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Soil Characteristics and Variation in Yield and Yield Components of Plantain (*Musa paradiasiaca* L. Aab) Intercropped with Melon on an Alfisol in South Western Nigeria

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Abstract: Plantains are major food crops in the developing countries and are widely grown across the world's tropical regions. There is sparse literature on soil characteristics on which plantains are grown and the yearly variation in the yield and yield components under different levels of K fertilizer applications. On-farm trials were conducted in 1993 and 1995 cropping seasons and the experimental design was randomized complete block design (RCBD) with four replications, which are farmers' field. The treatments were five levels of potassium fertilizers (0, 120, 240, 360 and 480 kg K ha^{-1}) applied as muriate of potash (MOP). Results of soil analysis and the suitability evaluation showed that available P content is sub-optimal and very much below the critical values recommended for sustained and continuous growth of plantain. Furthermore, the result of the suitability evaluation showed that potentially the land was rated was as highly suitable (S1) for plantain production. Results of mean yearly yield components (i.e. between leaf area, plant height, stem girth and number of functional leaves) showed significant differences between years and not across years. The coefficient of variation (CV) was less than 10% for all these parameters except for the mean bunch weight of plantain and it ranged between 197-320%. Furthermore, results showed that potassium fertilizer significantly affected the afore-mentioned yield components. In both cropping seasons, the yield of plantain increased at an increasing rate of K fertilizer application reaching the peak at 360 kg K ha^{-1} with bunch yields of 10.39 t ha^{-1} (1993) and 9.38 t ha^{-1} (1995) respectively, however, there were no significant differences between yields of different K rates across years. The study concludes that even in the current state of the soil, application of K fertilizer significantly increase yield and yield components within years, but not across years. Potassium fertilizer rate of 360 kg ha^{-1} resulted in mean bunch yields of 10.39 t ha^{-1} (1993) and 9.38 t ha^{-1} (1995) respectively. The fertilizer response equations for both years were:

1993 $Y = -2E\text{-}05x^2 + 0.0182x + 3.9117$; $R^2 = 0.9763$ **1995** $y = -4E\text{-}05x^2 + 0.0293x + 3.7694$; $R^2 = 0.9825$

The study concludes that of all the yield and yield components of plantain examined, the only parameter is likely to vary widely with years is the bunch weight of plantain.

Key words: Alfisol % Plantain % Potassium fertilizer % Yield % Southwestern Nigeria

INTRODUCTION

Plantain (Musa AAB) often plays a dominant role in farming systems of the forest zone of West Africa as well as many other African Nations. Production remains largely in the hands of small-scale farmers [1, 2]. Farmers' often intercropped on soils without adequate knowledge of the suitability of their lands for sustained and continuous cultivation of plantain and the right quantity of fertilizers to be applied. Literature showed that critical

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K for optimum plantain cultivation is between 0.20 and 0.21 cmol/kg [3]. Furthermore, Olaleye *et al*. [4] reported that optimum K fertilizer that resulted in the highest bunch yield of plantain was 360 kg K/ha. However, when plantain was intercropped with cassava, highest bunch weight of plantain and tuber yield of cassava was recorded at 240 and 360 kg K/ha [5]. After this level, increase in K fertilizer resulted in yield decline.

The knowledge of soil classification, though good, may not make much sense to small-scale farmers. What is more useful to him is the degree of suitability (i.e., excellent, very good, good, fair, or poor) of his/her land in terms of crop yield (and profit ?). Suitability evaluation attempts to group land units into classes based on their performances (or limitations) when used for a sustained and continuous crop production. To evaluate a given land according to its suitability for the production of a specific crop, the FAO [6] proposed a framework of land evaluation for rainfed agriculture. There is a very sparse literature on the soil constraints of plantains in the south western part of Nigeria and yearly variations in the yield and yield components of plantain grown on an Alfisol. Hence, the main aims of this present investigation were to identify soil constraints that could militate against plantain cropping and to assess the extent of variability in the yearly yield and yield components under different levels of potassium fertilizer application.

MATERIALS AND METHODS

Trials were conducted in 1993 and 1995 cropping seasons at Ayepe, which is an on-farm research site of Agronomy Department, University of Ibadan, Nigeria (Latitude 7°15' N and Longitude 4° 20'E). The site is located in the rainforest agro-ecological zone (AEZ). The climatic data is presented in Table 1. Onasanya [7] reported that the dominant soil series at Ayepe is an OxicPaleUstalf / Ferric Luvisol (or *Egbeda series*) (Table 2). The slope of the land is between 1-2%; and the soil is fairly well drained (WD) and stoniness in the upper

Table 1: Mean climatic data for the experimental site (1990-1995)

Months	Rain (mm)	Wind speed (Km hr^{-1})	Radiation (cal cm^{-2} hr^{-1})	Min Temp (°C)	Max. Temp (°C)	Relative Humidity (%)	Mean Number of rainy days
Jan	4.8	1.10	282.73	22.75	33.40	35.00	1.50
Feb.	59.5	2.25	308.57	23.95	34.45	35.00	5.50
Mar.	165.10	4.25	350.43	23.35	33.35	55.00	10.00
Apr.	149.25	2.00	306.65	24.20	32.85	60.00	10.00
May	171.80	3.50	332.97	23.45	31.75	60.00	11.00
Jun.	314.10	3.45	293.74	22.70	30.45	50.00	17.00
Jul.	289.95	3.70	232.98	22.45	28.75	25.00	16.00
Aug.	204.15	3.65	238.72	22.45	28.55	20.00	19.50
Sep.	155.45	1.80	207.15	22.70	29.00	10.00	16.50
Oct.	240.55	1.00	245.41	22.75	29.85	70.00	16.50
Nov.	19.45	2.60	376.26	22.65	32.90	30.00	2.00
Dec.	8.15	1.00	278.19	23.25	32.80	20.00	1.00
Mean	148.52	2.53	266.59	23.05	31.51	39.17	10.54
Total	1782.25	-	3199.07	-	-	-	-

Source: Nigerian Meteorological station, Ibadan, Nigeria

Table 2: Physical and chemical properties of the dominant soil in at the experimental site (Ayepe), south Western Nigeria

		g kg^{-1}				Cmol.kg^{-1}					%g kg^{-1}			mg/kg
Depths	pH	C sand*	F sand*	Silt	Clay	Na	K	Mg	Ca	CEC	Bsat#	TotN	OrgC	AvP
0-25cm	6.10	249.00	413.0	219.0	119.0	0.10	0.60	1.60	6.00	8.10	45.0	1.10	13.70	10.00
25-50	5.10	309.00	348.0	173.0	170.0	0.00	0.30	0.50	1.40	4.00	48.0	0.60	5.00	2.50
50-75	5.10	235.00	316.0	215.0	234.0	0.10	0.40	0.60	1.60	4.60	50.0	0.50	4.10	2.30
75-105	4.90	158.00	232.0	247.0	363.0	0.10	0.40	0.80	2.20	6.30	55.0	0.50	3.90	2.00
105-130	4.90	128.00	217.0	276.0	379.0	0.10	0.30	0.70	2.10	5.90	42.0	0.30	1.90	1.50
135-155	4.80	91.00	208.0	285.0	416.0	0.10	0.20	0.60	1.70	5.70	30.0	0.20	1.30	1.20
Mean	5.15	195.00	289.0	235.8	280.2	0.08	0.37	0.80	2.50	5.76	45.0	0.50	4.98	3.25
±SE	2.10	99.59	117.9	96.3	114.4	0.03	0.15	0.33	1.00	2.35	18.4	0.22	2.03	1.33

*Csand = coarse sand; Fsand= fine sand; #Bsat=Base saturation; OrgC= organic carbon, Av.P=available P

Table 3: Physical and chemical properties of the soil at the experimental site

Soil properties	1993	1995	Critical levels
PH (H_2O)	6.60	6.30	-
Organic Carbon (g/kg)	21.50	22.50	-
Total Nitrogen (%)	2.10	2.10	-
Available P (mg/kg)	3.50	5.40	>15†
Exchangeable Ca (cmol/kg)	9.52	8.54	>0.30*
Exchangeable Mg (cmol/kg)	1.32	1.24	>3.0*
Exchangeable Mn (cmol/kg)	0.15	0.14	-
Exchangeable K (cmol/kg)	0.18	0.20	0.20-0.21*
Exchangeable Na (cmol/kg)	0.30	0.25	-
ECEC (cmol/kg)	11.46	10.37	-
Sand (%)	66.00	67.00	-
Silt (%)	16.00	17.00	-
Clay (%)	18.00	16.00	-

† Castillo *et al*. (1995), * Akinyemi *et al*. (2003)

50 cm is <10%. Data were collected from literature on the optimum soil requirements for a sustained and continuous cultivation of plantain and these are detailed in Table 3. Before establishing the trials, a profile pit (1.55 m) was excavated in order to be able to evaluate the land for sustained and continuous plantain cultivation. Subsequently, soil samples (0-15 cm) were randomly collected from the pit horizon-wise. These soils were then composited, air-dried and representative samples taken for laboratory analyses. In the laboratory, these soil samples were crushed to pass a 2 mm sieve and some to further pass a 0.5 mm sieve. The samples (surface and profile pits) were analysed for pH (1:2 soil water ratio), particle size analyses [8], total N was analysed by macro-Kjeldahl method [9], exchangeable cations (K, Ca, Mg and Na) extracted with 1N NH_4OAC (pH 7.0). Potassium and Na in the filtered extracts was determined with a flame photometer, whereas Ca and Mg were determined with an atomic absorption spectrophotometer (AAS model Buck 200). Available P (Bray-1-P) was by colorimetry after Bray and Kurtz [10]. In order to evaluate the suitability of this pedon for plantain production, the land use requirements (LUR) in Table 3 were matched with the land characteristics/land quality (Table 2) using the conventional method of land evaluation [6]. According to the FAO method [6] land is classified qualitatively as high (S1), moderate (S2), marginal (S3), not suitable suitable (N) depending on how the LQ/LC meet the LUR. The result is the aggregate suitability of a pedon either currently (i.e. not modified by any amendment) or potentially (when soil characteristics such as organic carbon, texture and cation exchange capacity are used).

The on-farm experimental design was a randomised complete block design (RCBD) with four replications, which are farmers' field. The treatments were five levels of potassium fertilizers (0, 120, 240, 360 and 480 kg K ha^{-1}) applied as muriate of potash (MOP). A plot size of 13 m x 10 m was adopted in both seasons. Sword suckers of false horn plantain (Musa AAB) cv *Agbagba* was planted at a spacing of 3 m x 2 m and were obtained at the National for Horticultural Research Institute (NIHORT) Ibadan, Nigeria. These were trimmed with cutlass before being treated with Furadan 3G to control incidence of plantain weevil *(Cosmopolites sordidus*). These suckers were planted in mini pits of size 30 cm x 30 cm width and 30 cm deep at a spacing of 3 m x 2 m, which give a population of 1, 666 plants ha^{-1}. Nitrogen and phosphorus were applied at the rate of 100 kg N ha^{-1} and 60 kg P ha^{-1}, respectively at planting as Urea and as single super phosphate (SSP). Potassium fertilizer was split applied in two equal splits at 2 and 4 months after planting (MAP). The plots were hand weeded regularly throughout the trial. For sole plantain cropping, the following data were collected: leaf area, plant height, stem girth, number of functional leaves/plant and bunch weight after maturity. However, for plantain intercropped with melon, the following data were collected: number of hands/bunch, number of fingers/bunch, average bunch length, average bunch weight/plant and total bunch weight and detail results are presented elsewhere [4]. All these parameters were statistically analyzed using the general linear model procedure (PROC GLM) of the Statistical Analysis Systems [11]. Means were separated using Duncan Multiple Range Test (DMRT) at 5%. Since the coefficient of variation (CV) was designed to measure relative variability [12], it can thus be used to indicate variability amongst populations [13]. For field experiments, [14] stated a CV of between 10 to 15% for yield experiments is generally expected by most field crop researchers. Thus, the CV, which is a measure of variation, the standard deviation is expressed as a fraction of the mean. Yield responses to varying levels of potassium fertilizer in both cropping seasons were generated using Microsoft Excel 7.0 graphics. In order to assess the yearly variation in the yield and yield components of plantain, the coefficient of variation

RESULTS AND DISCUSSION

Soil Characteristics: Results of the detail soil analysis if the profile (Table 1) and surface physico-chemical (Table 2) showed that the texture of the pedon varied between sandy loam in the topsoil to sandy clay loam in the subsoil. Furthermore, the results showed that the pedon is moderately acidic in the topsoil with a pH of 6.1 and in the subsoil it varied from between 4.8 and 5.1. The soil is deep enough to allow for continuous and sustained cultivation of plantain. However, the main constraints in this soil are deficiency of P, Mg and exchangeable K (before the experiment). The effective cation exchange capacity (ECEC) of the surface soil ranged between 10.37 cmol kg^{-1} (1995) and 11.46 cmol kg^{-1} (1993). The total N of the soil was observed to range between 0.20 and 1.10 g kg^{-1}, which according to Sobulo and Adepetu [15] is of medium fertility level for a sustained and continuous cultivation of arable crops in southwestern Nigeria. In terms of available P (Bray-1-P), it ranged between 1.20 and 10 mg kg^{-1} which also suggests that this soil is of medium fertility level in terms of available P [16]. An optimum available P for plantain was estimated to be > 15 mg/kg [17]. In terms of exchangeable K, Akinyemi *et al.* [3] reported critical K of between 0.20 and 0.21 c mol kg^{-1}. Comparing this with values reported on Tables 2 and 3, it showed that K was deficient compared with the critical values earlier reported [3]. Plantain is a crop that requires high potassium for successful formation of fruits [18, 19]. Soil organic matter is known to exert a pronounced tropism on plantain/banana roots, but this may possibly be related to a higher availability of water or nutrients or the presence of organic compounds promoting growth tissues. According to Lahav and Turner [19], to establish a crop of plantain yielding 50 t ha^{-1} $year^{-1}$, of fresh fruit, very large amounts of nutrients are extracted from the soil. According to this author, plantain extracts form the soil about 76, 11 and 243 kg ha^{-1} of N, P and K respectively. From the results, it could be clearly seen that growth and yield of plantain is positively correlated with yield hence the importance of potassium to plantain. From the rough estimate of the amount of N, P and K requirements of plantain mentioned above, it could be clearly seen that for a sustained and continuous cultivation of plantain on these soils, about 360 kg K ha^{-1} would be required.

Land Suitability Evaluation for Plantain

Climate (c): The elements of climate important in evaluating a land for rice cultivation are mean annual rainfall, solar radiation, mean annual temperature and relative humidity. When these characteristics (Tables 1 & 2) were compared with the LUR (Table 3), results showed that these pedons highly suitable (S1) for successful cultivation of plantain.

Soil Fertility (f): The results of the land suitability evaluation is presented in Table 4 and showed that the land is at its current state not suitable (N1) and the major limitation is fertility (i.e. deficiency of P). However, potentially,-considering the soil organic carbon content and the cation exchange capacity (CEC), the land is highly suitable for plantain. Furthermore, results showed that these soil have optimum pH, total N, organic carbon and exchangeable cations (K, Ca, Mg), but the CEC is

Table 4: Factor ratings of land use requirements # for plantain

Land Qualities		Unit	S1	S2	S3	N1	N2
Factor Ratings	Land Characteristics	%	100-85	85-60	60-20	40-20	20-0
Climate (c)*	Annual Rainfall	mm	>1400	1200-1400	950-1100	850-900	<850
	Solar Radiation	$MJ.Cm^{-2}.day^{-1}$	>478	478-358	358-239	358-120	any
Soil Physical Characteristics**	Soil Depth	cm	>100	60-100	40-60	<40	any
	Clay	%	40-25	25-15	15-5	≤15, ≥ 5	any
Wetness (w)*	Drainage	-	1-3	1-3	3	any	any
Fertility Status (f)	pH	-	5.5-7.5	5.2-5.5	≤5.2, ≥8.2	≤5.2, ≥8.2	any
	Total N	%	>0.2	.1-0.2	>0.05-0.1	<0.05	any
	Organic carbon	%	2-3	1-2	3-4	>4	any
	P(Bray)*	$mg.kg^{-1}$	>15	10-15	5-10	1-5	<1
	P(Olsen)	$mg.kg^{-1}$	>10	7.5-10	5-7.5	<5	any
	K++	$cmol.kg^{-1}$	>0.2	0.1-0.2	<0.1	<0.1	any
	Ca*	$cmol.kg^{-1}$	>0.3	0.1-0.3	0.05-0.1	<0.05	any
	Mg*	$cmol.kg^{-1}$	3-5	1-2	<1	<1;>5	any
	CEC(soil)	$cmol.kg^{-1}$	>16	10-16	5-10	<5	any
Topography (t)	Slope	%	0-2	2-4	3-6	>6	>6

S.W.D= Surface Water Depth; F.D= Flooding Duration; G.W.T= Groundwater Table

* Castillo *et al*. (1995); ++ Akinyemi *et al*. (2003)

Table 5: Suitability class scores of the pedons in at Ayepe, Nigeria

Land Qualities		Unit	S1*	S2	S3	N1	N2
Factor Ratings	Land Characteristics	%	100-85	85-60	60-20	40-20	20-0
Climate (c)	Annual Rainfall	mm	S1	-	-	-	-
	Solar Radiation	$MJ.Cm^{-2}.day^{-1}$		-	S3	-	-
Soil Physical Characteristics	Soil Depth	cm	S1	-	-	-	-
	Clay	%	S1	-	-	-	-
Wetness (w)	Drainage	-	-	-	-	-	-
Fertility Status (f)	pH	-		-	S3	-	-
	Total N	%	S1	-	-	-	-
	Organic carbon	%	S1	-	-	-	-
	P(Bray	$mg.kg^{-1}$	-	-	-	N1	-
	P(Olsen)	$mg.kg^{-1}$	-	-	-	-	-
	K	$cmol.kg^{-1}$	-	S2	-	-	-
	Ca	$cmol.kg^{-1}$	S1	-	-	-	-
	Mg	$cmol.kg^{-1}$	-	-	S3	-	-
	CEC(soil)	$cmol.kg^{-1}$	-	-	S3	-	-
Topography (t)	Slope	%	S1	-	-	-	-
Aggregate suitability	Currently		N1f				
	Potential		S1				

* S1= Highly suitable; S2= moderately suitable, S3= marginally suitable, N1= not suitable currently and N2= permanently not suitable

Table 6: Mean yearly variation in yield components of plantain on an Alfisol

Yield components	1993	1995
Leaf area (cm^2)	2.185a†	1.797b
Plant height (m)	139.93a	129.96b
Stem girth (cm^2)	27.14a	24.63b
Number of functional leaves/plant	5.03a	4.58b

† Means with the same letter in across rows are not significantly different at 5%. DMRT

Table 7: Influence of potassium fertilizer on the total bunch weight of plantain ($t\ ha^{-1}$)

K rates	1993	1995
0	4.20c†	4.01c
120	6.84b	6.60b
240	9.97a	8.86a
360	10.39a	9.38a
480	10.11a	9.22a

† Means with the same letter across rows are not significantly different at 5%. DMRT

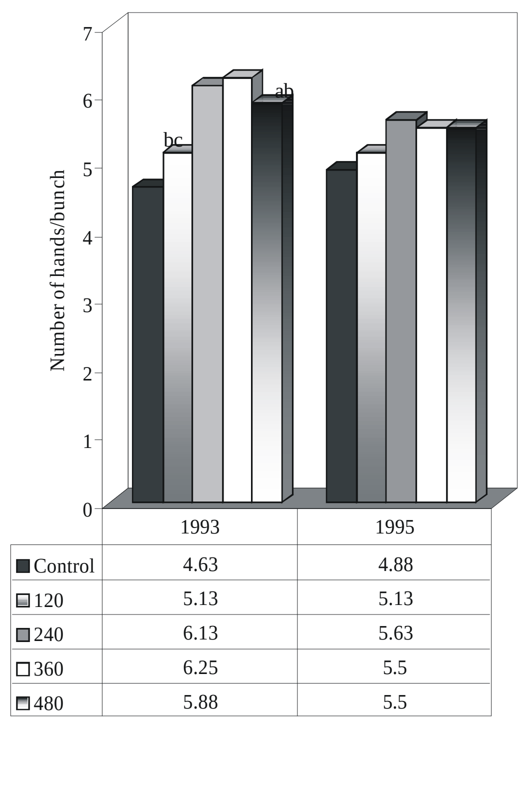
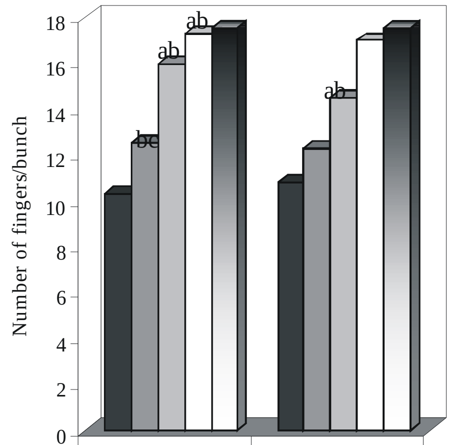


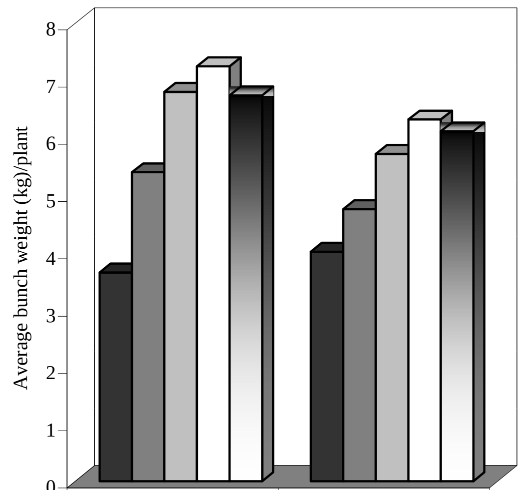
Fig. 1a: No of hands/bunch of plantains intercropped with melon

marginally suitable. It has been observed that the inherent fertility of most West African soils is closely related to the parent material [20-23]. Smyth and Montgomery [24] reported that the soils of south western Nigeria largely developed from the Basement Complex rocks of the Pre-Cambrian age, hence, such soils tend to be generally low in nutrients compared to those developed from the



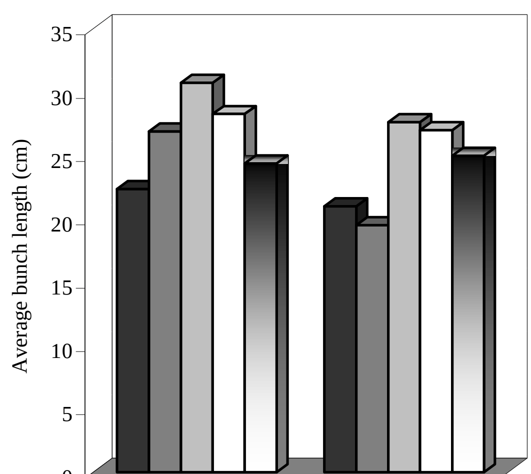
	1993	1995
Control	10.3	10.8
120	12.5	12.3
240	16	14.5
360	17.3	17
480	17.5	17.5

Fig. 1b:Number of Fingers/bunch intercropped with melon



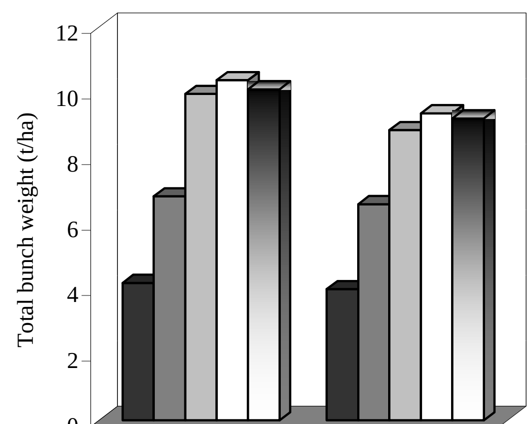
	1993	1995
Control	3.65	4.01
120	5.4	4.75
240	6.8	5.72
360	7.25	6.32
480	6.74	6.11

Fig. 1d: Average bunch weight/plant intercropped with melon



	1993	1995
Control	22.35	21
120	26.9	19.5
240	30.76	27.63
360	28.28	27
480	24.38	24.98

Fig. 1c: Average bunch length intercropped with melon

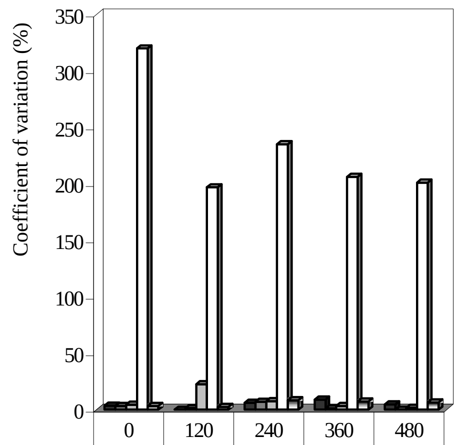


	1993	1995
Control	4.2	4.01
120	6.84	6.6
240	9.97	8.86
360	10.39	9.38
480	10.11	9.22

Fig. 1d: Total bunch weight intercropped with melon

sedimentary rocks [23]. Intensive leaching and weathering of these soils over the years have resulted in acidic reaction and low inherent fertility with regard to major and micro-nutrients [25, 26].

Hydrology/wetness (w): The soil has optimum drainage. However, climate, topography and soils interact to determine major hydrological processes in soils and this in turn determine the availability of surface or ground water or wetness of the soils.



	0	120	240	360	480
Hands/bunch	3.7	0	6	9	4.7
Fingers/bunch	3.4	1.4	7	1	0
Mean bunch length	4.4	22.6	7.6	3.3	1.7
Mean bunch weight	320	197	235	206	201
Total bunch weight	3.3	2.5	8.3	7.2	6.5

Fig. 2: Coefficient of variations of yield and yield attributes of plantain

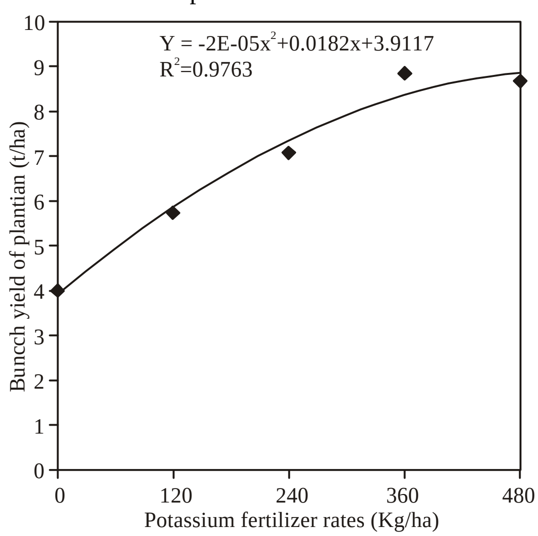


Fig. 3: Response of bunch yield of plantain to varying K Fertilizer in 1993 cropping season

Soil Physical Properties (i.e. Clay Contents) (s): The soil depth is >150 cm and it has optimum clay content.

Topography (t): Results showed that the topography is optimum for the cultivation of plantain.

Yearly variation in yield and yield components of plantain Significant differences ($p<0.05$) could be observed between the yield components of plantain in

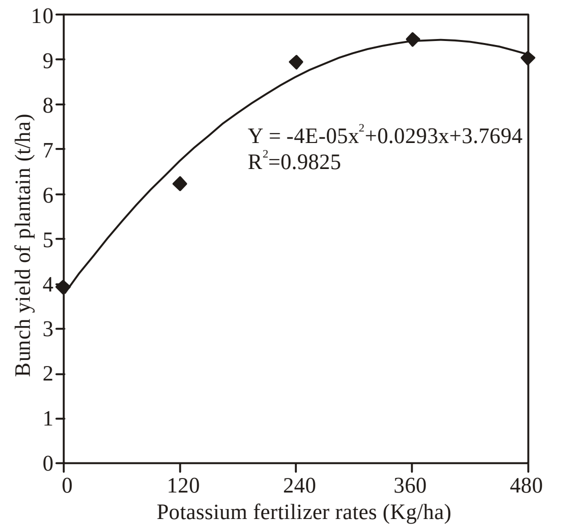


Fig. 4: Response of bunch yield of plantain to varying K Fertilizer in 1995 cropping season

both years (Table 5) and the total bunch weight of plantain (t ha^{-1}). Though, significant differences could be observed within years, but across years, there were no significant differences. When plantain was also intercropped with melon, similar trends could be observed across years (Figs. 2a-d). Results of the coefficient of variation (CV) computed showed that the CV's of all the yield components were less than 10%, except for the mean bunch weight of plantain where the CV's were $\geq$197% (Fig. 2). This result suggests that higher variability may be attributed to varying factors of production of which solar radiation is the most important. The Fertilizer response equations in both years are presented in Figs. 3 & 4 and it showed that the yield of plantain increased with increasing rates of K fertilizer, peaked at 360 kg ha^{-1} and started declining at 480 kg K ha^{-1}. The fertilizer response equations were:

1992 $Y = -2E\text{-}05x^2 + 0.0182x + 3.9117; R^2 = 0.9763$
1993 $y = -4E\text{-}05x^2 + 0.0293x + 3.7694; R^2 = 0.9825$

CONCLUSION

In this study, potassium significantly increased plantain bunch yield up to 360 Kg ha^{-1}, The study concludes that of all the yield and yield components of plantain examined, the only parameter is likely to vary widely with years is the bunch weight of plantain.

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