A DETAILED SOIL INVESTIGATION OF KAMLEZA NORTH, TAVETA.

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SOIL SURVEY UNIT

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The production of this report, covering as it does only a very small proportion of the lands available for development at Taveta, should not be thought to condone the previous _ad hoc_ development of this area. Irrigation should only be embarked upon in Kamleza as part of an overall scheme of irrigation and drainage devised for Taveta as a whole. The purpose of this Report is to highlight some of the manifest problems of Taveta development as typified by the soil situation in Kamleza, and to outline proposals for the establishment of soil reclamation experiments the results of which should be applicable to an extensive acreage in other parts of Taveta and elsewhere.

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I INTRODUCTION

(a) Site Location

The area known as Kamleza North comprises some 750 acres lying to the East and North East of the metamorphic outcrop of El Dorro Hill. It is approximately 6 miles South of Taveta township. To the East the area adjoins Kimorigo irrigation which in turn is bounded by the North-South course of the Lumi River. Land to the North is alienated and occupied by extensive privately owned Sisal estates. South of Kamleza North is the largely cultivated native land unit of Old Kamleza, whilst to the South West (and to the South of El Dorro Hill) is the Kamleza South development area.

(b) The Purpose and the Methods of Soil Investigation.

The purpose of this survey was to demarcate and describe separate soil types with a view to the production of export bananas by local farmers. It is assumed that soils found to match up to the necessary requirements will be subject to irrigation and will form part of a much larger production unit.

A reconnaissance survey covering 35,000 acres was undertaken at Taveta in 1945. So far as Kamleza North was concerned, that investigation divided the soils into two broad categories. A large part of the area was declared "suitable for irrigation; Class 2". The South Western quarter was pronounced " less suitable for irrigation, Class 3".

For the present survey, provisional soil boundaries were obtained from aerial photographs. Selected traverses of known position running East-West were cut through the bush and augerings carried out every 100 yards. Soil boundaries were finalised by more detailed augering; a total of 190 auger descriptions were compiled. 73 core samples were analyzed for salt content (indicated by electrical conductivity) and pH. The cores represented (caliche permitting) the top four feet of soil - one sample for each foot. In addition 28 soil pits were opened to a maximum of six feet. The pits were described in extenso in the field and then sampled on the basis of visible genetic profile development to provide a further 98 samples (For analytical results; see Appendices 2 and 3). Levelling along 3 chosen traverses (marked R2, R8, and R16 on the map) ascertained the height of the soil surface above datum for every 100 feet along the traverses. From this it was possible to calculate the height of the caliche (or stone line) above datum, and hence the slope of the underlying caliche. All these figures are entered on the map. Account should be taken of 11 inches of rain that fell in the month prior to this investigation.

2. GENERAL CHARACTER OF KAMLEZA NORTH

(a) Geology and Physiography.

Kamleza North lies between 2,340 and 2,355 feet above sea level. The area is dominated by El Dorro Hill in the South West. On its North and East flanks, this hill is described (Bear, 1955) as consisting of biotite garnet gneisses of metamorphic origin, though the core of the hill is composed of post-basement basic rocks grading from hypersthenic periodotites in the centre to norites and hyperites at the periphery.

Partially weathered and subsequently eroded material of gneissic origin fans out round the base of El Dorro Hill forming two concentric rings, the presence of which can be clearly ascertained from aerial photographs. The upper of these rings (immediately below the hill slopes) is covered by relatively dense bush growing on the coarse textured colluvium (hill wash deposit). Further from the hill, the bush is seen to open out, allowing a more open herbaceous ground vegetation to flourish on a slight slope down to the North and to the West. This open bush is growing on a heavy brown clay colluvium of strongly weathered material which has been sieved out from the coarse deposit and by virtue of its fine size, has been carried further down slope.

This brown clay thins out at the base of the slope and is seen in vertical section to be lying comformably upon a reddish brown clay, the weathering product of the superficial calareous tuffaceous grit (of Pleistocene are) which unerlies the rest of Kamleza North. These reddish clays slope gently down to the East towards the Lumi River.

In the East and adjoining the Produce Road the water table, its level possibly related to a layer of caliche and associated gravels, may lie within two feet of the soil surface at certain seasons. This phenomenon would appear to be only short term since the soils are in an oxidized state. However an existing irrigation canal flows North to South through Kamleza North (see Map). Near the Southern-most section of this canal, close to where a furrow branches off to feed Kamleza South, there is clear evidence for a high water table and surface flooding. This has resulted in gleiing (iron reduction symptoms) which extends to a considerable depth in the dark brown clays. This poorly drained phase may be associated with three features.

(i) The negligent attitude towards the canal which permits squatters to burrow through the canal banks at will.

(ii) The removal of topsoil to provide earth for canal banks.

(iii) The relatively depressed nature of the topography in this section.

(b) Climate.

Taveta has a sub-tropical, semi-arid climate. Out of a 22.4 inch rainfall, (41 years average at the District Office, Taveta), 2.7 inches falls in November, 3.8 inches in January; 4.6 inches in March; 7.5 inches in April. In the 5-month period from June to October, no more than one inch is to be expected. The potential annual evaporation has been estimated (Taveta Report, 1945) at 60 inches a year.

The 'winter' drought is a significant feature of the climate, accompanied by cold night air off the mountains. High winds are another problem (with regard to bananas, for example). The heavy "long" rains (March-April) often falling over a short period of time are a factor to be considered in drainage design.

(c) Water Supply.

Kamleza North canal water derives from the Njoro Kubwa springs, which may emanate from Lake Chala or the consequent drainage on Kilimanjaro itself. The main canal has a capacity of 70 to 75 cusecs, of which 3/10 (by agreement) is available for irrigation in the Native Land Unit beyond the Scheduled Sisal Estates. This water (rather over 20 cusecs) is also available for Kamleza South development, but, as only 12 cusecs would be required for general irrigation in Kamleza North (or rather more if padi rice were the chosen crop) the water supply should be considered adequate as regards quantity. Pits dug near the canal suggest that seepage is quite small.

Most of the hill slope soils are not under command of this canal as it is sited at present.

The water flowing into the North end of the investigation area was analysed as follows:-

m. eq./l

pH	E.C Micromhos	Na	K	Ca	Mg	NO_3	HCO_3	Cl	SO_4	NO_3	SAR	RSC	SSP
8.1	242	0.45	0.07	0.92	1.1	0.24	1.8	0.10	0.07	Tr	0.4	[illegible]	17.7

This is a reasonable irrigation water having both a low alkali and a low salinity hazard, though, in an ideal world, the pH level might be considered to be higher than the optimum. The dominance of Magnesium amongst the cations is unusual. The effect of this ion on soil physical condition is not well known.

(b) Natural Vegetation.

The dark reddish brown clays grow a rather dense bush dominated by Acacia mellifera, Albizia anthelmintica, Azima tetracantha, Balanites glabra, Cissus quadrangularis, C. rotundifolia and Dobera glabra accompanied by Achyranthes aspera. According to Dale and Greenway, (1961) the Azima is an indicator of saline soil. In 'open country' - gaps in the bush - tall Cynadon plechtostachyus is often accompanied by Abutilon maritianum. The soils are generally saline, and it would seem that the local people have shrewdly cleared the bush for cultivation only where the soil salt content is relatively low. In the extreme South East (near Hamisi's Corner) it may be the proximity of the water table which has encouraged stands of Acacia seyal seyal and A. tortilis, whilst along the Produce Road (the Eastern edge) a rather distinctive open vegetation may be a consequence of bush clearance and subsequent grazing pressure. This latter association is dominated by scattered stands of Cassia bicapsularis, Maerua sp., Pluchea dioscoridis and P. ovalis Solanum campylacanthum, occasional Gomphocarpus physocarpus and Hyphaene coriacea. This Hyphaene is, at Taveta, often found "growing on worn out soils with an underlying pan". (Dale and Greenway, 1961). The rather extensive low turf mostly consists of Cynadon dactylon and some Cenchrus ciliaris with Euphorbia hirta along the paths. Occasional bare patches in this part of the area signify surface salt accumulation; in general, however, the soils underlying this sod hold less salt than those beneath the bush. Occasional specimens of Suaeda monoica in the extreme South of the area are associated by Dale and Greenway (1961) with "salt pan". The stands of Suaeda and of Acacia seyal become extensive towards the Southern end of Old Kamleza; this portends worsening drainage conditions and increasing salinity.

The dark brown clays of the South Western slopes carry a herbaceous cover typified by an association of Aerva lanata, Disperma sp., Ecbolium revolutum, Hibiscus flavifolius, Indigofera tinctoria, Justicia flava, Neuracanthus scaber, and Pupalia lappacea. Scattered bush is represented by Acacia mellifera, Albizia anthelmintica, Cadaba ruspolii. Commiphora sp., Cordia sp. near gharaf, and Grewia tenax. Occasional tracts of sparse, but well grown Sporobolus marginatus (sometimes accompanied by S. helvolus), indicating saline and alkaline conditions, are dispersed throughout, achieving general dominance only along the slope immediately above the reddish brown clays, though Chloris roxburghiana and Cenchrus ciliaris frequently feature on the lowest levels of this slope (i.e. in close proximity to the boundary between the colluvium and the reddish brown clays). The mature heads of all these grasses can be easily distinguished on the aerial photographs as a narrow white line circumscribing the base of the hill.

Those Southern areas, close to the canal, suffering impeded drainage, support a growth of sedge - Cyperus alopecuroides, C. articulatus and C. rotundus retzii - and of generally tall grasses e.g. Panicum deustum, Panicum meyerianum, Sorghum sp. and Echinochloa colonum.

Moderate to dense bush covers the lower slopes affected by coarse Colluvium, with Acacia mellifera, Commiphora sp., Grewia bicolor and also Aerva persica, Dectyloctenium aegyptium, Sericocomopsis pallida and some stunted specimens of Adansonia digitata (baobab).

Species collected or identified during the survey are listed in Appendix 6.

(e) The Local Economy.

Sporadic grazing by very indifferent cattle and sheep is largely confined to the North East, across the road from Kimorigo Village, where several huts have been constructed. The majority of the squatter's shambas are however sited in the centre of the area and South Central. Along the length of the canal maize, sugar and rice are favoured. To the West of the canal there are scattered clearings of maize and beans. In the South (to the East of the canal and based primarily upon the more fertile reddish - brown clays) are medley of crops including maize, banana, cassava, cowpeas, with occasional intercroppings of cotton, yam and paw-paw. A considerable number of bee hives are tended in the bush.

3. SOILS OF KAMLEZA NORTH

I. Coarse colluvium.

The hillslope soils comprise the weathering products of the biotite gneiss found on the North and East sides of El Dorro Hill. Further down the hill the soil becomes deeper, but there remains a shallow coarse topsoil. It is suggested therefore that coarse colluvium is dumped in close proximity to El Dorro hill, whilst the fine fractions are sieved out and form a clay deposit at the base of the slope (Group II).

In an intermediate slope situation variable depths of coarse sand may be deposited on the clay surface during heavy rains. Here the surface texture varies from coarse sand through the range of sandy clay, a common variant being a coarse sandy loam. The underlying horizons consist of brown clay.

This group of soils covers a small proportion of the survey area. It is furthermore lying above the command of any foreseeable canal structures on a considerable slope. The soils need not therefore be considered further.

II. BROWN SALINE - ALKALINE CLAY.

These soils are found in the South West of the area and form part of a ring round the base of El Dorro hill. The soils lie on a marked slope down towards the North and the East. As a result of the relatively high lying topographical situation, the soils show symptoms of alkalisation with accompanying vertical clay movement. The soils are also saline.

A transitional soil occurs where the Brown colluvium thins out above Reddish brown clay. The soil occupies a narrow transiional zone and is not distinguished on the map from the Brown Saline - alkaline soils. Its characteristic features include a band of medium and large sized concretions of calcium carbonate in intimate association with manganese compounds; these occur at the junction of the colluvium and the underlying reddish clay. The concretionary material is presumably deposited from ground water; at one of the soil pits (R_{12} Al East) water flowed out along this plane of contact.

The salient feature of these soils is the high degree of alkalinity in the sub-soil as represented by high figures for the exchangeable sodium percentage, the pH (in water), and the great amount of (Sodium + Magnesium) relative to Calcium. The comparatively high levels of carbonate and bicarbonate are further evidence of advanced alkalization. In the presence of carbonate ions at high pH levels, the calcium and magnesium will tend to be precipitated. On wetting the alkaline clays are liable to swell and then disperse, rendering the sub-soils quite impermeable. Evidence for swelling and shrinking <u>in situ</u> is

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suggested by the prismatic structure of the second layer. The problems resulting from clay dispersion are seen to be very real when the high percentage of clay is taken into account (73% in the sub-soil; on average 14% more clay than occurs in the reddish brown sub-soils).

Furthermore the existing salinity levels, even in the surface soil, will render banana production uneconomic; due to the potential impermeability of the lower horizons, no prospect can be held out for soil reclamation by leaching.

The very low figures obtained for phosphate may well result from the laboratory method of phosphate determination which was devised for use on acid and neutral soils. It is to be expected, however, that a high proportion of existing phosphate will be unavailable for plant use.

In short, these soils are not considered suitable for irrigation agriculture.

Samples taken from similar dark brown clays in Kamleza South (which does not come within the scope of this report) show all the above symptoms of salinity and alkalisation, though the salinity would appear to be more intense in Kamleza South (about twice as much). Furthermore, for certain crops, high levels of magnesium may well depress the uptake of some nutrients.

The soils covering the greater part of Kamleza South should not therefore be considered for irrigation agriculture. (Figures for Kamleza South will be forwarded to Taveta separately.

NOTE: A saline layer is defined as one in which the EC (saturation) exceeds 2 millimhos per centimeter.

An alkaline layer is defined as one in which the Exchangeable Sodium Percentage exceeds 10.

(ii) Swampy Phase of Brown Saline-Alkaline Clay.

This represents those dark brown (sometimes dark greyish brown) soils, influenced by a high surface water table and seasonal flooding. The soils are saline and contain a high proportion of clay plus silt. Owing to their flooded condition at the time of the survey, no samples were obtained, but it is assumed that the soils in their present state are unsuitable for cultivation.

The soils are found close to the Southern end of the furrow and cover a very small proportion of the area. The following brief description is based on some dozen auger borings to 48 inches.

At 4 inches.

A wet dark brown/very dark greyish brown (10 YR 3/3) Clay, slight reaction with 10% hydrochloric acid.

At 12 inches:

A wet dark brown (10 YR 3/3) clay in water. Strong reaction with 10% hydrochloric acid. Occasional phases of fine gravel (a few inches deep) within the clay matrix.

At 40 inches:

Common light brown mottles in a dark brown (10 YR 3/3) clay matrix.

Vegetation Cover. Grass - sedge predominates.

Map Symbol: II B

III BROWN NON-SALINE, ALKALINE CLAY

These soils have a similar colour and textural range to the Group II Soils. There is, however, less evidence of clay translocation and, though the subsoil has a rather high percentage of exchangeable sodium, the soils are less alkaline; pH, bicarbonate levels and exchangeable sodium all point in the same direction, whilst there are no morphological symptoms of alkalinity. The permeability of these soils is however very slow and will tend to decrease further under irrigation.

The most important feature of these soils is their low salt content which would permit the cultivation of bananas without prior leaching.

The soils should have a low priority for irrigated agriculture and only be used if other considerations demand it.

The relatively high proportion of silt recorded from surface soils which have been subjected to cultivation is of some academic interest, and may result from microaggregation producing a pseudo-silt from particles of clay size. These microaggregates may not be fully dispersed in the laboratory prior to mechanical analysis.

This soil has a very limited distribution, occupying the top of a very small ridge which runs North/South parallel to and to the East of the furrow ending some 1000 yards North of the road which divides Kamleza North from Old Kamleza. By virtue of its relatively low salt content, the soil is subject to a modest amount of cultivation.

IV. REDDISH BROWN NON-SALINE NON-ALKALINE CLAY

These are the best soils in Kamleza North. Their distribution is however limited, and an approximate boundary has been marked on the map between these soils and the neighbouring saline clays. The vagueness of the boundary between these groups stems from the inability to distinguish differences either on a basis of soil morphology or of natural vegetation. Local cultivators have however, by trial and error, discovered the important distinction, the extent of these soils can therefore be said to correspond to the distribution of the cultivation on reddish brown soils. Aerial photography would reveal the extent of contemporary cultivation.

The good quality consistence and structure of these soils gives confidence that the related saline clays can be leached of their salt without detriment to their physical properties.

In general these soils should produce economic crops of irrigated bananas provided adequate levels of N and K fertilizers are applied to make good plant consumption - present levels of N and K should be adequate, but it will be important to maintain this level, especially since leaching of these nutrients (nitrate in particular) may be expected during irrigation.

The soils have one feature in common with the neighbouring Alkaline Clays, namely the rather higher bicarbonate content which may be the cause of the apparently lower levels of phosphate in the sub-soil. The soil phosphate reserve should however prove adequate.

It should be emphasized that present cultivation in this area does not have an inherently desalinizing influence. Thus auger borings in shambas of maize and beans to the West of the furrow have shown that there, the salinity levels are quite high and characteristic of the Group V soils.

V REDDISH BROWN SALINE CLAY.

The electrical conductivity of the sub-soil exceeds 2 millimhos/cm (and averages 12 millimhos). These soils comprise about 75% of Kamleza North. The salt concentration varies from place to place. This is demonstrated on the map. The soils have been divided into 2 sub-phases. The depths of caliche layers, stone lines and the water table are indicated on the map for every point where auger borings were made or soil pits sunk. The sub-phases are as follows:-

1. With caliche in top 40 inches

These soils were found to have field and chemical properties which did not significantly differ in any respect from those of deeper Reddish Brown Saline Soils. Associated with this sub-phase, particularly in the North East Corner of the area, are small patches of surface saline horizons, which are devoid of vegetation. Analyses confirmed that these are a result of abnormal but very local surface concentrations of salt.

For the purpose of this survey, Caliche, extensive coarse gravel and stone layers were treated as one and the same thing since each will be an equal impediment to the construction of a system of drains. Very moist or even wet soil may be associated with the caliche and in places this layer may act as an aquifer. It is not our purpose here to debate which is the hen and which the egg. Suffice to remark that much of the true caliche is based on pre-existing gravel nuclei round which has been deposited much calcareous material together with oxidation products of iron and manganese derived from the ground water of this or a preceding age. The gravel units become enlarged until they start linking together one with another to form very irregular cemented sheets. It is usual to find an inch or so of fine gravel lying above this caliche. Watts (1957) has made reference to this so-called hard pan "indicative of poor drainage some four feet below the surface". Unlike some other hard pans, this type is not susceptible to deep ploughing not only because of its indurated consistence and variable depth, but also on account of its particular thickness. Caliche below adjoining Kimorigo has been reported as being 3 to 5 feet thick.

It may be anticipated that caliche (or the equivalent) underlies practically all of the reddish brown clays. The slope of the caliche is, however, downwards in the general direction of the Lumi River. Thus drains may be laid so that water flows away to the East.

As a result of the slope of the surface relief, towards the North and East caliche is struck over closer to the top of the soil profile; in the North East corner a mere two feet of soil overlies this layer.

Bananas require a deep, well drained soil. If 40 inches of soil is taken as being the minimum desirable depth for the crop, then the North East corner of Kamleza North (see Map) must be considered too shallow for banana production.

2. <u>With Caliche below 40 inches.</u>

The surface layers are sometimes saline (see Map). Below 12 inches the soil is normally saline, often intensely so. Furthermore, within the soil profile the percentage of the exchangeable Sodium increases with depth and often attains alkalinity within the top 36 inches.

Termite mounds occur on these soils. The mounds tend to be richer in phosphate than the surrounding soils, and may be sited in situations with lower than the average clay. The level of organic material in the surface 12 inches is rather low, this may well be due to the consumption of available carbohydrates by termites. The termite mound is further characterised by a high level of soluble salts especially in the surface horizon.

One of the features of these reddish Brown Clays is their great variability in salt content, but it cannot be overemphasised that, with only a few exceptions, these soils in their present condition are too saline for the production of bananas.

Furthermore, below 24 inches, there is a wide range of Sodium and Chloride concentration. Exchangeable magnesium also increases with depth. In certain of these soils, dangerous levels of Sodium are encountered below 24 inches. Rather high levels of chloride may also be found below 24".

The analyses show that the soils gradually deteriorate with respect to both exchangeable Sodium and to the concentrations of chloride, on passing through Kamleza from North to South. At the same time the cation exchange capacity tends to decline. Thus comparatively low levels of exchangeable Sodium are detected in the soils lying to the West of the furrow, and to the North of Line 16 in the East (i.e. within 1,600 yards of the Northern boundary of Kamleza North). To the South of Line 16, however, (i.e. the South Eastern segment of Kamleza North near Hamisi's Corner) sub-soil alkalinity tends to be at danger levels.

Since the leaching of the soil salt (an essential preliminary to banana production) may well crucially influence the electrical properties of the soil clays so that dispersion takes place, it is vital that preliminary experiments be performed so that an accurate prediction can be made of the likely soil response on a large scale. If it should prove that these soils retain their structure after leaching is completed, then they may be considered for banana production. Existing permeability should be good, so that, in the early stages at least, leaching will be rapid.

The highest levels of P and K are to be found at the surface of these soils associated with organic material. Comment on the fertility status of these soils prior to leaching is somewaht futile since quantities of potassium and nitrate will be leached with the salt. The phosphate status of these soils is generally satisfactory and the phosphatic reserves would appear to be adequate. Much of this soil phosphate should be available for plant use. The occasional very high figures for surface phosphate are an indication of previous human settlement. The deep soils tend to have higher levels of phosphate in the 24 inches to 36 inches horizon than the shallower soils.

Under bush the surface organic content averages out at around 2% whilst under a grass cover organic matter comprises 3% of the surface soil. It will be important to try to maintain or increase the organic content of the soils.

3. With Ground Water significantly influencing the Profile.

These soils had a water table within 70 inches of the surface at the time of the survey. The soils contain an intensely Saline horizon some two feet above the water table. The sub-soil (and often the top-soil also) has an exchangeable Sodium percentage exceeding 10%. The existence of these soils serves to underline the necessity for the maintenance of a vertical movement of solutions downwards through the profile by the twin mechanisms of (a) adequate surface leaching and (b) adequate sub-surface drainage. These soils have a disjunctive distribution, account for only a small proportion of the reddish brown clays and are largely concentrated in the South East corner of Kamleza North.

The height of the water table is in any case an unsuitable criterion for soil mapping, as it is one subject to seasonal fluctuation. The few soils with a high water table are discussed separately since they provide admirable indications as to the direction of soil evolution should a high water table be permitted to exist after the introduction of irrigation.

SUMMARY AND PRELIMINARY PROPOSALS:

A. SOILS.

1. The Coarse Colluvium and the Brown Saline-Alkaline Clays are both unsuitable for irrigation agriculture.

2. The Brown Non-Saline, Alkaline Clays will degenerate physically under irrigation and become impermeable. Drought resistant crops should be tried on these soils without irrigation.

3. The Reddish Brown Non-Saline, Non-Alkaline Clays may be used for banana production without prior reclamation. Applications of sulphates of ammonium and potassium will be necessary for intensive production.

4. The Reddish Brown Saline Clays are generally too saline for the economic production of bananas. These soils may also be dangerously alkaline in the South East of the area (towards Hamisi's Corner). Both the salinity and the degree of alkalinity vary widely from one part of the area to another, but there is a tendancy for both to increase towards the South.

The saline Non-Alkaline soils and certain of the saline Alkaline soils can be reclaimed through leaching without too drastic a reduction in soil permeability. There are some saline and alkaline soils, however, to which gypsum should be applied before leaching is attempted. Since, clearly, crop trials will be initiated at Taveta before development is embarked upon, the procedures for leaching and for the application of soil amendment should be resolved in these trials (See Proposal C, below).

5. The soils towards the North East are mostly less than 40 inches in depth and may well be too shallow for bananas. There is no reason, why other crops should not be tried on the shallower soils.

6. The Reddish Brown clays are underlain by caliche and also by intensely saline ground water, the depth of which fluctuates on a seasonal basis.

B. DRAINAGE.

1. The maintenance of reasonable horizontal and vertical permeability is an essential prerequisite.

2. The provision of adequate deep drainage is a sine qua non (preferably 6 feet deep).

3. A massive yet pisolitic sheet of caliche lying beneath Kamleza North will interfere with the construction of a drainage system. This caliche slopes gently down in the direction of the Lumi River.

4. The estimated capillary rise of soil solution in the reddish brown saline clays is a distance of 2 feet above the water table.

5. A system of sub-surface drains is required combining.

(a) Surface drainage of the waste irrigation water and runoff from precipitation,

and

(b) Sub-surface drainage to lower the level of the water table and remove the substantial amounts of excess irrigation water (the leaching requirement) necessary to prevent a renewed build-up of soil salinity.

6. Field studies on drainage design should be started some seasons before initiating development in Kamleza North; on the basis of these, drain spacing and depth will be decided.

7. Drainage water should be carried right away from the area & kept separate from the irrigation furrows.

8. A continuous check should be made on the level of the ground water at selected points by means of piezometers.

9. Excessive use of irrigation water over and above the leaching requirement must be prevented, possibly by levying a water rate on a sliding scale.

10. The canal banks should be compacted so as to reduce seepage to a minimum without resort to costly canal linings.

11. The Department of Water Development might be encouraged to consider the feasibility of employing pumps to operate below the caliche aquifer so as to lower ground water levels.

C. FIELD TRIAL ON KAMLEZA NORTH.

1. A crop trial should be initiated on 2 acres of land.

2. Ideally this trial should be sited on some of the potentially more difficult soils near Hamisi's corner. Preliminary soil analysis should be made to ensure that the soil is indeed saline and alkaline, and to provide a reference point.

3. The site will require a feeder furrow from the main Kamleza canal, and adequate sub-surface drainage leading off to join up with existing drainage in Kimorigo. The site should be as uniform as possible. Costs will include bush clearing and site levelling.

4. The following trials should be considered:-

(i) Frequency of water application. Over and above the consumptive use of the bananas, account should be taken of the leaching Requirement to ensure that salt carried in the irrigation water does not accumulate in the profile. Thus the annual irrigation requirement =

$$C + L - R$$

where C = Consumptive water use by bananas
L = Leaching Requirement.
R = Total effective rainfall.

The calculation for leaching requirement takes account of the quality and quantity of both rainfall and irrigation water. Assuming a total irrigation requirement for bananas of 70 inches and an effective rainfall of 18 inches, then the leaching requirement for Kamleza furrow water is 9" (i.e. 9% of the 70 inches), and the Irrigation Requirement is 59 inches.

(ii) Soil leaching. A simple comparison of leaching methods may be carried out:

(a) Ponding. During ponding a rice crop could be taken.

(b) Pre-Irrigation in furrows, followed by the immediate planting of the crop under trial.

In addition to this it will be necessary to compare crops grown on leached soils with crops on unleached. Since the soil chosen will be alkali, it may well be essential to apply gypsum soil amendment to prevent physical degeneration during or after leaching. The 2 treatments (Leaching and gypsum application) can be simply combined in a trial in which a plot is divided into three parts:

(a) Untreated soil.
(b) Straightforward leaching.
(c) Gypsum application followed by leaching.

The level of gypsum will depend upon the degree of alkalinity of the chosen soil. The application would be most unlikely to exceed 10 tons per acre. Adequate water must be applied to dissolve the gypsum and wash it into the soil. The best method in practice may well be to irrigate, where necessary, with gypsum fortified water.

Where leaching is performed, it will be necessary to replace potassium and nitrogen which disappear with the salt. The amount of fertilizer required may be determined by soil analysis after leaching. If fertilizer is not applied, then clearly any comparison of crop yields on the different treatments will be meaningless. The trial will be evaluated not only on the basis of crop yields but also by means of soil chemical analysis and field permeability measurements.

During this trial a check should be kept of ground water level. For this purpose rows of piezometer tubes should radiate out from the plots. Salt content may be assessed in the drainage water.

(iii) Post - Leaching Fertilizer and Spacing Trial.

Firm recommendations for this cannot be made until the results of thepost-leaching soil analysis are known. Ammonium sulphate, potassium sulphate, and diammonium phosphate should all be tried.

5. If funds will not run to the provision of a long furrow and drains, then the 2 acre plot will of necessity be sited close to the Kamleza Canal. It will be essential to site this plot on uncultivated land which is as uniform as possible. The soil type should be saline, but will almost certainly be non-alkaline since Reddish Brown Clays only border the canal in the Northern part of Kamleza North. For this reason the trial need not include gypsum applications. Otherwise the proposals under paragraph 4 above can still be adhered to. Due to the absence of an accessible flow of drainage water, it is suggested that certain of the piezometer tubes should be of sufficient bore for it to be possible to sample the ground water for analysis.

The site and its environs will be sampled prior to leaching and then flooded and planted to Rice. The leached area and the unleached surround should be resampled after harvest, and, presuming leaching to have been satisfactory and the ground water strata capable of carrying away the leachate, the rice may be followed by a test crop of bananas with fertilizer applications as considered desirable. A comparison should be made with bananas planted at the same time on adjacent unleached land.

V. REFERENCES

Bear, L.M. 1955 "Geology of the Taveta Area".

Report 32. Geological Survey of Kenya. Government Printer, Nairobi.

Blaney, H.F. and Criddle, W.D. 1950 "Determining water requirements in irrigated areas from climatological and irrigation data" U.S. Department of Agriculture. Soil Con. Serv. Tech Paper 96.

Dale, I.R. and Greenway, P.J. 1961. "Kenya Trees and Shrubs".

Jacks, J.V. 1936. "Tropical soils in relation to tropical Crops" Imp. Bur. of Soil Sci. Tech. Comm. 34 pp.33 - 35.

Jacob, A. and Von Uexkull, H. 1960. "Fertilizer Use" 2nd Ed.

Simmonds, N.W. 1959. "Bananas".

Soil Survey Manual 1951. U.S.D.A.

Taveta Report 1945.

Wardlow, C.W. 1961. "Banana Diseases".

Watts, D. 1957. "Report on Irrigation Schemes at Taveta" Min. of Works.

Watts, D. 1961. "Inspection Report on a visit to Taveta", Min. of Works.

APPENDIX 1
ANALYTICAL METHODS

The dried soil samples were ground to pass a 2mm sieve for all the chemical determinations except Nitrogen and Organic Carbon. For total Nitrogen and Organic Carbon, the surface samples were determined by the methods of Kjedahl and Walkey-Black respectively.

The soil pH was determined on 1:5 Soil: H_2O and also on 1:5 Soil: KCl after mechanically shaking for half an hour, using a glass electrode. The supernatant liquid of the water extract was employed for the electrical conductivity measurement. Also the conductivity of the saturation extract was measured for selected samples. The textural analyses were carried out using the Buoyouco's Hydrometer. The Cation Exchange Capacities (C.E.C.) were estimated after first saturating with sodium acetate, washing with alcohol, and then leaching with ammonium acetate, the sodium content being measured in a flame photometer.

For the exchangeable bases, the soil sample was washed with a 1:1 water-alcohol mixture and then leached with ammonium acetate, all the elements except Magnesium being measured in a flame photpmeter. The Magnesium was estimated in a colorimeter. The water soluble salts were measured in a 1:5 water extract, the carbonate and bicarbonate being estimated by titrating with the dilute sulphuric acid; the Chloride by titrating with silver nitrate; sulphate was estimated by colorimeter.

APPENDIX 2: RELATION OF CONDUCTIVITY TO SALT CONTENT

Electrical conductivity (EC_e) provides an estimate of salt content. Soil is considered saline when the electrical conductivity of the saturation extract (EC_eSat) is greater than 2 millmhos per centimeter at 25°C.

The estimation of salinity employing a saturation extract has the advantage that the saturation percentage (the quality of water required to saturate a known weight of soil expressed as a percentage) is directly related to the field moisture ranged. The soluble salt concentration in the saturation extract tends to be about one-half of the concentration of the soil solution at the upper end of the field moisture range, and about one-fourth the concentration that the soil solution would have at the lower dry end of the field moisture range (wilting point). The conductivity of the saturation extract can therefore be used for estimating the effect of soil salinity on plant growth.

Where a large number of soil samples is involved, the above method of estimating salinity is slow and cumbersome. In this case more dilute extracts are used, the 1:5 extract being employed at these Laboratories. Using a dilute extract, the results may be related to the conductivity of the saturation extract. Conversion factors take account of the texture and saturation percentage. For a sandy soil (the saturation percentage = 30%), the conversion factor is $\frac{500}{30}$; for a clay soil (the saturation percentage = 60%) the coversion factor is $\frac{500}{60}$. If for a particular conductivity of a 1:5 extract, the product obtained by multiplying by the relevant factor exceeds 2 millimhos per centimeter, then this is sufficient to indicate a saline soil. Conversions as above only approximate to the results that would be obtained from saturation-extracts and merely serve to indicate the obviously saline soils.

APPENDIX 3

PROFILE DESCRIPTIONS* AND ANALYTICAL DATA:-

INTRODUCTION.

This appendix provides a compendium of the field and laboratory data. For each major soil type, a representative profile is described; this is followed by a table of analytical data for that profile. Following this is a table providing computed mean figures (and the range of the individual results) for all the soils analyzed and grouped into the particular soil type under consideration. The mean data in the horizontal columns marked "1" refer to the surface horizons, whilst those in Columns marked "2" are ascribed to horizons nearest in depth to a hypothetical layer 24 inches to 36 inches deep.

* Technical terms explained in Soil Survey Manual (1951)

Soil Profile Brown Saline Alkaline Clay

Pit Location: $R_{16}A_1$ E

Relief - Slight slope down to East: Microrelief plane.

Rooting Depth - 46 inches.

Maximum Rooting Density - 0 to 6 inches.

Surface - very slight cracking.

Vegetation Cover - 90%. Albizia anthelmintica and Acacia mellifera with Neurcanthus scaber, Hibiscus flavifolius, Aerva lanata, Indigofera tinctoria, Disperma sp.,Chloris roxburghiana, Sporobolus marginatus, Drake-Brockmania somalensis and Leptochloa obtusiflora.

Land Use: Grazing.

Map Symbol: II

Lab. No. 4417: Depth 0 to 4 inches.

The soil is a dark brown (10 YR 3/3 moist) slightly hard clay; with moderately developed medium crumb and blocky structure. Fine black stones are common on the surface. Fine and medium roots are abundant. The soil reaction with 10% hydrochloric acid is strong, pH = 7.0. The lower boundary is clear and even.

Lab. No. 4418: Depth 4 to 25 inches. The soil is dark grey brown (10 YR 4/2 moist) hard clay with a strongly developed medium sized prismatic macrostructure, breaking down into strongly developed blocky peds. Fine shaley gravel pebbles occur infrequently. There are few, fine and medium roots. Medium sized lime spots are common. Reaction with 10% hydrochloric acid strong. pH = 7.3.

Lab.No.4419: Depth 25 to 44 inches. The soil is a brown (7.5 YR 4/2 moist) clay, hard, with a strongly developed, fine and medium sized, blocky structure. Clay cutans are evident. Very fine gravel units are common. There are very few fine and medium roots. The soil tastes salt. The reaction with 10% hydrochloric acid is strong. pH = 7.3. The lower boundary is even and gradual.

Lab. No. 4420: Depth 44 to 68 inches.

The soil is brown (7.5 YR 4/2 moist) clay; hard and of a moderately developed, medium and fine sub-angular blocky structure. The medium sized greyish pink mottles are abundant. There are abundant clay cutans. Roots are rare, and medium sized lime spots are infrequent. The soil tastes salt. Strong reaction with 10% hydrochloric acid. pH = 7.3. The lower boundary is clear but undulating.

Lab. No. 4421: Depth 68 to 75 inches.

The moist soil is a reddish brown (5 YR 4/4) firm clay, of a moderately developed, medium sized, sub-angular blocky structure. Ggreyish pink mottles and clay cutans are abundant. There are few fine lime spots. The soil tastes salt. Strong reaction with 10% hydrochliric acid. pH = 7.2. Medium size caliche pebbles increase with depth. The lower boundary is abrupt but irregular.

Below 75 inches: Caliche.

TABLE 1 a

Brown Saline - Alkaline Clay

Pit Ref. R_{16} A 1 E

Lab. No. 4417 to 4421

Depth Inches	TEXTURE% Sand	Silt	Clay	pH 1:5 H_2O	KCl	% C	% N	ppm P	CEC ME/100g SOIL	EXCHANGEABLE BASES ME/100g SOIL Ca	Mg	K	Na	EXCH Na % (ESP)
0 - 4	29	14	57	8.6	7.0	0.90	0.13	2.0	51.0	29.0	6.3	2.8	2.0	3.8
4 - 25	23	10	67	9.1	7.3	-	-	0	52.5	12.0	6.6	1.7	24.0	45.7
25 - 44	13	12	75	9.2	7.3	-	-	0	62.8	17.4	6.3	2.4	32.8	52.2
44 - 68	17	10	73	9.4	7.3	-	-	0	68.0	11.0	4.4	2.2	43.6	64.1
68 - 75	21	14	65	9.5	7.2	-	-	0	64.0	11.7	4.0	2.0	42.4	66.3

NOTE: Salinity and Alkalinity is assessed on the basis of the top 36 inches of the Soil Profile.

Depth Inches	EC_e 1:5 Mlmhos cm	EC_e Sat. Mlmhos cm	COMPOSITION 1:5 H_2O EXTRACT ME/LITRE Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
0 - 4	0.5	2.3	0.51	0.20	0.16	2.60	1.96	0.04	0.70	2.35
4 - 25	2.3	-	0.20	0	0.08	20.80	14.36	2.04	2.75	5.40
25 - 44	3.6	4.6	0.08	0	0.08	32.80	25.48	2.95	1.0	5.40
44 - 68	3.1	-	0.08	0	0.04	28.60	20.28	1.20	0.80	7.90
68 - 75	2.7	3.3	0.06	0	0.03	24.60	17.19	0.30	1.20	5.60

Soil Profile: Dark brown over Reddish brown clay.
Pit Location R_{11} A_o

Relief-Plane: Base of slope facing North East.

Rooting Depth - 60 inches.

Maximum Rooting Density - 0 to 2 inches.

Vegetation cover - 10% herbs: Cyperus alopecuroides, Cyperus rotundus retzii, Crotalaria sp., Pluchea ovalis.
- 90% Grass: Echinochloa colonum (70%) Panicum meyerianum (10%).

Land Use - Grazing

Map Symbol: II

Lab. No. 4402: Depth 0 to 12 inches.

The moist topsoil (0 to 2 inches) is dark brown (10 YR 3/3); 2 to 12 inches is dark yellowish brown (10 YR 3/4). The soil comprises friable clay of a weakly developed sub-angular blocky and crumb structure. Roots, which are abundant in the top 2 inches and common thereafter, are fine and medium. Reaction with 10% hydrochloric acid is strong. pH = 6.9. The lower boundary is even and clear.

Lab. No. 4403: Depth 12 to 29 inches.

The soil is a dark greyish brown (10 YR 4/2 moist) clay; very hard, with a strongly developed, medium and fine, blocky structure. Thin clay cutans are evident, as are fine black (Mn?) concretions. Medium sized lime spots are few. Reaction with 10% hydrochloric acid is violent on the line spots, strong on the matrix. There are few fine roots. The lower boundary is abrupt but undulating. Streaks of this horizon can be found in horizon 3. pH = 7.4.

Lab. No 4404: Depth 29 to 43 inches

The moist matrix is yellowish red (5 YR 4/8) but there are present abundant blotches of reddish brown (5 YR, 5/4) and dark brown (10 YR 3/3, 7.5 YR 4/2) material. The soil is a somewhat massive clay with large lime spots. Fine to large calcareous stonesdecrease with depth. There are few fine roots. The reaction with 10% hydrochloric acid is violent. pH = 7.7. The lower boundary is irregular and diffuse.

Lab. No. 4405: Depth 43 to 73 inches.

The moist soil is reddish brown (5 YR 4/3) clay with abundant black and grey mottles and much cutanic material. The structure is of moderately developed medium sized blocky peds. Black (? Mn) concretions are common, and there are few medium and large lime spots. Few fine black stones and few large caliche pebbles increase with depth. The reaction of the matrix with 10% hydrochloric acid is moderate, yet violent on the lime spots. Roots are rare. pH = 8.1. The lower boundary is irregular and abrupt.

Below 73 inches = caliche.

TABLE 1 b

Brown Over Reddish brown Clay | Pit Ref. $R_{11}A_o$ | Lab.No.4402 to 4405

Depth Inches	TEXTURE %			pH 1:5		% C	% N	ppm P	CEC ME/100g SOIL	EXCHANGEABLE BASES ME/100g SOIL				EXCH. Na% (ESP)
	Sand	Silt	Clay	H_2O	KCl					Ca	Mg	K	Na	
0 - 12	17	14	69	8.9	6.9	0.84	0.09	0	65.5	30.8	7.8	2.1	1.3	1.9
12 - 29	13	14	73	9.6	7.4	-	-	0	65.5	13.2	9.4	1.6	18.0	27.5
29 - 43	27	18	55	9.8	7.7	-	-	0	46.0	12.2	5.4	1.5	21.4	46.5
43 - 73	17	16	67	9.9	8.1	-	-	2	65.5	6.4	2.3	2.3	37.4	57.1

Depth Inches	EC_e 1:5 mlmhos cm	ECe Sat mlmhos cm	COMPOSITION 1:5 H_2O EXTRACT ME/LITRE							
			Ca	Mg	K	Na	Cl.	SO_4	CO_3	HCO_3
0 - 12	0.2	-	0.51	0.32	0.06	1.0	0.64	0	0.60	2.23
12 - 29	0.7	-	0.08	0	0.08	8.60	0.56	0.02	2.40	5.75
29 - 43	1.4	1.85	0.10	0	0.04	13.60	0.80	0.24	4.80	6.75
43 - 73	1.4	2.1	0.08	0	0.04	17.60	0.24	0.20	9.0	4.90

TABLE 1 c

Brown Saline - Alkaline Clay

Map Symbol II

	TEXTURE %		pH 1:5		% C	ppm	CEC ME/100g SOIL	EXCHANGEABLE BASES			EXCH. Na % (ESP)
	Silt	Clay	H_2O	KCl				Ca	Mg	K	
MEAN 1	12	61	8.8	6.7	1.0	4	52	17	6	3	2.7
MEAN 2	13	73	9.3	7.4	-	2	57	11	8	2	43.0

	EC_e 1:5 mlmhos/cm	EC_e Sat mlmhos/cm	COMPOSITION 1:5 H_2O EXTRACT ME/LITRE							
			Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
MEAN 1	0.3	2.3	0.2	0	0.2	1.4	0.8	0.1	0.5	1.7
MEAN 2	2.9	12.2	0.1	0	0	23.0	15.0	2.1	2.0	5.2

Pit Location $R_{22}A_1$ E

Soil Profile: Brown Non-Saline, Alkaline Clay.

Relief - Plane.

Rooting Depth - 50 inches.

Maximum Rooting Density - 0 to 4 inches.

Vegetation Cover - Weed Species: Abutilon mauritianum 20%
Aspilia sp. 10% Indigofera tinctoria 10%.
Pluchea Ovalis 10%.

Also recorded (10% cover) are: Aerva lanata, Chenopodium opuliferum, Pavonia propinqua, Ipomoea mombassana, Euphorbia hirta, Corchorus trilocularis, Sorghum sp. and Echinochloa colonum.

Situation: On edge of cassava, beans, maize and paw paw.

MAP SYMBOL: III

Lab. No.4458: Depth 0 to 6 inches.

The soil is dark brown (7.5 YR 3/2 moist) clay; slightly hard, with a moderately developed sub-angular blocky and crumb structure. Fine roots are abundant. Grey organic residues can be seen. There are also few, fine and medium pieces of gravel. This soil demonstrates a strong reaction with 10% hydrochloric acid; pH = 6.7. The lower boundary is undulating and gradual.

Lab. No. 4459: Depth 6 to 26 inches.

The soil is a somewhat firm dark brown (7.5 YR 3/2 moist) clay; speckled with dark coarse sand grains (fine and common), containing mixed gravel of a fine and medium size; with a weak to moderately developed sub-angular blocky structure of medium sized peds. Medium sized pebbles of caliche are rare. There are few fine roots. This soil demonstrates a strong reaction with 10% hydrochloric acid; pH 6.7. The lower boundary is even, but diffuse.

Lab. No. 4460: Depth 26 to 48 inches.

The soil is a dark brown (7.5 YR 3/2 moist) firm clay, having darker faces on the peds, which are moderately developed coarse sub-angular blocky. Considerable clay cutans are evident. Roots are rare. With the mixed gravel (of a few; fine and medium units) are occasional medium sized lime spots. There are also a few old white root channels. This soil demonstrates a strong reaction with 10% hydrochloric acid: pH = 6.7.

Lab. No. 4461: Depth 48 inches plus.

The soil is a reddish brown (5 YR 4/4 moist), slightly firm clay, more or less structureless, with abundant red, grey and blue mottling with accompanying faces on the peds. Very occasional black root channels are also present. Abundant caliche pebbles of a wide size range constitute a considerable part of the matrix, but conditions in the field indicate that this layer should have a rather rapid permeability. The caliche tends to increase with depth. Large lime spots are common, and the soil demonstrates a moderate to strong reaction with 10% hydrochloric acid. pH = 6.7.

TABLE 2 a

Prown Non-saline, Alkaline Clay — Pit Ref. $R_{11}A_1E$. — Lab.No.4406 to 4408

Depth Inches	TEXTURE %			pH 1:5		%C	%N	ppm P	CEC ME/100g SOIL	EXCHANGEABLE BASES ME 100g SOIL				EXCH. Na % (ESP)
	Sand	Silt	Clay	H_2O	KCl					Ca	Mg	K	Na	
0 - 7	27	18	55	8.9	7.7	1.7	0.2	5	58.5	25.6	6.2	6.1	0.9	1.5
7 - 28	19	12	69	8.9	7.3	-	-	0	60.0	23.4	8.4	2.1	1.7	2.8
28 - 63	17	12	71	9.4	7.1	-	-	0	58.5	11.3	10.8	1.9	9.0	15.4

Depth Inches	EC_e 1:5 Mlmhos cm	EC_e Sat. mlmhos cm	COMPOSITION 1:5 H_2O EXTRACT ME/LITRE							
			Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
0 - 7	0.3	2.0	0.55	0.40	0.55	0.95	0.98	0.02	0.45	2.30
7 - 28	0.3	1.0	0.27	0.32	0.04	1.55	0.48	0.02	0.50	2.10
28 - 63	0.7	1.0	0.05	0.0	0.06	6.15	0.44	0.12	1.54	4.60

TABLE 2 b.

Brown Non-saline Alkaline Clay

Map Symbol III

	TEXTURE %		pH 1:5		% C	ppm	CEC	EXCHANGEABLE BASES ME/100g SOIL			EXCH.
	Silt	Clay	H_2O	KCl		P	ME/100g SOIL	Ca	Mg	K	Na % (ESP)
MEAN 1	19	58	8.7	7.2	1.5	12	53	25	5	6	1.5
MEAN 2	13	66	9.0	6.9	-	1	52	16	9	2	12.4

	EC_c 1:5 Mlmhos cm	EC_e Sat. mlmhos cm	COMPOSITION 1:5 H_2O EXTRACT ME/LITRE							
			Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
MEAN 1	0.4	1.4	0.6	0.5	0.6	1.0	1.1	0	0.8	2.4
MEAN 2	0.7	0.5	0	0	0.1	4.6	0.3	0.1	1.4	3.6

Pit Location $R_{16}A_4$ E.

Soil Profile: Reddish Brown Non-saline Non-alkaline clay.

Relief - Plane.

Rooting Depth - 19 inches.

Maximum Rooting Density - 0 to 5 inches.

Vegetation Cover - Weeds and Maize.

Land Use: - Maize Cultivation.

Map Symbol: IV.

Lab. No. 4425: Depth 0 to 10 inches.

The soil is dark reddish brown (5 YR 3/3 - moist) clay; soft, with a weakly developed subangular blocky and crumb structure. Fine roots are common. There is no reaction with 10% hydrocloric acid. pH = 7.1. The lower boundary is gradual and undulating.

Lab.No. 4426: Depth 10 to 34 inches.

The soil is a dark reddish brown (2.5 YR 2/4 moist) friable clay with common faintly dark mottles. It has a weakly developed, medium sized sub-angular blocky structure, and contains few fine units of gravel and red flakes of stone. The roots are fine and few and a certain proportion of these are decaying. Coarse but faint lime spots are also present. Below 15 inches there is a moderate reaction with 10% hydrochloric acid; from 10 to 15 inches there is only a slight reaction. pH = 6.9. The lower boundary is even and gradual.

Lab. No. 4427: Depth 34 to 47 inches.

The soil is a dark reddish brown (5 YR 3/4 moist) firm clay with dark mottling and red speckles. It has a weakly developed, fine to coarse sized, sub-angular blocky structure and the horizon becomes very moist with depth. It contains common units of a fine gravel, and rare medium sized lime spots. The peds have brown cutans. Roots are rare. Reaction with 10% hydrochloric acid varies from moderate to strong. pH = 6.9. The lower boundary is undulating but abrupt.

Below 47 inches are found more than 50% units of caliche.

TABLE 3 a

Reddish Brown Non-saline, Non-alkaline Clay   Pit Ref. $R_{16}A4$ E.   Lab. No. 4425 to 4427

Depth Inches	TEXTURE % Sand	Silt	Clay	pH 1:5 HO_2	KCl	% C	% N	ppm P	CEC ME/100g SOIL	EXCHANGEABLE BASES ME/100g SOIL Ca	Mg	K	Na	EXCHANGEABLE Na % (ESP)
0 - 10	19	24	59	9.1	7.1	1.34	0.16	50	46.8	19.6	4.9	4.4	0.5	1.1
10 - 34	19	18	63	8.6	6.9	-	-	11	45.8	20.4	4.3	3.2	0.6	1.3
34 - 47	17	16	67	8.5	6.9	-	-	4	46.8	23.4	7.0	1.5	0.7	1.5

COMPOSITION 1:5 H_2O EXTRACT

Depth inches	EC_e 1:5 mlmhos/cm	EC_e Sat mlmhos/cm	Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
0 -10	0.1	0.6	0.02	0	0.25	0.30	0.16	0.10	0.20	1.45
10 - 34	0.2	-	0.42	0	0.15	0.40	0.38	0.02	0.40	2.08
34 - 47	0.3	0.7	0.42	0.36	0.04	0.50	0.44	0	0.45	1.98

TABLE 3 b

Reddish Brown Non-saline, Non Alkaline Clay — Map Symbol IV

	TEXTURE %		pH 1:5		% C	ppm	CEC	EXCHANGEABLE BASES ME/100g SOIL			EXCHANGEABLE
	Silt	Clay	H_2O	KCl		P	ME/100g SOIL	Ca	Mg	K	Na % (ESP)
MEAN 1	23	62	8.6	6.6	1.3	29	47	19	4	6	1.4
MEAN 2	17	59	8.5	6.6	-	9	46	19	5	4	1.1

	EC_e 1:5 mlmhos/cm	EC_e Sat mlmhos/cm	COMPOSITION 1:5 H_2O EXTRACT ME/LITRE							
			Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
MEAN 1	0.3	1.4	0.3	0.1	0.6	0.7	1.0	0	0.4	1.4
MEAN 2	0.3	0.8	0.4	0.2	0.3	0.4	0.3	0	0.4	1.9

Soil Profile: Reddish Brown Saline Clay with Caliche in top 40 inches. Pit location R_2 A_8 E.

Relief - Plane.

Rooting Depth - 23 inches.

Maximum Rooting Density - 0 to 5 inches.

Vegetation Cover - 100 %

Grass 90 % Cynodon dactylon 80 %
Cenchrus ciliaris 10 %

Herbs 10 %. Abutilon mauritianum, Achyranthes aspera, Coccinia sp., Commelina sp., Justicia flava, Cissus quadrangularis, Pluchea dioscoridis, Ocimum hadiense, Solanum campylacanthum, Pupalia lappacea.

Bush: Acacia tortilis spirocarpa, Cassia bicapsularis, Maerua sp.

Land Use - Severe grazing.

Map Symbol - VII

Lab. No. 4371: Depth o to 6 inches.

The soil is a dark reddish brown (5 YR 3/3 moist) clay, friable with a crumb structure. Fine roots are abundant and there is much organic matter. The reaction with 10% hydrochloric acid is slight; pH = 6.4 The lower boundary is even and diffuse.

Lab. No. 4372: Depth 6 to 23 inches.

The soil is a dark reddish brown (5 YR 3/3 moist) clay, with a weakly developed madium and fine sub-angular blocky structure. Slight cutans are evident as are few, large caliche pebbles. Fine roots are common. There is a moderate reaction with 10% hydrochloric acid below 20 inches; pH = 6.4. The lower boundary is irregular and abrupt.

Below 23 inches; Caliche.

TABLE 4 a (1)

Reddish Brown Saline Clay with Caliche in Top 40 inches   Pit Ref: R_2A_8E Lat. No.4371 to 4372

Depth Inches	TEXTURE %			pH 1:5		% C	% N	ppm P	CEC ME/100g SOIL	EXCHANGEABLE BASES ME/100g				EXCH, Na % (ESP)
	Sand	Silt	Clay	H_2O	KCl					Ca	Mg	K	Na	
0 - 6	19	16	65	8.1	6.4	1.36	0.13	28	48.0	17.2	4.9	7.5	0.7	1.4
6 - 23	27	12	61	8.0	6.4	-	-	18	48.8	22.0	6.0	3.5	0.9	1.8

Depth Inches	EC_e 1:5 mlmhos cm	EC_e Sat. mlmhos cm	COMPOSITION 1:5 H_2O EXTRACT ME/LITRE							
			Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
0 - 6	0.6	3.5	0.68	0.26	1.30	1.30	3.36	0.20	0	1.55
6 - 23	1.2	8.1	1.82	1.56	0.39	3.45	7.48	1.74	0	1.80

TABLE 4 a (ii)

Reddish Brown Saline Clay
with Caliche in top 40 inches
and surface devoid of vegetation.

Lab. No. 4512 to 4513

Depth inches	TEXTURE %			pH 1:5		EC 1:5 mlmhos/cm	ppm P
	Sand	Silt	Clay	H_2O	KCl		
0-12	31	20	49	7.8	6.6	5.1	19
12 - 24	29	14	57	8.5	6.5	1.1	3

CONTD/31..

Soil Profile: Reddish Brown Saline Clay with Caliche below 40 inches. Pit Location R_2 A_4 E.

Relief - Plane.

Rooting Depth - 45 inches.

Maximum Rooting Density - 0 to 9 inches.

Vegetation cover - 100%.

Bush: 30%, Dobera glabra, Maerua sp. 10%, Acacia mellifera mellifera 20%.

Herbs: 10% including Talinum portulacifolium, Neuracanthus scaber, Disperma sp., Achyranthes aspera, Hibiscus flavifolius Ornithogalum longibracteatum, Cissus quadrangularis.

Grass 60%; Cynadon plectostachyus.

Land Use - Nil

Map Symbol - V.

Lab. No. 4474: Depth 0 to 8 inches.

The soil is a dark reddish brown (2.5 YR 2/4 moist) clay; soft, with a weakly developed sub-angular blocky and crumb structure of fine sized peds. Fine and medium roots are abundant. There is no reaction with 10% hydrochloric acid; pH = 6.9. The lower boundary is clear and tongues into the second horizon.

Lab. No. 4475: Depth 8 to 28 inches.

The soil is a dark reddish brown (2.5 YR 3/4 moist) clay; hard, with a moderately developed sub-angular blocky and crumb structure of fine and medium sized peds. Very slight clay coatings are evident. Fine and medium roots are common. The soil tastes salt. There is no reaction with 10% hydrochloric acid; pH = 6.7. The lower boundary is even and gradual.

Lab. No. 4476: Depth 25 to 45 inches.

The soil is a dark reddish brown (2.5 YR 3/4 moist) clay; hard, with a moderately developed sub-angular blocky and crumb structure of fine and medium sized peds. Slight clay coatings are evident. Fine roots are common. The soil tastes salt. There is moderate reaction with 10% hydrochloric acid; pH = 6.6. The lower boundary is abrupt and irregular.

Below 45 inches; Caliche.

TABLE 4 b (i)

Reddish Brown Saline Clay with Caliche below 40 inches   Pit Ref. $R._2A._4E$ Lab No. 4474 to 4476

Depth inches	TEXTURE % Sand	Silt	Clay	pH 1:5 H_2O	KCl	%C	%N	ppm P	CEC ME/100g SOIL	EXCHANGEABLE BASES ME/100g SOIL Ca	Mg	K	Na	EXCH. Na % (ESP)
0-8	19	17	64	8.3	6.9	1.01	0.13	106	43.5	10.0	4.0	6.2	0.25	0.6
8-28	25	15	60	7.4	6.7	-	-	32	41.2	9.3	3.7	4.8	0.6	1.5
28-45	25	23	52	7.6	6.6	-	-	50	46.0	13.2	5.0	5.8	2.7	5.9

Depth inches	EC_e 1:5 mlmhos/cm	EC_e Sat mlmhos/cm	COMPOSITION 1:5 EXTRACT ME/LITRE Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
0 - 8	0.1	0.6	0	0	0.52	0.30	0.27	0.20	0	1.22
0 -28	3.6	-	7.72	3.45	1.68	4.0	25.96	0.70	0	1.40
228-45	3.8	20.4	3.0	2.5?	1.60	14.80	23.0	2.43	0	1.30

CONTD/33...

TABLE 4 b (ii)

Section through a Termite Mound — Pit Ref. R_5A_3W — Lab. No.4488 to 4489

Depth inches	TEXTURE % Sand	Silt	Clay	pH 1:5 H_2O	KCl	% C	% N	ppm P	CEC ME/100g SOIL	EXCHANGEABLE BASES ME/100g SOIL Ca	Mg	K	Na	EXCH. Na % (ESP)
0 - 12"	30	24	46	8.0	6.4	0.50	0.17	40	41.2	12.1	3.1	5.8	1.1	2.5
12 - 36"	30	20	50	7.6	6.4	-	-	33	35.5	9.4	3.5	5.9	2.1	5.9

Depth inches	EC_e 1:5 mlmhos/cm	EC_e Sat mlmhos/cm	COMPOSITION 1:5 EXTRACT ME/LITRE Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
0 - 12"	1.8	-	1.74	0.75	1.52	3.70	7.02	1.65	0	1.76
12 - 36"	4.0	-	3.84	2.50	2.40	14.0	24.44	2.80	0	1.70

TABLE 4 b (iii)

Reddish Brown Saline Clay

Map Symbol V & VI

	TEXTURE % Silt	Caly	pH 1:5 H_2O	KCl	% C	ppm P	CEC ME/100g SOIL	EXCHANGEABLE BASES ME/100g SOIL Ca	Mg	K	EXCH. Na % (ESP)
MEAN) 1	17	60	8.0	6.7	1.2	35	43	15	3	6	1.6
RANGE) 1	13-24	54-69	7.2-9.0	6.2-7.6	-	1-238	33-49	8-29	2-5	4-7	<1-7
MEAN) 2	20	58	8.0	6.6	-	30	42	14	6	5	9.8
RANGE) 2	13-26	49-69	7.0-9.1	6.1-7.1	-	Tr-78	32-50	9-22	2-12	3-7	<1-28

	ECe 1:5 mlmhos/cm	ECe SAT mlmhos/cm	COMPOSITION 1:5 H_2O EXTRACT ME/Litre Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
MEAN) 1	0.9	1.2	0.2	0	0.7	0.7	0.9	0.3	0.1	1.3
RANGE) 1	0.1-2.6	0.5-3.5	0-1.1	0-0.3	0.3-1.3	0.2-2.0	0.2-3.4	0-1.2	0-0.4	0.8-2.1
MEAN) 2	3.3	11.5	1.7	1.4	0.9	15	17	2.1	0.2	1.6
RANGE) 2	0.3-9.6	0.7-28.2	0-4.6	0-5	0.2-1.8	0.5-58	0.5-54	0-7.4	0-1.0	0.9-2.8

Pit Location R_{16} A_8E

Soil Profile: Reddish Brown Saline Clay with Ground Water significantly influencing the Profile.

Relief - Plane

Rooting Depth - 72 inches.

Maximum Rooting Density - 0 to 6 inches.

Vegetation Cover - 100 %.

40 % Bush - Dobera glabra 20 %, Azima tetracantha 10 %. Also Acacia tortilis spriocarpa, Cadaba ruspolii, Commiphora sp., Cassia bicapsularis, Cissus rotundifolia. 20 % Herbs - Abutilon maritianum 10 %, Indigofera tinctoria 10 %. Also Indigofera schimperi, Justicia flava, Ruellia patula, Sonchus excauriculatus, Pluchea ovalis, Cissus quadrangularis. 40 % Grass - Cynadon plectostachyus 40 %, also Cenchrus ciliaris.

Land Use - Nil.

Map symbol - None.

Lab No. 4440: Depth 0 to 4 inches.

The soil is a dark reddish brown (5 YR 3/4 - moist) clay, varying from soft to slightly hard consistence, with a moderately developed crumb and sub-angular blocky structure. Fine to large roots are abundant. No reaction with 10 % hydrochloric acid; pH = 7.1. The lower boundary is clear but undulating.

Lab No. 4441: Depth 4 to 8 inches.

The moist soil is a dark reddish brown (2.5 YR 3/4) friable clay with a weakly developed crumb and sub-angular blocky structure. The soil tastes salt and salt crystals are visible on the ped surfaces. There are also clay cutans on the peds. Fine and medium roots are abundant. No reaction with 10 % hydrochloric acid; pH = 7.1. The lower boundary is clear and even.

Lab No. 4442: Depth 8 to 33 inches.

The moist soil is a dark red (2.5 YR 3/6) but speckled friable clay with a moderately developed, medium and coarse sized sub-angular blocky structure. The speckles are black, and possibly are incipient manganese concretions. Black deposits aling root channels are common. There are also common black manganese concretions, and few very fine units of gravel. Fine and medium roots are common. The soil tastes salt. Very fine white salt crystals are common. There is a very slight reaction with 10 % hydrochloric acid; pH = 6.8. The lower boundary is even but diffuse.

Lab No. 4443: Depth 33 to 52 inches.

The moist soil is a dark reddish brown (2.5 YR 2/4) very friable and structureless clay with very slight cutans on the ped faces. Very faint grey and red mottling is abundant. Very fine black manganese concretions occur occasionally. The soil tastes salt but no salt crystals are visible. There are few fine and medium roots. There is a moderate reaction with 10 % hydrochloric acid; pH = 6.8. The lower boundary is even and gradual.

Lab No. 4444: Depth 52 to 72 inches

The wet soil is a dark red (2.5 YR 3/6) structureless clay. It is very slightly sticky, but non-plastic. There are a few units of medium sized caliche. There are also a few fine and medium roots. The reaction with 10 % hydrochloric acid varies from slight to moderate; pH = 7.1. The lower boundary is irregular and abrupt.

Below 72 inches is wet caliche. The ground water is highly saline. Table 4 c (i) below gives the analytical data for the ground water.

TABLE 4 C (i)

Ground Water Location Ref. R_{16} A_8 E

pH	EC_e millimhos /cm	Composition of the water ME/Litre									Sodium absorption Ratio
		Ca	Mg	K	Na	Cl	SO_4	NO_3	CO_3	HCO_3	(SAR)
8.2	9.0	0.42	1.09	1.03	45.0	6.58	11.73	0	1.86	14.36	51

TABLE 4 c (ii)

Reddish Brown Saline Clay with Ground Water Significantly influencing the Profile

Pit Ref R_{16} A_8 E · Lab. No. 4440 to 4444

Depth Inches	TEXTURE % Sand	Silt	Clay	pH 1:5 H_2O	KCl	% C	% N	ppm P	CEC ME/100g SOIL	EXCHANGEABLE BASES ME/100g SOIL Ca	Mg	K	Na	EXCH. Na % (ESP)
0 - 4	23	20	57	8.0	7.1	1.68	0.22	45	38.0	17.2	1.9	5.9	0.8	2.1
4 - 8	25	14	61	7.5	7.1	-	-	14	32.0	12.8	1.1	5.6	2.8	8.6
8 - 33	23	22	55	7.2	6.8	-	-	15	32.0	11.7	1.7	5.0	6.0	18.8
33 - 52	17	22	61	9.3	6.8	-	-	19	33.5	7.0	2.0	3.8	8.8	26.2
52 - 72	17	26	57	9.5	7.1	-	-	20	34.5	6.1	1.8	3.5	9.6	27.8

Depth inches	EC_e 1:5 mlmhos/cm	EC_e Sat Mlmhos/cm	COMPOSITION 1:5 H_2O EXTRACT ME/LITRE Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
0 - 4	0.4	1.7	0.63	0	0.84	1.45	0.8	0.02	0.65	2.57
4 - 8	1.6	-	1.02	0	0.96	7.40	8.24	1.80	0	1.10
8 - 33	3.4	21.4	1.84	0	1.04	21.24	22.20	3.48	0	1.06
33 - 52	2.7	-	0.21	0	0.21	22.35	13.30	3.64	1.45	3.90
52 - 72	1.8	8.5	0.10	0	0.08	14.20	3.32	2.16	0.90	2.80

TABLE 4 c (iii)

Reddish Brown Saline Clay with Ground Water significantly influencing the Profile

	TEXTURE %		pH 1:5		% C	ppm P	CEC ME/100g Soil	EXCHANGEABLE BASES ME/100g SOIL			EXCH. Na %
	Silt	Clay	H_2O	KCl				Ca	Mg	K	
MEAN 1	18	60	8.3	6.7	1.3	44	38	14	3	6	11
MEAN 2	21	58	8.4	6.7	-	14	36	12	4	5	17

	EC_e 1:5 mlmhos/cm	EC_e Sat mlmhos/cm	COMPOSITION 1:5 H_2O EXTRACT ME/LITRE							
			Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3
MEAN 1	0.3	1.0	0.2	0	0.5	1.2	0.7	0.1	0.2	1.6
MEAN 2	1.7	14.8	1.5	0.4	0.7	19.0	17.0	3.8	0.1	1.4

APPENDIX 4

SOIL PERMEABILITY EXPERIMENTS

Experimentation was performed on (I) Undisturbed soil cores in the laboratory and (II) Soil horizons in the field.

These provide some indication of initial infiltration rates and ultimate soil permeability. inadequate permeability is not only undesirable from the point of view of the plant roots, but also may prevent leaching or lead to an increase in salinity over the years. Excessive permeability on the other hand would increase the effective water consumption, thereby raising costs of production.

Results indicate that initial infiltration rates (for the first half an hour) are moderately slow (120-500 m.m. per 24 hours) on the Reddish Brown Clays regardless of whether they are saline and alkaline or not. As leaching procedes, permeability gradually falls in both the saline-alkali clays and the saline, non-alkali clays. Permeability rates after 16 hours of leaching are generally slow (around 100 m.m. per 24 hours); some of the saline and alkali reddish brown clays showed a very much greater decrease in permeability than others. Clearly the saline and alkali clays in the South East of Kamleza North are in a critical condition in the sense that a slightly higher alkali content or a specific variation in clay content may lead to clay dispersion after leaching and the development of impermeable layers.

The analyses of the Brown Saline - Alkali clay clearly show that these soils are unsuitable for irrigation agriculture. A test was, however, carried out on the Brown Non-Saline, alkali clay. Permeability after 5 hours leaching was 8.6 m.m. per 24 hours (the minimum desirable permeability = 30 m.m. per 24 hours). After 21 hours, permeability had further decreased to 3.4 m.m.per 24 hours. After several days permeability was practically nil. These soils would require careful treatment and are therefore not recommended for use under irrigation. They would however be capable of growing somewhat indifferent crops without irrigation.

APPENDIX 5. "SOIL CONDITIONS" IN RELATION TO BANANA GROWTH.

The banana requires a relatively deep, well drained loamy soil. Jacob and Von Uexkull (1960) state that "with adequate irrigation and fertilizer treatment light permeable soils are greatly preferable to heavy ones". Heavy soils should be in excellent structural condition to ensure good drainage and deep rooting. The best soils have an optimum pH range of 6.5 to 7.5 (Jacob and Von Uexkull, 1960). It is well known that low pH levels favour the spread of Panama disease, but Simmonds (1959) considers that "mhere Panama disease is not serious or where resistant clones are cultivated, it would seem that pH, within wide limits, is unimportant". The Institute Francais de Recherehes Fruitieres Outre-mer (hereafter referred to as I.F.R.F.) has found that the banana can tolerate a wide range of pH, from 4.5 to 8.0. Experience in Ecuador has shown that bananas do well within pHs. of 7 to 8, provided the soil structure permits good drainage. In the Jordan valley, Cavendish bananas are grown economically on soil with up to 40% lime and a pH of "8 and over". Alkali chlorosis, causing a condition known as "plant failure", has been reported from Haiti (Wardlaw, 1961) on soil of pH 7.5 to 9.2. Wardlaw considers that the symptoms of alkali chlorosis may be due to essential nutrients being rendered unavailable by the "alkali complex" but are also a direct result of alkali toxicity possibly caused by soil bicarbonate.

There seems to be general agreement over the need for good drainage, though this requirement appears to be subject to varity differences. It is reported from Fiji that with a water table above 3 feet Veimama bananas suffered decreased growth whereas healthy stools of Cavendish and Lady's Finger existed even where the water was within 2 feet of the surface.

The crop's water requirements are especially high. Simmonds (1959) recommends water applications every 5 to 10 days. In the Jordan valley, Cavendish bananas require about 50% extra irrigation water over and above the calculated water requirement. It is suggested that this additional water is necessary not only to maintain the concentration of salts at a favourable level (the leaching requirement), but also to reduce soil temperature. A report from the U. S. salinity laboratory (Riverside, California) also points out that the soil temperature may be involved in crop responses.

Under the conditions of the Jordan valley, the range between field capacity and two thirds of total available water constitutes the optimum range of soil moisture for Cavendish bananas. Between successive water applications, the moisture content of the root zone may drop below the optimum range; the longer the duration of sub-optimal conditions, the greater the loss of assimilation products. Application of the Blaney-Criddle formula to Taveta conditions (assuming a mean temperature of 70° to 75°F; with a banana consumptive use factor of 0.95) would suggest that the monthly water requirements will be of the order of 5.8 inches.

lbs/acre Nutrients removed by crops of varying yield

Crop Yield Tons per acre	N	lbs per acre per year K_2O	P_2O_5
30	56	201	18
12	No data	170	13
6	"	85	6
3	"	43	3

The loss of organic matter resulting from lowered fertility or excessive cultivation can be serious since this leads to degenerate structure and consequent impeded drainage. Nitrogen (N) is often the first nutrient to lomit yields, and a loss of organic material may be associated with loss of N. Heavy applications of trash mulch can mitigate this loss to some extent. N should be applied in as frequent and small a dressing as is economically feasible.

Bananas require rich soils if consistently good yields are to be obtained. This applies to all cultivated varieties, but to some more than others (Wardlaw, 1961). Removal of Potassium (K) is at a very high rate, whereas the plant intake of Calcium (Ca) is relatively low. Bananas are very sensitive to disquilibrium between the cations, and there is general agreement that the K: N and K: (Ca + Mg) ratios play an important role in banana nutrition, and in the quality and keeping properties of the product (Mg = Magnesium). According to Jacob and Von Uexkull (1960) the crop requires K at between 3 and 5 times the quantity of N. Excess K can, however, cause the disease 'yellow pulp' (a premature yellowing and softening of the banana flesh), whilst some varieties of Cavendish are susceptible to fungus if the soils are deficient in K. In Guinea an optimum K:N of 1.3 to 1.7 is proposed. Work in Cameroon, however, suggests a K:N of 3 to 3.5.

Ca and Mg may have a two-fold role in banana physiology: they act as nutrients, and also their ions tend to readjust disequilibrium caused by excess K. Wardlaw (1961) believes that, in practice, each soil should be treated as a separate problem with regard to ionic disequilibrium.

Since the time taken to maturity is of great economic importance for the marketing of an expert crop, it should be noted that maturity is usually hastened by applications of N, response varying up to a 20% reduction of time to shooting. The rate may be depressed by applications of either P (Phosphate) or K in the absence of the other.

Fertilizers should be placed close to the roots at the time of planting.

NUTRIENTS	N	P_2O_5	K_2O
Lower limit of Adequacy in p.p.m.	1200	10 - 20	250 - 300

Higher levels of K may be required if the soils are alkaline, or contain much free lime.

⊠ Derived from Simmonds (1959)

Management practices in Somalia include Crotolaria as a green manure crop, guano and heavy doses of ammonium sulphate.

In 1936, Jacobs proposed 0.05 % salt as the upper limit of tolerance for bananas, which is equivalent to a soil electrical conductivity of around 1 millimho per cm (at 25°C). This proposal is supported by practical results in Jamica and in Honduras.

Rather than salt content per se, the I.F.R.F. considers that the chloride content of the (dried) soil is the factor limiting yields, and proposes 50 milligrams of chloride per 100 grams of dry soil as the critical level (possibly equivalent to around 14 m.eq. per litre of saturation extract). In Jamaica, investigations (quoted in Wardlaw, 1961) have shown that bananas are particularly sensitive to the chloride ion, as when muriate of potash (KCl) is used excessively as a source of K. In the Jordan valley, Wardlaw reports that certain non-infectious diseases of bananas have been traced to excessive concentrations in the soil of chlorides and bicarbonates of sodium, Together with excessive humidity and over-irrigation; in low-lying areas bananas were killed. In Somalia, however, bananas are regarded as being more sensitive to Calcium and Sulphate ions than to sodium or Chloride.

Pot experiments on Musa sapiens at Riverside showed that its leaves are injured by salts of both chloride and sulphate. Thus marginal leaf burn may be regarded as a general salinity effect rather than one caused specifically by chloride. M.sapiens is reported as suffering "minor leaf burn" at 4 millimhos/cm, though M.ensete, the inedible African banana, suffers injury at 2.5 millimhos. Under Californian conditions, therefore, it would appear that bananas are relatively salt sensitive, but that there are considerable varietal differences in salt tolerance. This general result is confirmed with Musa cavendishii (Dwarf Cavendish) in Somalia.

Banana plantations in Somalia on "fine textured" soils with an electrical conductivity of 8 to 9 millimhos have been abandoned after 5 years. These bananas showed evidence of leaf tip burn and marginal burning, with a general purplish appearance and unthrifty growth. Experience on the Guiba River (near Margherita, North of Chisimaio) with irrigated bananas has suggested the following tolerance limits:-

Electrical Conductivity Millimhos per cm.		⊠ Sodium Adsorption Ration	
0 - 2	Excellent	0 - 10	Bananas unaffected.
2 - 4	Yield slightly affected	10 - 15	Yield severely affected.
4 - 8	Yield moderately affected.		
8	Yield uneconomic.		

The quality of the irrigation water is also important: for good results in Somalia the salt content should have a conductivity below 1.3 millimhos per cm., and should contain only low levels of sulphate.

The I.F.R.F is, however, concerned with the chloride concentration within the irrigation water, and has suggested that water containing up to 8 - 10 m.eq. Chloride per litre may be recommended for use. In the Jordan valley, however, the concentration of Chloride is permitted to reach 11 m.eq. per litre. In the view of the I.F.R.F. 2.3 millimhos per cm is the upper limit for irrigation water electrical conductivity.

⊠ Sodium Absorption Ratio = $\dfrac{Na}{\sqrt{\dfrac{Ca + Mg}{2}}}$

APPENDIX 6

PLANT SPECIES COMMONLY OCCURRING IN KAMLEZA NORTH

Plants with an Abundant or Frequent Distribution are marked with a 'plus' sign

Abutilon mauritianum	+
Acacia bussei	
" drepanolobium	
" mellifera mellifera	+
" paolii	
" seyal seyal	+
" tortilis spirocarpa	+
Acalypha indica	
Achyranthes aspera	+
Adansonia digitata	
Aerva lanata	+
" persica	
Albizia anthelmintica	+
Amaranthus dubius	
Aristida adscensionis	
Aspilia sp.	
Asystasia charmian	
Azima tetracantha	+
Balanites glabra	
Brachiaria leersioides	
Cadaba glandulosa	
" ruspolii	
Capitanya otostegioides	
Capparis tomentosa	
Cassia bicapsularis	+
Cenchrus ciliaris	+
Chenopodium opuliferum	
Chloris roxburghiana	+
Cissus quadrangularis	+
" rotundifolia	+
Coccinia sp.	
Commelina sp.	
Commiphora sp.	+
Cordia ovalis	
" sp. near gharaf	
Crossandra stenostachya	
Crotolaria polysperma	
Crotolaria sp.	
Cyathula orthacantha	
Cynadon dactylon	+
" plectostachyus	+
Cyperus alopecuroides	+
" articulatus	+
" rotundus retzii	
Cyphostemma sp.	
Dactyloctenium aegyptium	
Dalechampia scandens	
Digera alternifolia	
Disperma sp.	+
Dobera glabra	
Drakebrockmania somalensis	+
Ecbolium revolutum	+
Echinochloa colonum	
" haploclada	
Enteropogon macrostachyus	
Eragrostis superba	
Erythrochlamys spectabilis	
Euphorbia hirta	+
" sp.	
Gloriosa simplex	
Gamphocarpus physocarpus	+
Grewia bicolor	
" similis	
" tenax	
" villosa	
Haarera alternifolia	
Helinus mystacinus	
Heliotropium strigosum	
Hermannia uhligii	
Hibiscus flavifolius	+
" vitifolius	
Hyphaene coriacea	
Indigofera schimperi	
" tinctoria	
Justicia caerulea	
" flava	+
Lannea stuhlmanii	
Lantana rhodesiensis	
leonotis nepetaefolia	
Leptochloa obtusiflora	
Leucas microphylla	
Lintonia nutans	
Maerua oblongifolia	
" sp.	
" subcordata	
Melhania ovata	
Melia azedarach	
Monechma debile	
Moringa oleifera	
Neuracanthus scaber	+
Ocimum hadiense	
Ornithogalum longibracteatum	
Orthosiphon sp.	
Panicum deustum	+
Panicum maximum	+
" meyerianum	+
Parquetina pigrescens	
Pavonia glechomifolia	
" propinqua	
Phragmites communis	
Phyllanthus maderaspatensis	
Pluchea dioscoridis	+
" ovalis	+
Polygonum selicifolium	
Pupalia lappacea	+
Rhynchosia mirima	+
Sericocomopsis pallida	
Sesamothamnus sp.	
Setaria pallide-fusca	
" verticillata	
Solanum campylacanthum	+
Sonchus exauriculatus	+
Sorghum sp.	
" vericilliflorum	
Sprobolus helvolus	
" marginatus	
" pyramidalis	
Suaeda monoica	

Svensonia laeta
Talinum portulacifolium
Triumfetta flavescens.
Withania somnifera.

This is the first record in Kenya of Haarera alternifolia.