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SOIL MANAGEMENT FOR MAIZE PRODUCTION IN THE CARIBBEAN

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INTRODUCTION

There is little experience in the Caribbean area in the commercial maize production and associated soil management requirements. As with all cereal crops, commercial maize production would involve complete mechanised systems and the problem of soil management would have to be considered with this in mind. Obviously, maize in some form is an old crop in the Caribbean where it is mainly grown in small cultivations, the main use of the crop being for green corn as a vegetable. Very little of this crop presently end up as grain corn used for livestock feed and it is for this purpose that the commercial production of maize is important in the region. Although there must be other examples of cultivation of corn for grain in the region, there are only three outstanding examples.

One of these is in Belize at Spanish Lookout where the Mennonite farmers have been cultivating maize for grain for up to 20 years. The crop is used as livestock feed mainly in their own farming but some of the grain is also sold outside of the settlement. The soil on which the crop is grown is a vertisol, an extremely fine textured soil with high montmorillonite content in the clay fraction. In this case the farmers, under normal conditions, could manage the soil for up to 2500 kg/ha of grain which is not a high yield with 100 kg/ha of a 12:24:12 fertilizer at planting plus 60 kg/ha urea six weeks later. Problems which the farmers have not yet been able to solve include soil fertility maintenance for continuous maize production, what constitute adequate drainage, the layout of the land and soil management for the growing of two maize crops in one year.

Another area where commercial cultivation of maize is being attempted is in Antigua where the Antiqua Agricultural Industries Limited aim at eventually cultivating over 5,000 ha in maize. This enterprise is only about three years old and it presently has a little over 1,000 ha cultivated, and therefore well below its target. The soils used are very fine textured clays rich in montmorillonite not unlike the Spanish Lookout soil of Belize. Fertilizer (20:12:12) at 600 kg/ha is applied at planting. Seedbed preparation for planting is done by discing, harrowing then cultivated with a spring tyne harrow (Widrich cultivator). All operations are mechanically done and there is a yield expectancy of 5,500 kg/ha.

In Guyana, the Caricom Corn/Soya Project has cultivated a fairly large area on free-draining brown, sandy soils with very low fertility and moisture retention properties. The main problems here are fertility maintenance where up to 80 percent of inputs is in fertilizers. Soil erosion is also a serious problem. This activity is several years old.

From the limited attempts at commercial maize cultivation in the region, it may be said that many problems of soil management have emerged and these are seriously affecting the commercial prospects of the crop. It may also be said that in all cases inadequate scientific investigations of potential soil problems were done prior to the launching of these schemes. This has resulted in incorrect field procedures which are proving very costly.

SOIL MANAGEMENT REQUIREMENTS

Soil management requirements for maize is a function of the type of soil and the particular weather characteristics during which the crop is to be grown. Soils of different textures and clay mineralogy would have different management requirements. Also, the particular weather and soil moisture regime in which the crop is to be grown would impose constraints on soil management. The problem will be discussed under the various soil requirements for the maize crop.

(i) Tillage: – Tillage requirements for maize appear to be influenced the world over by what is done in the mid-western U.S., without thinking of the particular conditions of soil, climate and degree of mechanisation which applies there. Thus in Antigua, Belize and Guyana on Vertisols in the first two and on a coarse textured sandy soil in the last case a deep fine seed-bed is prepared in the traditional sense. The purpose of soil tillage is to allow the seed to be inserted into the soil in the first place and to reduce the soil to sufficient fineness so that the roots of the crop could grow easily and maintain contact with the soil. It is also done with the aim of improving the structure of the soil so that the roots of the growing crop could grow more freely into the soil.

Tillage to the extent that is usually practiced in tropical soils particularly clay soils, with the main objective of improving the rooting volume of the soil probably does not fulfil this purpose for many soils. In fact there is some evidence that in clay soils, soil physical conditions In fact there is some evidence that in clay soils, soil physical conditions deteriorate in direct relationship to the extent of tillage (Ahmad and Paul, 1978). Since the structure of tropical soils is determined by special circumstances depending on whether the particular soil is a Vertisol, an Oxisol, an Ultisol etc., it is not surprising that traditional tillage practices may not necessarily improve soil physical conditions and could have different effects.

Excessive tillage, apart from possibly allowing the soil to compact to a greater degree than before the cultivation, is usually associated with accelerated soil erosion and loss of applied fertilizer by surface run-off. There are examples of this occurring in the three examples of commercial maize production in the Caribbean already referred to. It seems important that experiments should be done to determine the optimum tillage requirements for any soil to be used for maize cultivation. This is particularly important since in the Caribbean area as a whole, clay soils with differing soil mineralogy and behaviour are likely to be important maize-growing soils in the future. The effects of minimum tillage, over-tillage and zonal tillage on the soil and crop should be assessed before a cultivation regime for commercial maize production should be decided upon. Data are already available showing considerable soil physical deterioration on Vertisols in Belize following about 20 years of continuous maize cultivation.

The suitability and use of machines and implements in maize cultivation should also receive attention. In the case of Antigua, it would appear that the wrong type of machines was introduced from the inception. The adequacy of the particular machinery and implements should be studied in relation to its role in soil compaction, trafficability in the particular soil and the tillage requirements of the soil.

(ii) Soil drainage:- It is an established fact that maize is unlike many other graminaceous crop plants in being intolerant to poor soil drainage. Consequently, on land of little relief and on fine textured soils, land layout to facilitate drainage is a very important aspect of soil management. A suitable land layout must facilitate the surface drainage of much of the water that falls as rain in the wet season since the natural infiltrability and permeability of such soils is extremely poor.

The cambered bed was introduced in countries such as Guyana and Trinidad for the cultivation of sugar cane. This crop, being a more adaptable crop to poor soil drainage, performs more or less equally in all positions of the bed. Other crops have been tried on such beds but none have been as successful as sugar cane. Especially with maize, there is a very strong "edge" effect in which the rows of plants on the slopes of the bed perform much more poorly than the rows at the crest of the bed. This effect is noticeable almost everywhere maize is grown on cambered beds. In heavy clay soils increasing water- logged conditions in the wet seasons is evident from the crest of the bed to the sides. A cambered bed layout alone could be ruled out as an effective layout of a field in a flat area on clay soils as a means of adequately draining the soil for maize.

In addition to the constraint of the cambered bed on mechanisation this "edge" effect on crop productivity is important. Where differential soil drainage is not the main factor in differences in crop production across the camber, differences in soil fertility caused by piling top soil on the crest of the bed in making the cambered bed is noticeable by differential crop performance.

Alternative methods of soil drainage and land layout would have to be found. Some of these could be as follows:-

(i) Box-drains in association with cambered beds:- In this suggestion, box-drains between the cambered beds is proposed, the width and depth of the drains being variable and dependent on soil texture, amount of rainfall and land relief. In such a system, there must be effect means of collecting the water from these drains and draining it away from the cultivated area. Such drains would have to be graded to allow even and quick flow. The whole system is expensive to instal and a great problem to maintain with mechanised cultivation. The type of seedbed preparation now being practiced would be a problem to achieve, in this layout.

(ii) Mole-drains in association with cambered beds: Mole drains established across the camber have been effective in draining a very fine textured vertisol in the Spanish Lookout area of Belize. In such a layout, the cambered beds could be wider and in Belize, a width of about 20 metres is considered possible. The moles are made during the cultivation operations and it is not an expensive operation. This combination is now being tried in Guyana in sugar cultivation where the cost of making the moles is estimated to be about forty dollars (Guyana) per hectare. Such moles could be made for each planting although it is not now known whether this would be necessary. In clay soils where the subsoil drainage is good as in some of the fresh to brackish water swamp-derived soils of Guyana and Surinam, this layout has real promise. With a wider bed, mechanisation is easier and less of the land area is lost through drainage channels.

(iii) Individual banks:- In this layout, individual ridges are made for each row of maize. At the present time, this layout works well in land of some relief and in areas where the internal soil drainage is good as in some loamy soils of Trinidad. On clay soils and in areas of flat topography it is obvious that it would not work. However, if it is combined with land grading so as to imposed surface drainage in the area, it could well be successful. The layout has been fairly successful for sugar cane on clay soils in Trinidad. Some other advantages are very little land wastage in the form of drains and ease of mechanisation of all operations. Disadvantages are the very high cost of the initial land grading and the differential soil fertility that would be imposed for a crop such as maize. This layout again pre-supposes the establishment of an efficient system of receiving ditches which are well graded to enable even and rapid flow of water from the site.

As an alternative to land grading in association with individual ridges, land layout according to the contour as is done for rice cultivation could be tried. This, however, would impose some problems of making the ridges once the contour bunds have been built. If the right vertical interval is selected, the crop may well be cultivated on the flat without ridges and this would facilitate mechanisation. There is good reason to believe that in the more permeable of the clay soils in Guyana and Surinam, this layout could be successful. Drains would be built on the inside of the contour bund which would receive water from the level above that contour. Once again, an overall drainage system to drain the water collected by these contour ditches would be needed.

(iv) Flat planting:- This field layout, where no particular provision is made for external or internal soil drainage, is possible only on coarse textured soils with rapid internal drainage. In developing the vast areas of brown sands and loams in Guyana and Surinam, this feature is of great importance. Maximum use of the land area for the cultivation of the crop is achieved and the various mechanical operations are facilitated to a maximum degree. It is unsuitable for fine textured soils or soils of poor internal drainage.

(iii) Soil water relations:- It is recognised that maize, like most other cereal crops, has specific demands for water at the crop establishment and pre-tasseling through silking stages. If the soil is at field capacity or close to it just at planting and water can be extracted at low tensions just before tasseling through silking, water would not limit crop productivity. In figure 1, the

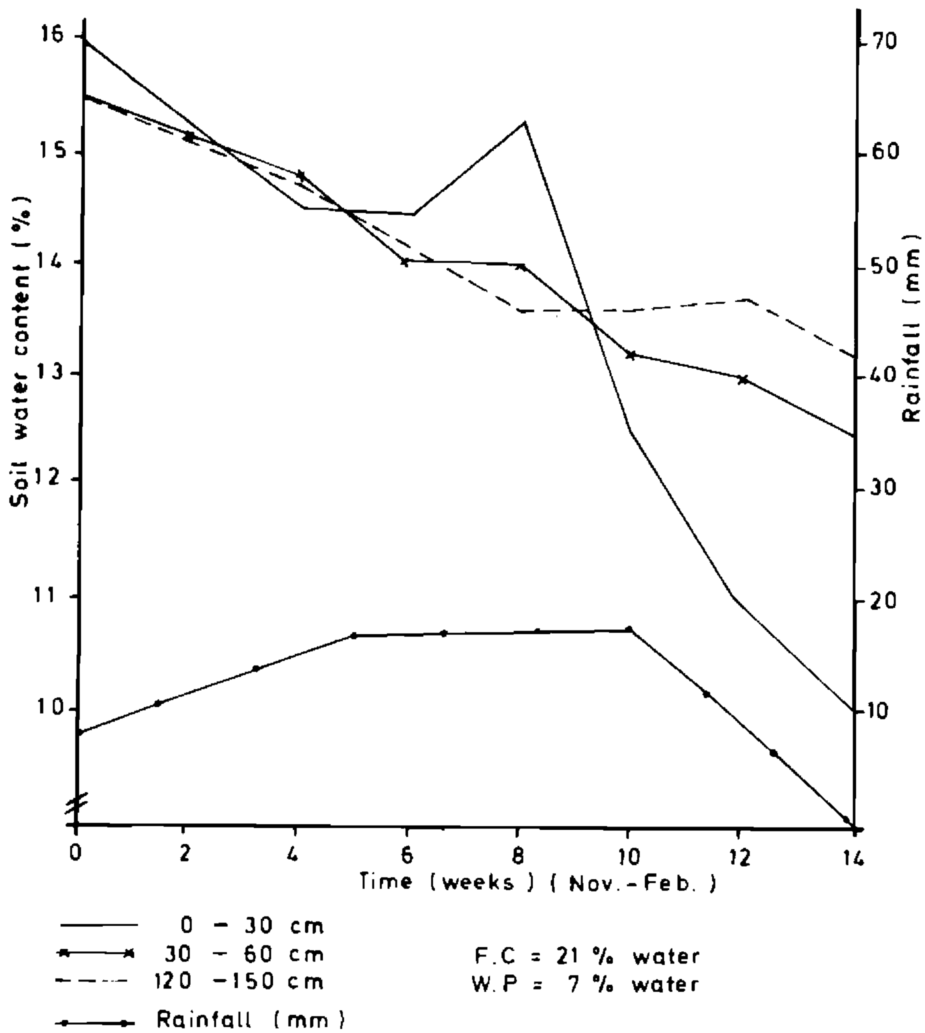

Fig. 1 Variations in soil water content and rainfall during growth of maize crop.

soil water content in maize experimental plots in the Trinidad dry season (1978) is shown. Note that as the dry season advanced, the soil water content of the surface layer approached wilting point but the crop did not suffer from drought effects. In this case, the crop was extracting water from deeper soil layers, the water content of which did not decrease as sharply.

If there is water deficiency at the critical stages of the crop as is obtained in the drier years in Antigua, for example, the yield and quality of the crop is low and particularly there would be no response to fertilizers. This has been observed repeatedly in experiments in the drier areas of the Caribbean.

Unless water is very easily available and readily applied, irrigation is not likely to be an economic practice in maize cultivation. It is better to plan the cultivation of the crop to take advantage of the natural weather pattern or to manage the soil for maximum water use. In a system for continuous maize cultivation involving two crops per year, the second crop which is usually planted towards the end of one wet season and matures into the dry season could suffer from water deficiency. Soil management for maximum water use would involve the encouragement of deep rooting by paying attention to appropriate cultivations, fertilizer placement and application, and placement of ground limestone where this is considered necessary. Effective weed control in water deficient conditions is of particular relevance.

The other extreme of water relations i.e. water-logging, was considered earlier with respect to drainage. Maize is particularly adversely affected by water-logging caused by poor drainage; adequate drainage is an essential pre-condition for cultivation of maize.

The effect of mulching as a management factor in influencing water relations in Trinidad's conditions of maize is summarised in table 1. In the wet season when there is excess soil water

Table 1. Effect of surface mulch on growth and yield of maize (kg/ha)

Duration of Crop	Dry matter production at eight weeks				Yield of grain			
	No nitrogen		Nitrogen (100 kg/haN)		No nitrogen		Nitrogen (100 kg/haN)	
	No mulch	mulch	No mulch	mulch	No mulch	mulch	No mulch	mulch
Wet Season June-August	465	307	504	0	not determined			
Wet to dry season (Nov.-Jan.)	2100	2818	3008	3373	3704	4706	5242	6290
Dry Season March-May	1320	5187	1934	6186	not determined			

if anything, mulching has proved to be detrimental on the soil in the University area in Trinidad. Perhaps the type of mulch used i.e. fresh bagasse, may have been important in creating anaerobic soil conditions in the top layer where the maize roots are concentrated. If a crop is grown at the time of the year when the rainy season is tailing off i.e. November-January, mulching is not of importance in water conservation. However, if a crop is planted in December or January and grows through the dry season, mulching was shown to be essential if a crop is to be expected. The depth of mulch beyond about 2 cm, evenly distributed, does not appear to be of much importance. Other effects of mulching such as soil erosion control, weed control and soil temperature control make this practice of great value in most cases. The great problem is the availability of mulching materials and the cost and problem of applying it to the soil planted with maize.

(iv) Soil fertility:- Maize is one of the most responsive crops to soil fertility and infertility. For this reason, the plant is used extensively as an indicator in nutrient availability and soil fertility studies.

Aspects of soil fertility that are important in the Caribbean context are soil acidity or alkalinity and their related problems, and supply and availability of the various nutrients.

Soil acidity: Soil acidity is a problem in maize production only in some parts of the Caribbean i.e. parts of Guyana, Surinam, Trinidad, Jamaica, Puerto Rico and Belize. It does not seem to be important in the Leeward and Windward Islands. The main effects of soil acidity are indirect, in the form of Al toxicity and P deficiency.

Some of the early studies on the effect of Al on plant growth utilised maize as one of the test plants. There is no specific foliar symptom of Al toxicity; growth depression occurs but it is a nonspecific symptom. Uptake of the element causes root damage. In the early stages the roots become discolored, then the branch roots stop growing and finally the entire root system stops growing (Mc Lean and Gilbert, 1927; Lignon and Pierre, 1932). Evans (1955) described similar symptoms for sugar cane and used the term "coralloid" roots to describe the short, thickened and discolored root systems which result from high Al. Trenel and Alten (1934) concluded that Al was a specific root poison for maize and the poisoned roots were unable to translocate the element to other parts of the corn plant. Thus, the concentration in the roots get higher as the toxic effects become more advanced. In extreme cases, P is precipitated within the roots in Al-bound forms (Wright and Donahue, 1954) and eventually the plants affected display foliar symptoms of P deficiency. The uptake, translocation and metabolism of Ca is also adversely affected, leading to foliar symptoms of Ca deficiency.

Ahmad (1960) working on the frontland clays and pegasse soils of Guyana found that Al and to a lesser extent P, accumulated in the roots of maize plants growing in acid soil. Al was found to be more immobile in the roots of maize than cowpea which was related to an apparent greater tolerance of cowpea to higher Al concentrations in the soil solution. From these studies it was concluded that plants which are able to translocate Al from root to leaves appear to be more resistant to Al toxicity.

Correction of Al toxicity and the induced P deficiency which results is achieved by the use of ground limestone to the extent where the pH was 5 or higher. In Guyana and Surinam where there are no reserves of $CaCO_3$ rock and where the soils require large dressings of lime to achieve the desired pH change, it becomes very expensive. The use of dilute sea water (Evans and Cate, 1962) to achieve partial reclamation is an interesting innovation but the difficulties involved in controlling the use of dilute sea water on land, the availability of large quantities of fresh water for leaching after sea water flooding, and the careful check in changes in soil chemical and physical properties are problems in its wide use.

With current lack of facilities for bulk handling and application of ground limestone throughout the region, and therefore the high cost of treating soils, it is doubtful whether ameliorating acid soils by liming under existing conditions is economical. Where it is to be done, there are no particular precautions that are necessary and it need only be done to the extent that the exchangeable Al content is substantially lowered i.e. about pH 5.

Soil alkalinity: Maize is being grown successfully on soils whose pH is much higher than 7 without any apparent injurious effects. In such cases the continued use of ammonium sulphate obviously plays an important role.

(v) Nitrogen:- Few factors have as great an impact on corn production as the extensive use of nitrogen fertilizers. In the midwestern U.S., it is recognised that up to 150 kg N/ha is needed for a yield expectancy of 6,000 kg/ha grain. In Antigua, in the fertilization regime used there, 120 kg/ha is applied for an average yield of 5,000 kg/ha. About the most efficient use of nitrogen is achieved by the Mennonite farmers in Belize who apply 12 kg/ha at planting in the form of a 12:24 NPK fertilizer at 100 kg/ha for a yield expectancy of 2,000 kg/ha. A side dressing of 25 kg N/ha applied as urea six weeks after planting could raise the yield expectancy to 3,000 kg/ha and it is considered a very worthwhile practice.

The nature of the response to nitrogen as well as phosphorus and potassium in several West Indian soils was studied by the Department of Soil Science and UWI and the results are summarised in figures 2 to 5 (Baynes and Walmsley, 1973 and Forde et al, 1975). It is to be noted that in every case except for Barbados, there was a considerable response to nitrogen fertilizer. The no response in Barbados to all fertilizers is interpreted as due to a partial soil water deficiency and not to adequate levels of the nutrients in the soil.

The kind of nitrogen fertilizers used is of some importance. For example, in the high pH soils of much of the West Indies, sulphate of ammonia could be a good form on account of the acidifying effect. On these soils, this form always produces a bonus effect over the nitrogen which is supplied. In some cases, volatilisation losses could be severe if the fertilizer is applied to the soil surface in high soil pH situations. Also loss from surface run-off could be important. In slightly acid, loam soils, the recovery of added nitrogen by maize could be very good but as the texture becomes more clay, the soil more compact, and the pH higher, the recovery is decreased.

In some situations in Trinidad, side-dressing in the form of anhydrous ammonia injected into the soil could be successful although this method of applying nitrogen to soils has never been tried in the Caribbean.

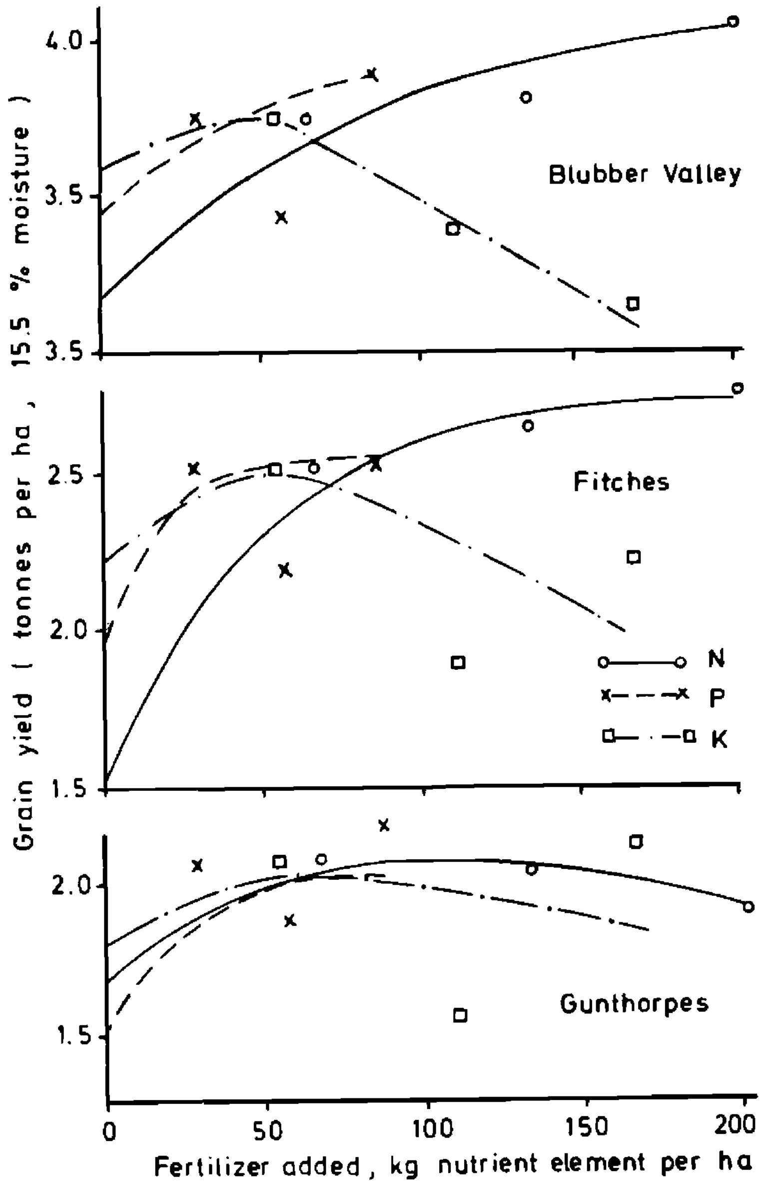

Fig. 2. Influence of different rates of N, P and K fertilizers on mean grain yield of maire in Antigua.

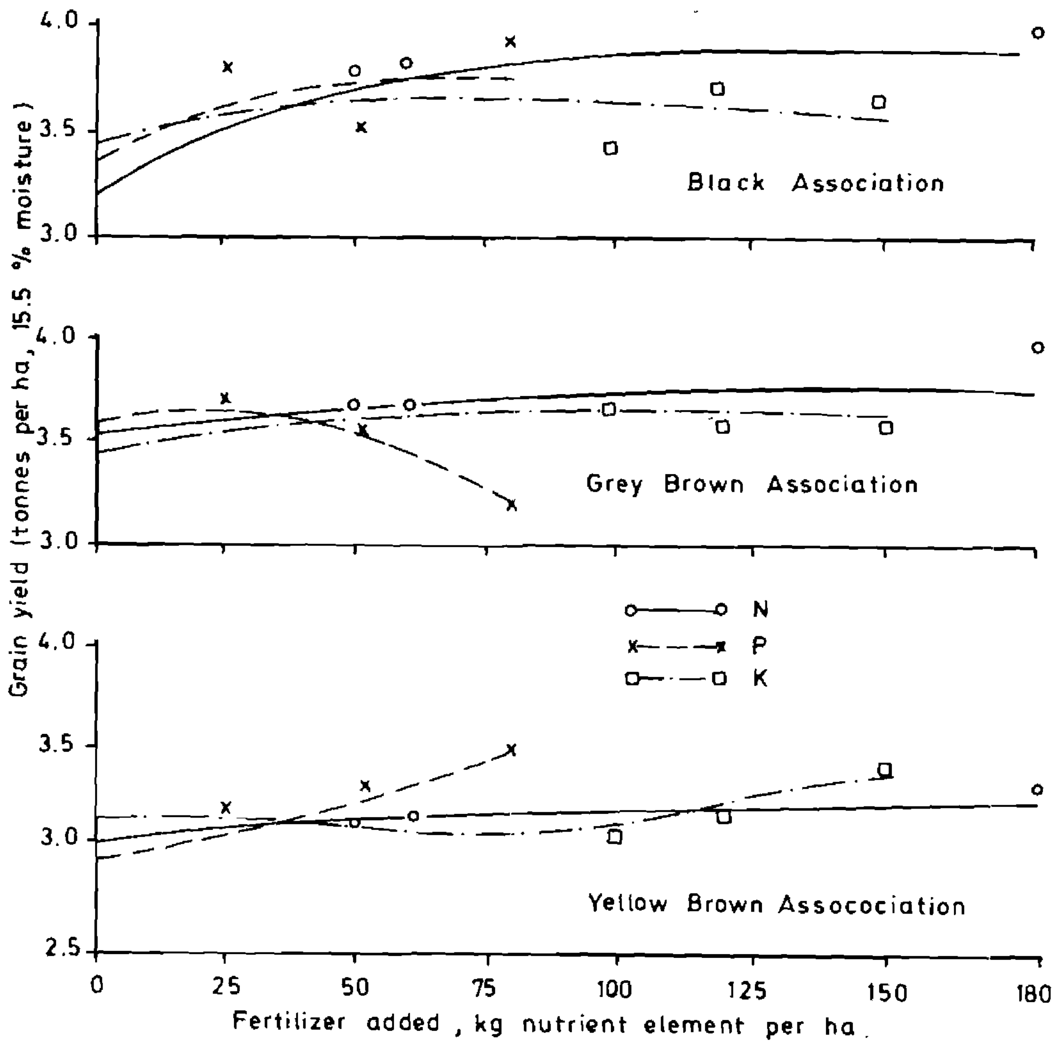

Fig. 3. Influence of different rates of N, P and K fertilizers on mean grain yield of maize in Barbados.

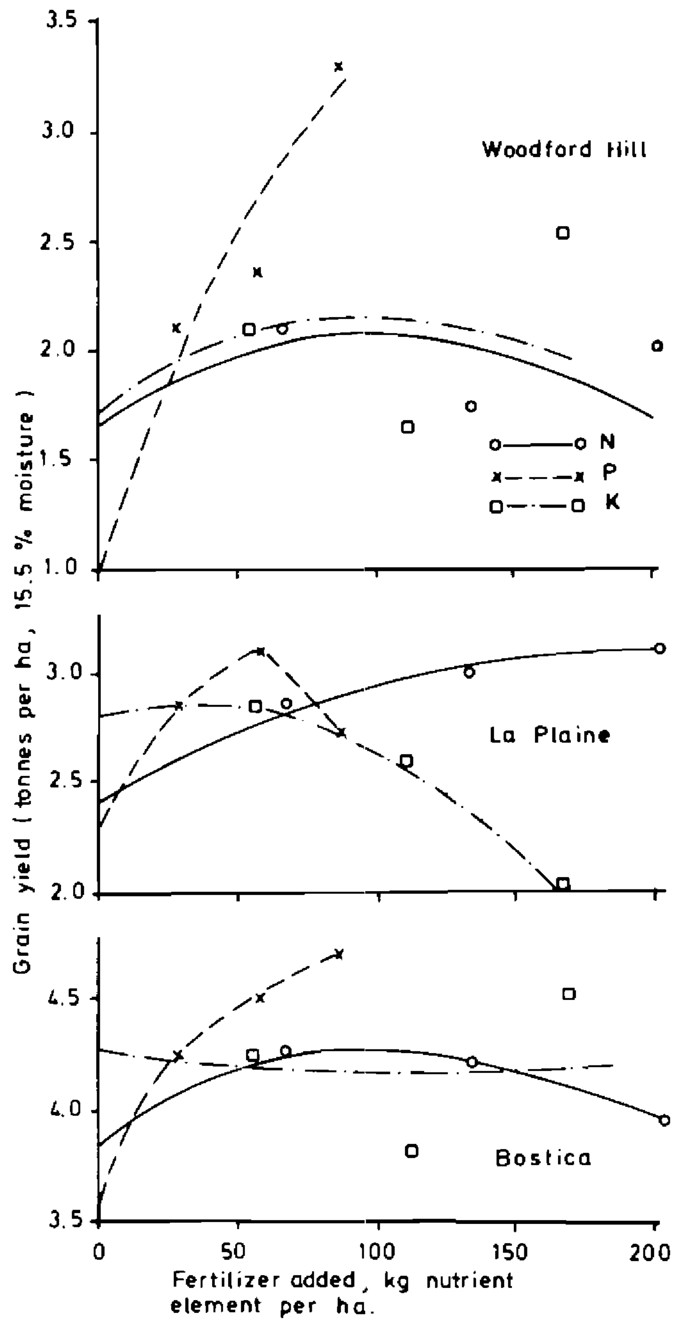

Fig. 4. Influence of different rates of N, P and K fertilizers on mean grain yield of maize in Dominica.

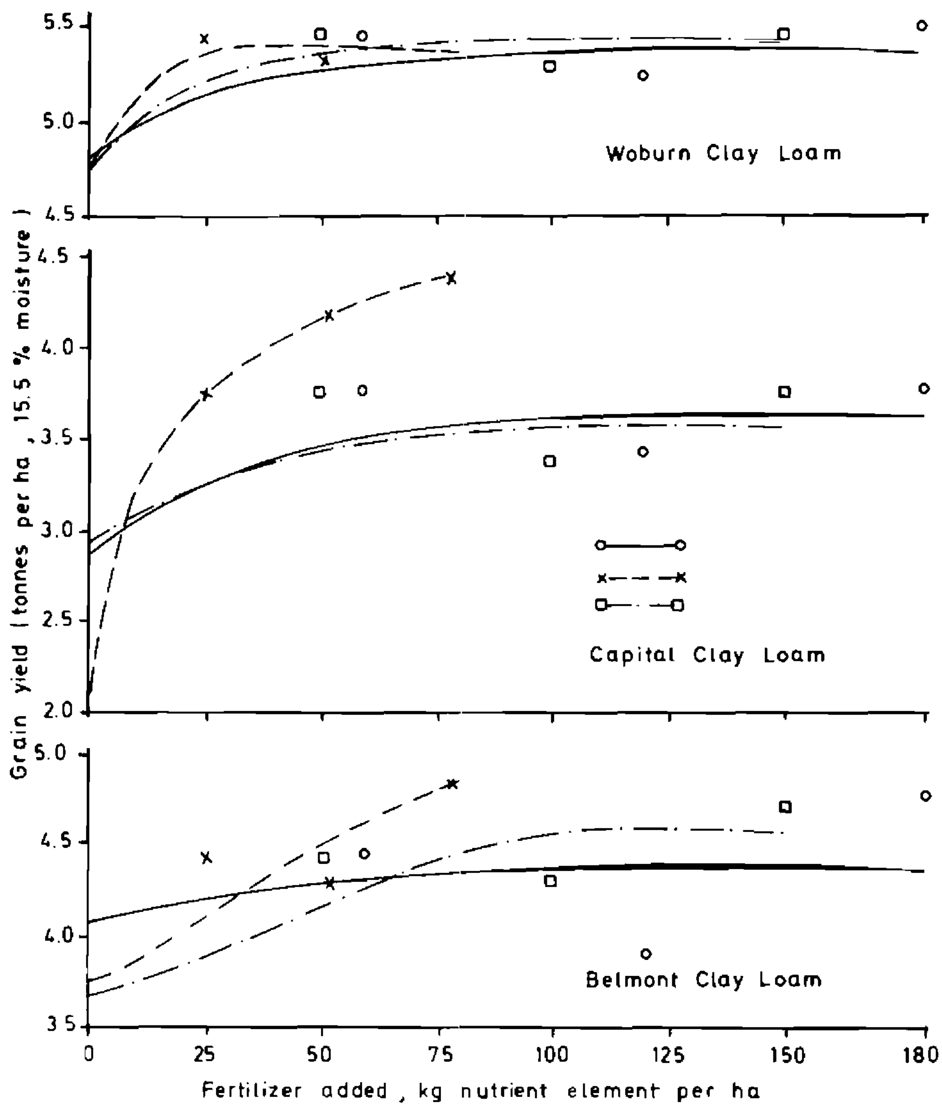

Fig. 5. Influence of different rates of N, P and K fertilizers on mean grain yield of maize in Grenada.

Table 2. Fertilizer recommendations for some of the soils of the Caribbean assuming minimum 3,000 kg/ha grain production

Island and Soil Series	Soil Taxonomy name	Texture	Fertilizer recommendation		
			N	P	K
				kg/ha	
ANTIGUA					
Blubber Valley	Cumulic haplustolls	clay	100	25	50
Fitches	Typic calciustolls	clay	100	25	50
Gunthorpes	Udic chromusterts	clay	50	25	50
BARBADOS					
Black soil	Typic chromusterts	clay	50	–	50
Grey brown	Udic chromusterts	clay	50	–	–
Yellow brown	Vertic tropudult	clay	50	50	–
DOMINICA					
Woodford Hill	Typic tropudults	clay	50	75	50
Espagnol	Typic durustolls	clay	150	25	150
La Plaine	Udic durandepts	clay	100	50	25
Boetica	Entic dystrandepts	clay	50	75	25
GRENADA					
Capitol clay loam	Oxic humitropept	clay	50	50	50
Woburn clay loam	Paralithic vertic	clay	50	25	50
MONTSERRAT					
Grove	Typic ustipsamment	ashy	25	25	25
Amersham	Typic tropudalfs	loam	50	80	25
Riley's	Typic tropudalfs	loam	50	25	50
ST. KITTS					
Shadwell	Mollic vitrandepts	ashy	50	25	50
Golden Rock	Mollic vitrandepts	ashy	25	25	25
Sandy Bay	Mollic vitrandepts	ashy	200	–	–
Mansion	Typic tropudalfs	ashy	50	75	50
ST. LUCIA					
Balembouche	Aquic tropic argiudolls	clay	100	15	25
Raveneau clay	Udic chromusterts	clay	50	25	50
ST. VINCENT					
Akers sandy clay loam	Udic argiustolls	loam	50	25	50
Bellevue sandy clay	Typic eutropept	loam	50	25	50
Soufriere cindery gravelly loamy sand	Typic vitrandept	cindery	150	25	50

(vi) Phosphorus and potassium:- There are many Caribbean soils which are low in P or K or both. In the volcanic islands, low P availability is often a cause of low productivity in maize as seen from experiments carried out in Grenada and Dominica. In general, the vertisols in the Caribbean which are formed from limestone are well supplied with P but may be deficient in K. The exceptions are the Vertisols of Belize derived from calcareous rocks which are quite low in P and those of Antigua on marl which are high in K. Soils derived from sedimentary and recent alluvial materials and those formed on shales or schists tend to be adequately supplied with K but in some cases responses to P may be obtained. The coastal clays of Guyana and Surinam are well supplied with K, and P may also be adequate. However, P and K availability in the brown sands is too low to have much of an impact on crop requirements.

The extent of response and recovery of P and K for any soil for maize should be found by experimentation. In some of the high P fixing soils, non-conventional ways of using P fertilizers for greater efficiency must also be found. Examples of such soils are the bauxitic soils of Jamaica. Except in these special circumstances, P and K fertilizers could be applied at planting, placed in close prominity to the planted seed.

Fertilizer recommendations for several West Indian soils for maize are given in table 2.

(vii) Soil management for erosion control:- Soil erosion is probably the most important soil hazard in commercial maize cultivation.

Under existing procedures for tillage and other cultivation operations for maize, the soil is left in a very erodible condition for long periods of time and as a result, serious examples of soil erosion could be seen where maize is commercially grown in the Caribbean. Surface erosion is the most serious form, although gullying and landslipping could be easily caused particularly with Vertisols on sloping topography. Much can be done in managing the soil to minimise erosion. The extent of tillage which was already discussed is very important in this respect. Minimum tillage and zonal tillage as opposed to fine uniform seedbed preparation should be considered seriously. The substitution of cultivation for weed control by the used of herbicides is also a means to reduce soil erodibility. Where maize is grown on sloping land, the layout of the land should be in accordance with good soil conservation practices.

(viii) Crop rotations:- Few soils in the Caribbean could support indefinitely, continuous cultivations of maize. As an example of soil deterioration, 20 years of continuous maize at Spanish Lookout has resulted in erosion of topsoil, soil compaction and lowering of soil fertility. From observations of the farmers, maize should only be grown continuously for up to 5 years and that this should be rotated with pasture for three years. This rotation is a means of maintaining the soil in reasonable physical condition due to "resting" of the soil for the three years of pasture and to allow fertility to accumulate. In Antigua, continuous maize even for a few years has resulted in marked modification of the natural flora where grasses and other weeds, some introduced, have replaced the naturally prolific legume vegetation.

In normal crop rotations, several variations are possible. For instance, within one year, a maize crop could be rotated with a grain legume crop. Alternatively, maize followed by maize or sorghum could be grown for up to five years and then the soil allowed to recuperate by putting it in pasture for up to three years. A severe disadvantage here is the deterioration, under pasture and grazing, of any drains, ditches or particular land layout which is necessary for growing of maize.

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