hours. The same pipetting method as under A was finally carried out.

The three measurements represent respectively: A) the soil sample in its original state, of which the aggregate stability is being tested; B) the soil sample brought to full dispersion which yields the maximum in the fraction < 50 µ; C) the soil sample of which any instability due to exchangeable sodium has been removed by the C-treatment. The stability state of the soil may then be worked into an index, using the three results:

$$\text{Index} = \frac{A - C}{B - C} \times 100$$

, or in words: The instability which can be prevented by Ca treatment, projected on a linear scale with the result of A as 100 and that of C as 0.

Another way of expressing could be : Ratio = A/C x 100; however the Index is prefered.

-4.1 The above test has been carried out on 4 soil samples from different parts of the Chemilil area, which were treated with low levels of gypsum, of 0 - 1 - 3 me/100gr soil respectively. (The soils were treated as for C, but leaching was done with 0 - 10 ml 0.1N - 10 ml 0.3N gypsum solution, and washing with water was continued until the soil was SO_4-free).

Table 4. Results of the Aggregate Stability Test of four Soil Samples of the Chemilil Area, as influenced by low Levels of Gypsum Treatment.

Sample	Depth (inch)	ESP	B	A: Gypsum treatment, me/100grs: 0		1		3		C
			a	a	b	a	b	a	b	a
Ang'ogo	0-12	4.2	64	13	6 130	10	0.5 100	10	0.9 100	10
Nyalenda	12-24	5.2	81	36	33 257	19	8 136	16	4 114	14
$Ahero_I$	0- 4	8.6	81	33	22 174	22	5 116	19	0.2 100	19
$Ahero_I$	4-12	17.5	83	67	77 394	48	48 282	31	22 182	17

A, B and C are the procedures of the test; a = the fraction $< 50\mu$ measured;
b-top = Index; b-bottom = Ratio

Comments:

From the table it appears that the Ang'ogo topsoil sample has a good aggregate stability, as it shows little or no aggregate breakdown when compared with the reading of C. This is reflected in the measurement of the fracion $< 50\mu$ of A as compared with that of C and in the Index and Ratio of the 0-Gypsum treatment. The gypsum treatments of 1 and 3 me/100gr therefore show hardly any improvement. With the other three soils, gypsum treatment does lower the fraction $< 50\mu$ found in A andtherefore also the Index and the Ratio. Nyalenda and Ahero 0-4" are practically completely "reclaimed", but Ahero 12-24" still shows a considerable Index value at the 3 me/100 gr treatment. This soil may be termed alkali, with an ESP of 17.5. The 3 me/100gr gypsum treatment brings the ESP theoretically down to a level of approx. 12.5, which apparently still causes significant instability.

I-4.2 Two soils of the previous experiment, $Ahero_I$ 0-4" and Ang'ogo 0-12" were selected to investigate the effect of imposed ESP levels on the aggregate stability of the soil

Bulk samples were leached with excess 0.5N $CaCl_2$, washed with water until the samples were Cl-free, air dried for 10 days and carefully ground again. A range of ESP levels was then established on a series of subsamples of the treated soil, using the same procedure as outlined in III-2.3, and the stability test was carried out in duplicate.

Table 5. Effect of increasing ESP Levels on the Aggregate Stability of two Kano Plain Soils *

Soil		ESP	Fraction < 50 μ B	A	C	Index	Ratio (A/Cx100)
Ahero	0-4"	0.96	81	19	19	0	100
		2.88	81	20	19	1.6	105
		3.87	81	27	19	12.9	142
		6.50	81	30	19	17.7	158
		8.10	81	31	19	19.4	163
Ang'ogo	0-12"	0.59	75	6.5	6.8	-0.4	96
		2.54	75	7.6	6.8	1.2	112
		3.89	75	7.5	6.8	1.0	110
		4.91	75	9.1	6.8	3.4	134
		5.93	75	8.6	6.8	2.6	127
		6.77	75	9.4	6.8	3.8	138

*ESP levels established after saturating the exchange complex with Ca.

Comments:

In the ESP range of 0-8 a marked decrease in aggregate stability is observed in the Ahero soil, which is rather abrupt from ESP 2.88 to 3.87. This is reflected in the increases in Index and Ratio.

The Ang'ogo sample clearly shows more inherent stability as the Index levels hardly go up with increasing ESP. This stability showed also in percolation tests and in the occurrence of stable crumbs in the field.

From the table it is also clear that Index is more suitable to characterize stability than Ratio: For Ahero, a Ratio value of 142 corresponds with an Index value of 12.5, whereas for Ang'ogo, almost the same ratio value (138) corresponds with an Index of 3.8. Yet it is apparent from the corresponding fraction < 50μ-values of A and C of both soils that the Ahero soil is much less stable than the Ang'ogo soil.

I/4.3

The stability test applied to outgrowers blocks.

In Appendix 3, the aggregate stability test has been applied on a large number of soil samples which were also tested by the percolation method of chapter IV. The results are shown on the right hand part of the tables, with the < 50μ fractions of the B,A and C treatments and the calculated Index and Ratio.

A linear regression analysis between ESP and Index yields a correlation coefficient of 0.71 which is highly significant. Because of the uniformity of the soil textures, a good correlation is also found between ESP and A-C. Index and III/I (the ~~reduction in~~ reduced percolation rate) show a weak relationship of the type $Y = \frac{a}{X}$.

Discussion.

From the results of the laboratory experiments with the Chemilil soils it is concluded that exchangeable sodium in the rel. low ESP range of 0-8 has in principle an adverse influence on these soils. It has been demomstrated that both water percolations and aggregate stability are decreased by increasing ESP levels, which negative effect can be counteracted by treatments with also small doses of gypsum. However there is a difference between soils with respect to their sensitivity towards ESP level. Some soils remain rel. unaffected within the above range of ESP values, whereas others show appreciable aggregate breakdown* and very low to zero water percolation rates (upon prolonged percolation) at ESP levels as low as 4-6.

Notwithstanding these variations a firm correlation ($r=0.71^{**}$; n= 87) has been found between the ESP and the aggregate breakdown as expressed by the "Index" for a wide range of soils, sampled from the outgrower's blocks.

The reduced percolation rate (III/I) for the same soils, show when plotted against ESP, a scatter of points without apparent relationship. A closer inspection allows the conclusion that at ESP values greater than 8 the reading for III (= approx. constant percolation rate) and therefore also of III/I are always zero. Within the intervals ESP 0-10 and III/I 0-15 a significant negative correlation (r= 0.64; n=47) is found. One could infer from these observations, that on soils with low percolation rates the adverse effect of ESP is already apparent at lower levels than on soils with high water percolation rates.

Between Index and III/I a relationship is found of the type:

$$\text{Index} = \frac{\text{Constant}}{\text{III/I}} \;;\; (r=0.68; n=86) \quad \text{or} \quad \text{III/I} = \frac{\text{Constant}}{\text{Index}} \;;\; (r=0.63; n=86).$$

A curve of this type could be interpreted as follows: With Index values greater than 7, the chance is small that III/I values are greater than 15 (mm/24h); and with III/I values from 20 and more, the chance is small that Index values of 6 or more are found.

If the Index, which is a meaure for aggregate breakdown, is regarded as the causative factor for reduced water percolation rates, the situation could be described as: With increasing Index levels up to 7, the III/I values rapidly fall back to a level of less than 15, after which they decrease more gradually with further increases of the Index values.

The regression analyses were done on many samples; Due to the appreciable scatter it is not feasible to make use of the regression lines.

*with in some cases visble dispersion.

The problem soils of the Chemilil Outgrower area are high in clay content and are of the swelling type, which characteristics are known to result in poor water transmitting properties, especially when the soil is in the wet state.

Application of gypsum on such soils is usually considered only if it has been established that exchangeable sodium is responsible for the deterioration of the soil structure and for a swelling behaviour which is excessive compared with the normal swelling of such (montmorillonitic) soils.
The optimum rates of gypsum to be applied as found in field experiments by the Senior Sugar Officer are in the magnitude of 2 tons per acre. Not only were higher rates uneconomic; further responses often failed to show at all.
A dressing of 2 tons per acre-foot of gypsum amounts to approx. 1.3 me/100grs of soil.* If the improvement is brought about by the replacement of exchangeable Sodium by Calcium, the changes in ESP are hardly spectacular and may even escape routine laboratory investigation.

For a soil with a cation exchange capacity of 50 me/100gr or more, the removal of 1 me/100gr of exchangeable Sodium would lower the ESP with 2 units or less. If a depth of 2 feet is taken, the reduction in ESP would be 1 unit or less.

In the above calculations, ideal mixing of the gypsum with the soil was assumed. In the field this condition is never fulfilled; locally higher concentrations of gypsum occur against lower concentrations elsewhere. It may then be reasoned that the effectiveness of the rather low application rate of 2 tons per acre lies in these locally higher concentrations, whereby a situation can be visualized comparable to a slowly permeable membrane which has been punctured in several places. Although the gypsum is usually worked into the top foot of the soil, its effective working depth can be considerably greater, based on the above principle and due to its being washed into the many cracks, which may extend as deep as 3 feet in a dry soil.

Application of gypsum also means raising the electrolyte concentration of the soil solution, with as a temporary effect, the reduction of swelling, aggregate break-down and dispersion.
This electrolyte effect is also apparent in the field trial in Miwani (table 1.), which was laid down more than two years before the soil samples for the test were taken.

The initial percolation rates (1st reading) increase with increasing gypsum rates. At constant percolation rate (last reading), these differences

*assuming that 1 acre-foot contains 4,000,000 lbs of soil.

have practically disappeared for the 0-12" sample; for the 12-24" sample some differences remain, which are permanent improvements after the electrolyte effect has disappeared.

Thus, even in soils which are not negatively influenced by exchangeable Sodium, gypsum treatment has an enhancing effect on the water percolation rate, which in the field means a better water penetration and therefore an increased moisture storage. Whether the improvements by gypsum application will be shown in crop yields depends on: a) for the better drained soils, whether the the previous condition had limited crop production; b) for the poorly drained soils, whether the improvements have surpassed the treshold level above which they become significant in relation to an improved crop performance.

Considering the generally low water percolation rates and the far from excessive total rainfall in the area, the electrolyte effect may be a rather long lasting one.

In the meantime, as a result of the improved soil-water conditions, root development is enhanced, which in its turn may have a favourable effect on the structure stabilty of the soil. It may therefore be appreciated, that the distinction between a temporary and a permanent gypsum effect is difficult to make in the field. This is particularly the case if enhanced root activity succeeds in taking over the role of improving soil structure and its stability from the temporary electrolyte effect. It is however believed that for those soils with a high Index value as determined by the method in chapter III, coupled to a low constant percolation rate or III/I value, enhanced root activity alone will never be able to establish stable structures so as to improve crop production in a pemanent way.

The beneficial effects of gypsum observed do not exclude the validity of such measures of cambered beds, deep soil cultivation and properly spaced open drains etc. The most effective and economical combination is likely to yield the best results. If the soil is intrinsically unstable, measures to loosen the soil to effect better water penetration, may fail due to collapse of structure. On the other hand, once a soil has indurated or compacted horizons, a possible effect of gypsum can only be optimal in combination with some mechanical operation to break up the compacted soil.

The most likely explanation for the adverse Sodium effect at low ESP levels on the aggregate stability of a large part of the soils of the area, is that the aggregating bonds between soil particles are already weak. In these dark, swelling, heavy clay soils, the main aggregating effect must come from organic matter, since iron coatings and -bridges, and positive charges which give rise to cardhouse structures are here relatively unimportant. Under prolonged wet condition of the soil, the organic molecule chains, which hold the particles together and which are coiled in the dry state, become stretched whereby the aggregating bonds are weakened.

V. Conclusions and Recommendations.

In the report it has been established that on soils from the Chemilil Outgrower's area, the aggregate breakdown and reduction in percolation rate can be caused by exchangeable Sodium at ESP levels below 8.

The results support for certain soils the conclusion drawn by the Senior Sugar Officer from his field experiments, that gypsum application at relatively low doses can be beneficial for the soil-water relationships of those soils.

A simple test has been adopted and succesfully applied on a large number of soils from various parts of the area, by which the rate of aggregate breakdown is appraised. The test also distinguishes between those cases in which aggregate breakdown can be prevented by treatment with Calcium (gypsum), and where Calcium treatment will have no effect.

Further field experimentation involving gypsum and mechanical disruption of deeper soil layers is recommended on selected soils.
The choice of the experimental sites should be guided by the Index value of the above test and the water percolation rates of the soils, so as to include a range of soils with a varied reaction towards the treatments.

NOTE. A soil with an Index value > 10 and a constant water percolation rate (CPR) < 5 mm/24h is likely to respond to gypsum treatment.

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APPENDIX I.

Soil Series distributed over the Various Outgrowers Cooperative Blocks (Songhor Report.)

Owuor I:- West and South, Kbc; East Rac. Proportion 2:1
Simbi II: Kbo and AC plus a small strip CxC
I: Kbc and AC.
Lila : Kbc and AC.
Migore: Kbc and AC.
Nyatao: - Kbc and AC plus a small patch Asi in South - East.
Pawteng-I: North-East Kbc, centre and west, Bist.
" II: In the north a small strip C x C; in the centre a strip Asi, in the west and east Kbc.
Orago II: Very mixed: C x C, AC, Kbc.
Olasi: Kbc.
Omanyi: Kbc
Nubian: C x C.
Kanjuro: In the north-west Kbc, in the south and south-east Rac.
Kamwala (near railway); Largely Pcl.
Kamwala: In the north-west Rac, in the south Vcl: Proportion (2:1).
WasWeta: In the north-west Rac, in the south Vcl: Proportion 2:1.
Kirungu (railway) Pcl.
Kirungu: In the north Rac; centre Ccl: South Vcl.
Rawo: $^4/_6$ Ccl in the north $^1/_6$ Bcl and in the south $^1/_6$ Rac.
Geyo: In the north Ccl; in the south Rac. Proportion 1:1
Nikwa: In the north-east Kbc; in the south-west, very mixed.
Openda (railway): From west to east, $^1/_5$ Kbc, $^1/_5$ Ccl, $^1/_5$ Kbc and $^1/_5$ mixed AC and Ccl.
Wanjare, 2 blocks: Ac and Kbc.
Block Openda, Okwach, Mikwa, Onyange:
Mikwa - Onyange: Mainly Rac. In south-west edge C x C.
Openda - Okwach: Kbc plus Ac and some Rac.

Legend and internal drainage class.

Ac	-	Aristos clay loam, extremely poor drainage.
Asi	-	Awasi loam, poor drainage.
Bcl	-	Babu clay loam, good drainage.
Bist	-	Bhanji stony loam, poor drainage.
Ccl	-	Chemilili clay loam, moderate.
Cxc	-	Complex of arable clay soils, moderate drainage.
Kbc	-	Kibigori clay, very poor drainage.
Pcl	-	Patel clay loam, poor to very poor drainage.
Rac	-	Rama clay loam, moderate drainage.
Vcl	-	Volo clay loam, poor drainage.

APPENDIX 3.

Results of a percolation test (para III.3) and an aggregate stability test (para III.4) for soil samples from the Chemilil outgrower's blocks.

Field ref.	depth*	ESP	Percolation readings I	II	III	III/I %	fraction<50μ B	A	C	Ind.	R
Simbi W2	0-12"	3.0	75	33	25	33	80	17	13	6.0	131
	12-24	3.4	40	25	2.0	5.3	84	21	20	1.6	105
	24-36	4.3	90	56	3.6	4.0	90	21	20	1.4	105
Simbi W3	0-12	3.5	22	5.6	5.2	22	83	14	12	2.8	117
	12-24	4.2	141	94	29	21	80	17	13	6.0	131
	24-36	4.6	39	26	0	0	89	22	15	9.5	147
Lela W6	0-12	4.9	117	78	59	50	65	15	12	5.7	125
	12-24	6.8	102	5.0	4.0	3.9	75	15	13	3.2	115
	24-36	7.3	159	87	5.0	3.1	89	18	13	6.6	138
Genya W8	0-12	3.9	96	63	41	43	63	14	13	2.0	108
	12-24	5.2	129	81	25	19	76	13	12	1.6	108
	24-36	5.1	99	53	5.8	5.9	83	17	16	1.5	106
Orago W 13	0-12	2.8	315	282	72	23	81	13	10	4.2	130
	12-24	4.0	129	63	17	13	89	17	14	4.0	121
	24-36	7.9	51	19	4.2	8.2	88	28	18	13	156
Orago W 14	0-12	5.3	228	260	62	27	69	12	12	0	100
	24-36	9.1	60	14	19	32	64	25	20	11	125
Rawo W 20	0-12	1.2	339	369	144	117	23	6	5	-	-
	12-24	5.6	231	176	21	9	63	17	7	18	143
	24-36	8.5	57	6	0	0	73	41	22	37	186
Rawo W 21	0-12	2.2	300	178	27	9	78	11	11	0	100
	12-24	2.8	132	120	46	35	81	19	18	1.6	106
	24-36	3.8	87	67	35	40	79	32	33	0	100
Kamwala W 23	0-12	3.3	51	34	5.0	9.8	76	17	17	0	100
	12-24	3.6	81	53	6.4	7.9	82	17	15	3.0	113
	24-36	3.9	72	48	6.0	8.3	84	27	26	1.7	104
Kamwala W 24	0-12	2.2	516	561	139	27	84	6	6	0	100
	12-24	3.1	324	321	39	12	86	7	8	0	100
	24-36	4.2	168	100	9.8	5.8	85	10	7	3.8	143
Geyo W 25	0-12	0.8	924	861	638	69	82	7	6	1.3	117
	12-24	1.0	207	200	159	77	86	9	9	0	100
Geyo W 26	0-12	2.2	186	176	187	101	74	10	8	3.0	125
	12-24	3.1	159	133	60	38	80	12	9	4.2	133
	24-36	3.9	69	46	9	13	85	20	16	5.8	125
Simbi I R4	0-12	3.5	468	420	300	64	92	13	12	1.3	108
	12-24	5.6	708	558	259	37	89	12	10	2.5	120
	24-36	7.4	228	141	13	5.7	89	18	11	10	163
Simbi I R5	0-12	3.6	75	49	30	40	92	11	10	1.2	110
	12-24	3.4	110	59	8.6	7.8	89	12	10	2.5	120
	24-26	4.7	75	111	7.4	9.9	89	21	17	5.6	124
Nyatao R7	0-12	3.6	81	40	51	63	81	10	11	0	100
	12-24	3.8	90	69	27	30	-	-	-	-	-
	24-36	5.2	93	61	29	31	74	27	19	15	142

* depth in inches ; I= first reading after 5 min; II= 30 min after I; III= 48 hours after II; B=fraction<50μ fully dispersed; a=not treated; C= Ca-treated.

(APPENDIX 3.....continued-1).

Field ref.	depth	ESP	Percolation readings I	II	III	III/I%	fraction<50μ B	A	C	Ind.	R
Nyatao R 9	0-12"	4.4	123	120	63	51	81	19	19	0	100
	12-24	5.8	78	43	5.6	7.2	88	17	14	4.1	121
	24-36	7.1	60	40	3.6	6.0	87	32	18	20	178
Migore R 11	0-12	3.3	129	75	50	39	87	16	17	0	100
	12-24	3.9	78	43	5.0	6.4	89	16	12	5.2	133
	24-36	5.3	40	29	1.0	2.1	88	24	14	14	171
Pawteng I R 12	0-12	4.2	36	19	9	25	70	12	10	3.3	120
	12-18	6.7	f*	760	210	-	48	4	3	2.2	133
Pawteng II R 14	0-12	3.4	210	66	31	15	-	-	-	-	-
	12-24	5.6	36	22	2.0	5.6	86	16	11	6.7	145
	24-36	7.1	33	18	1.0	3.0	83	30	24	10	125
Pawteng II R 15	0-12	3.4	54	35	17	31	-	-	-	-	-
	12-24	4.2	45	26	13	29	89	23	13	13	177
	24-36	5.3	39	17	2.4	6.2	92	20	18	2.7	111
Ang'ogo R 17	0-12	4.1	25	12	1.6	6.4	78	19	13	9.2	146
	12-24	5.7	120	69	5.4	4.5	84	17	9	11	189
	24-36	6.3	60	36	13	22	87	28	24	6.3	117
Ang'ogo R 18	24-36	7.2	57	35	0	0	87	41	19	32	216
Abuogo R 19	0-12	6.3	72	35	1.0	1.4	90	22	12	13	183
	12-24	10.5	198	43	0	0	91	38	12	33	317
	24-36	10.9	33	12	0	0	91	60	21	56	286
Abuogo R 21	0-12	2.5	900	591	120	13	74	12	12	0	100
	12-24	5.5	147	89	7.0	4.8	84	14	14	0	100
	24-36	9.5	93	61	0	0	88	32	16	22	200
Nyalenda R22	0-12	4.2	249	159	92	37	88	25	9	20	278
	24-36	5.3	144	77	3.4	3.0	90	22	16	8.1	138
Openda R 23	12-24	15.1	14	4.4	0	0	68	31	9	37	344
Openda R 25	0-12	5.5	14	37	1.0	7.1	82	23	21	3.3	110
	12-24	7.0	186	114	11	5.9	83	17	11	8.3	155
	24-36	10.8	6.6	7.0	0	0	88	35	20	22	175
Okwach R27	0-12	5.2	25	27	1.0	4.0	72	20	13	12	154
	12-24	7.2	171	87	0	0	83	19	11	11	173
	24-36	9.2	33	16	0	0	85	28	16	17	175
Okwach R 28	0-12	3.9	480	413	97	20	77	9	9	0	100
	12-24	5.0	84	72	27	32	89	11	9	2.5	122
	24-36	6.0	51	17	1.4	2.7	87	20	20	0	100
Mayogu R 32	12-24	5.6	183	180	31	17	82	9	8	1.4	113
	24-36	6.8	90	85	21	23	83	18	15	4.4	120
Kirungu R 33	0 -12	3.5	960	477	41	4.3	-	-	-	-	-
	12-24	27.9	0	0	0	0	84	44	15	42	293
	24-36	24.2	198	157	0	0	82	80	19	97	420
Kirungu R 34	12-24	5.4	177	79	0.4	0.2	89	12	8	4.9	150
	24-36	6.9	28	14	1.4	5.0	86	32	19	19	168
Kanjuro B T 2	12-24	4.6	114	68	26	23	85	14	12	2.7	117
	24-36	4.8	36	29	7.4	21	88	18	19	0	100
Kanjuro B T 3	0-12	1.9	240	129	113	47	74	10	9	1.5	111
	12-24	3.3	372	201	180	29	84	11	10	1.4	110
	24-36	3.7	53	33	6.4	12	87	15	14	1.4	107
Wasweta T 3	0-12	3.0	285	189	79	28	57	16	15	2.4	107
	12-24	5.1	26	19	1.0	3.8	80	22	13	13	169

f* faster than 1000 mls/24hour