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Physiological nutrient use efficiency of banana hybrids across agro ecological regions in Uganda

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Banana is an important source of food and income for millions of people in sub-Saharan Africa and Uganda in particular. This makes it one of the most important food crops in the country. However, production is limited by both biotic and abiotic constraints. Among the biotic constraints, is the decline in soil fertility. In addressing some of these biotic and abiotic constraints, banana breeding programmes are developing and releasing new banana varieties with limited information of their efficiency to capture soil nutrients. This study was to establish the physiological nutrient use efficiency of three new banana varieties namely FHIA17, M9 and M2 at harvesting time. The study was carried out in 8 (eight) districts of Uganda. Soil and tissue samples were collected from already established banana plantations for analysis of N, P, K, Ca and Mg. Tissue samples were collected by destructive sampling. Means of nutrients within district were separated using the Least Significant Difference (LSD) test at 5% level of significance (SAS, 2008). The nutritional status of bananas and the concentrations in various organs were, with respect to N, P, K, Ca and Mg, levels subjected to ANOVA. The relationship between plant content of the five nutrients and their concentration in the soil was determined by coefficient of correlation (r). The results showed no major significant nutrient use efficiencies between cultivars with FHIA 17 having the highest nutrient use efficiency. There were a few positive correlations between soil and plant nutrients.

Key words: Nutrient concentrations, Banana cultivars**,** destructive sampling, nutrient interactions.

INTRODUCTION

Bananas are grown on about 1.5 million ha of land and represent 38% of total arable land in Uganda (NARO, 2000). This makes it one of the most important food genomes are reported to be late introductions in East Africa (Simmonds, 1982). The East African highland cooking and juice bananas (*Musa spp.* AAA-EA) and exotic juice bananas (*Musa spp.* ABB) are important staple foods in East Africa, providing more than 25% of carbohydrates and 10% of the calorie requirement for 70 crops in the country (FAO, 2004). The most commonly grown bananas in Uganda are those belonging to the genome AAA, while AAB and ABB million people (Karamura, 2001). The East African highland bananas are by far the most widely distributed cultivar in the region, stretching from Eastern Democratic Republic of Congo to the southern fringes of the Ethiopian highlands and down to Mbeya in Southern Tanzania. Concerns about banana yield decline, have been voiced so often that it is now considered as an established fact (Baijuka and Wuijsen, 1998). However, most reports are based on farmers' perception (Gold et al., 1993).

In Uganda, a substantial proportion of the bananas are grown near the homestead (Zake et al., 2000). Plots near the homestead generally receive more organic household residues and are often more mulched than fields further away. Bananas are grown primarily for home consumption but are increasingly becoming a source of income for many households. They have a high industrial potential through juice, wine and assorted post-harvest food stuff production. For example, in South-western Uganda, there is a common proverb “Ataine Rutookye n'ente tashwera” meaning “One without a banana plantation and cows does not qualify to marry, for he would not sustain a family” (Tumuheirwe et al., 2003). To most people in the Central region of the country, Matoke, a common recipe from cooking bananas, is synonymous to food (Pekke, 2004). Both the high production and consumption of banana reflects the important role bananas play in food security of the Ugandan people and justifies why it is important to improve and protect the crop.

Whereas, it is the major food crop for at least 30% of the people in Uganda (FAO, 1995), production decline in the country is a reality (Bekunda and Woomer, 1996). This decline has been attributed to low soil fertility, pest and diseases such as Fusarium Wilt, Black Sigatoka and Banana Bacterial wilt (Gold et al., 1993; Wortman et al., 1994). Soil nutrient deficiencies have been caused by continuous cultivation, crop harvests, soil erosion and a host of socio-economic and post-harvest problems (Rubaihayo et al., 1993). The most affected area of the country in banana production decline is the Lake Victoria Basin, a high rainfall region lying within 25 to 30 Km around Lake Victoria (Bekunda and Woomer, 1996).

Uganda is the second largest centre of banana diversity in the world, with a total of 95 banana varieties currently grown among banana producers (Karamura, 1998). A typical household in Uganda grows an average of 7 banana varieties simultaneously with a maximum of 27 varieties (Tumuhairwe et al., 2003). However, banana production has declined over the years from 8.5 to 5.6 tonnes /ha due to low soil fertility as one of the major constraints (Zake et al., 2000). Most farmers perceive continuous cropping and erosion as the main causes of soil fertility decline (Bekunda et al., 1999). Others attribute low banana yields to poor soil fertility, increasing pest pressure [especially the banana weevil (*Cosmopolites sordidus)*, Nematodes (*Radopholus similis)*, *Helicocotylencus multicinctus* and *Pratylechus goodeyi*], disease [black Sigatoka (*Mycosphaerella fijienisis)*, banana bacterial wilt], poor husbandry and moisture stress (Gold et al., 1999; NARO, 2000).

Bananas require large nutrient quantities which must be supplied through fertilizer application in order to obtain optimum yields. Bananas require nitrogen, phosphorus and potassium in large amounts for proper growth and production, and fertilizers not only improve soil nutrient status but also increase plant productivity (Guo et al., 2009). Regular inspection of soil nutrient status plays an important role in diagnosing nutrient deficiencies and sometimes toxicities that can affect crop growth and result in low yield. Plants that are efficient in absorption and utilization of nutrients greatly enhance the efficiency of applied fertilizers, reducing cost of inputs, and preventing losses of nutrients to ecosystems. Inter and intra-specific variation for plant growth and mineral nutrient use efficiency is known to be under genetic and physiological control and are modified by plant interactions with environmental variables. There is need for breeding programs to focus on developing cultivars with high Nutrient use efficiencies (NUE). Identification of traits such as nutrient absorption, transport, utilization and mobilization in plant cultivars should greatly enhance fertilizer use efficiency. The development of new cultivars with higher NUE, coupled with best management practices (BMPs) will contribute to sustainable agricultural systems that protect and promote soil, water and air quality. To deal with nutrition problems and determine the role of management practices, nutrient analysis of soil and plant tissues is an accurate, reliable and quantitative approach to diagnose and precisely correct nutrient deficiencies or toxicities. It is a useful tool in diagnosing nutritional disorders and helps in crop management decisions.

So, it is important to know the nutrient efficiencies of banana plants and soil nutrient status for better plant nutrition management and achieving better production.

This study is specifically on hybrids because, they appear to have higher yields, resistant to some diseases like black sigatoka, they have bigger biomass and so there was need to establish their yield performance, and their nutrient use efficiency. The information would be of great importance during up scaling and information on their growth requirements would be availed and this would help farmers to manage the hybrids well.

MATERIALS AND METHODS

Study area and experimental design

The study was carried out in 8 districts of Mukono, Jinja, Kamuli found in western Uganda, Wakiso and Mityana in the central and Kyenjonjo, Kabarole and Mubende in western Uganda where plantations of the

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studied cultivars had already been established. An augmented incomplete block design was used **i**n already established farmers' fields. The fields were planted with three hybrids namely FHIA17, M2 and M9, including a local check cultivar Mbwazirume as a control.

Data collection

Physiological nutrient use efficiency and plant nutrient concentration

Nutrient use efficiency was computed as the fruit yield produced per kg of plant nutrients accumulation in above ground biomass or product yield per content of nutrient. Total plant biomass (above ground) was defined as the sum of dry weights of the fingers, peduncle, leaves and pseudo stem. Total nutrient uptake was calculated from measurements of N, P, K, Ca and Mg mass fractions in fingers, peduncle, leaves and pseudo stem biomass and dry weights of the plant parts at harvest (Nyombi et al., 2009). In order to calculate nutrient totals in the plant, the following equation was used.

$$TAGN = 0\%\ MFW*NCF+\%MPW\ *NCP+\%MLW*NCL+\%\ MPsW*NCPs+\%MCW*NCC$$

Where,TAGN = Total above ground nutrient in the plant at maturity, 0%, MFW = finger weight at 0% moisture, NCF = nutrient concentration in the finger, MPW = peduncle weight at 0% moisture, *NCP = nutrient concentration in the peduncle, MLW = leaf weight at 0% moisture, NCL = nutrient concentration in the leaf, %MPsW = pseudo stem weight at 0% moisture, NCPs = nutrient concentration in the pseudo stem, %MCW = corm weight at 0% moisture, NCC = nutrient concentration in the corm.

The samples were then moved to the laboratory for analysis of total N, P, K, Ca and Mg. Handling and preparations were based on procedures as described by Okalebo et al. (2002). From the bunches of each variety, a few fruits were picked, their peel and pulp separated and total sample fresh weights taken. These samples were later oven dried at 70°C for 48 h and the dry matter weight recorded.

The dry matter of the whole plant was also calculated using the following equation:

$$(Sdf*tff/fsf)+(sdl*tfl/fsl)+(sdp_s*tfp_s/fsp_s)+(sdp*tfp/fsp)+(sdc*tfc/fsc)$$

Where, Sdf = Sample dry matter of the fingers, Tff = total fresh weight of the finger, Fsf = fresh sample weight of fingers, Sdl = sample fresh weight of the leaf, Tfl = total fresh weight of the leaf, Fsl = fresh sample weight of the leaves, sdp_s = sample fresh weight of the pseudo stem, tfp_s = total fresh weight of the pseudo stem, fsp_s = fresh sample weight of the pseudo stem. Sdp = sample fresh weight of the peduncle, Tfp = total fresh weight of the peduncle, Tsp = fresh sample weight of the peduncle, Sdc = sample fresh weight of the corm, Tfp = total fresh weight of the corm, Fsp = fresh sample weight of the corm.

Destructive sampling was carried out and three (3) sub-samples taken from the corm, pseudo stem, peduncle, functional leave and fingers on the banana plants. The samples were obtained from the upper, middle and lower parts of the plant parts, that is, leaves, pseudo stem, corm, fingers and peduncle; Total fresh weight of the whole bunch, pseudo stem, peduncle, leaves and fingers were measured and recorded. The samples were oven died at 70°C for 48 h and dry weight recorded. The harvest index (fruit yield) as a proportion of above ground was determined from the sub sample.

Soil and plant nutrient analyses

Composite soil samples (of 5 sub- samples per plot) were taken from 45 fields where the plant samples were collected at a depth of 30 cm. These were plantations where fertilizers had not been applied. The samples were then taken to the laboratory and preparation and handling was based on procedures as described by Okalebo et al. (2002). Samples were oven-dried at 40°C for two consecutive days, and were thoughly mixed and ground using a mortar and a pestle to pass through a 2 mm sieve. The soils were analyzed at the National Agricultural Research Laboratories, Kawanda in central Uganda. Soil pH was determined using deionised water at sediment to water ratio of 1:2.5. Soil texture was determined using the hydrometer method (Bouyoucos, 1936). Soil organic carbon was determined by oxidation with excess aqueous potassium dichromate mixed with sulphuric acid, followed by titration against ferrous ammonium sulphate (Okalebo et al., 2002).

Total N was determined by Kjeldahl oxidation and semi-micro Kjeldahl distillation (Bremner, 1960). Exchangeable bases (K, Mg and Ca) were extracted using excess 1M ammonium acetate solution. Exchangeable K was then determined by flame photometry, while Mg was determined using atomic absorption spectrophotometry.

Phosphorus in the extract was determined using the molybdenum blue colorimetric method (Okalebo et al., 2002). (LSD) test at 5% level of significance (SAS, 2008).

The nutritional status of bananas, with respect to N, P, K, Ca and Mg, was evaluated by comparing the analytical data with established critical levels. The relationship between plant content of the five nutrients and their concentration in the soil was determined by coefficient of correlation (r). All laboratory analyses were done in duplicate to increase precision of results.

Above-ground dry matter was computed as the sum of fruit, peduncle, corm, leaves and pseudo stem. All directly measured plant parameters were based on oven-dried plant material.

Data Analysis

Response variables for growth parameters and yield components were checked for normality using t test and found to be relatively normally distributed, necessitating no data transformation. Exploring the effect of cultivar, agro ecological zone and farm soil texture on genotype performance was done by exposing the data to Analysis of Variance (ANOVA) using the general Linear Model (GLM) in SAS software. Means within each agro ecological zone and later by district were separated using the Least Significant Difference (LSD).

The nutritional status of bananas, with respect to N, P, K, Ca and Mg, was evaluated by comparing the analytical data with established critical levels. The relationship between plant content of the five nutrients and their concentration in the soil was determined by coefficient of correlation (r).

RESULTS AND DISCUSSION

Tables of mean Nutrient element concentration in different organs of various banana cultivars

Generally, most of the nutrient elements in the various organs were not statistically significant except for a few. The major differences were observed in organs of FHIA 17 and M2. For example, Ca in the peduncle and in the fingers of FHIA17 was significantly different from those of M2 (Figures 1-6). Ca in the peduncle is said to have the potential to reduce finger drop, since its major purpose is

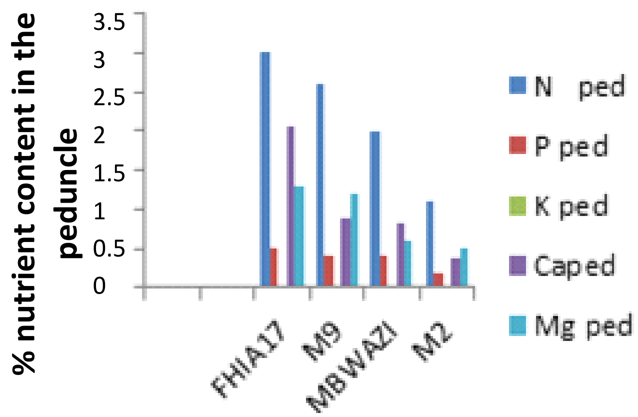

Figure 1. Percentage nutrient content in the peduncle.

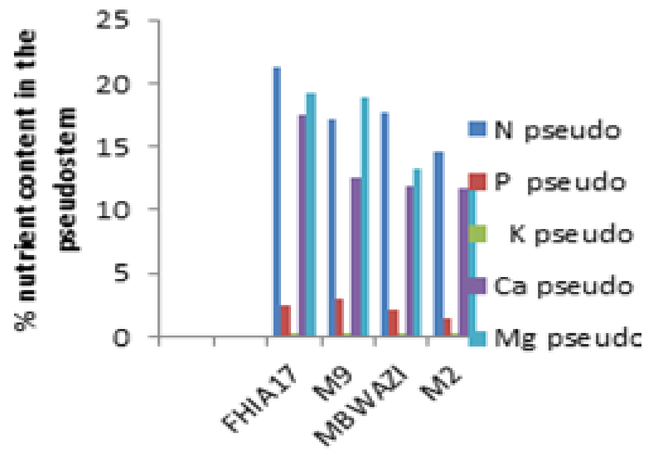

Figure 4. Percentage nutrient content in the pseudostem.

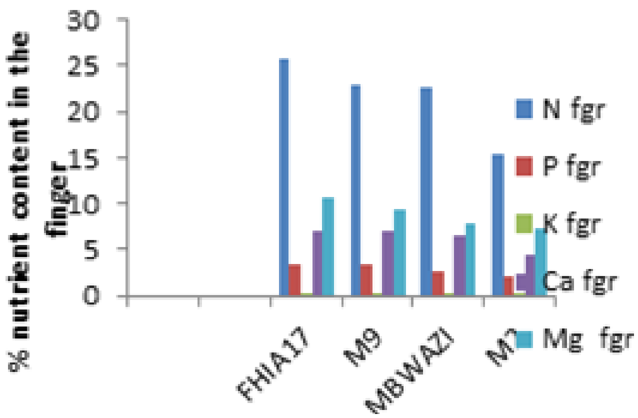

Figure 2. Percentage nutrient content in the fingers.

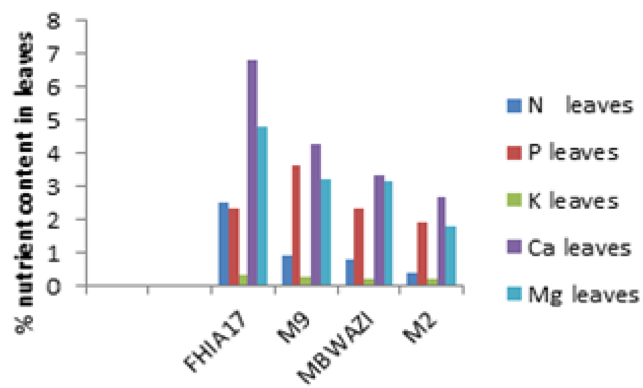

Figure 5. Percentage nutrient content in the pseudostem.

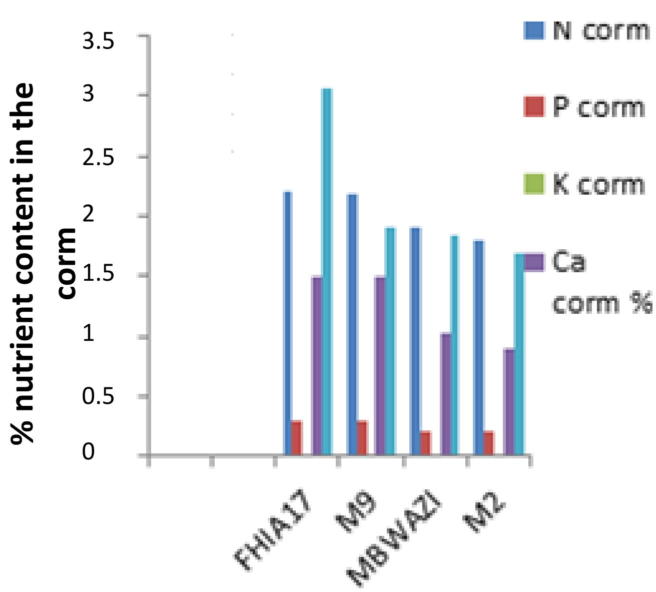

Figure 3. Percentage nutrient content in the corms.

N Ped= Nitrogen concentration in the Peduncle; P ped = phosphorus concentration in the Peduncle; K ped = potassium concentration in the Peduncle; Caped = calcium concentration in the Peduncle; Mg ped = magnesium concentration in the Peduncle; N fgr = Nitrogen concentration in the fingers; P fgr = Phosphorus concentration in the fingers; K fgr=Potassium concentration in the fingers; Cafgr = Calcium concentration in the fingers; Mg fgrs= Magnesium concentration in the fingers; N pseudo = Nitrogen in the pseudo stem; P pseudo= phosphorus in the pseudo stem; K pseudo =potassium in the pseudo stem; Ca pseudo= Calcium in the pseudo stem; Mg pseudo= Magnesium in the pseudo stem; N corm =Nitrogen concentration in the corm; P corm = Phosphorus concentration in the corm; K corm = Potassium concentration in the corm; Ca corm= calcium concentration in the corm; Mg corm = magnesium concentration in the corm; N leaves = Nitrogen concentration in the leaves; P leaves=Phosphorus concentration in the leaves; K leaves= Potassium concentration in the leaves; Ca leaves = Calcium concentration in the leaves; Mg leaves = Magnesium concentration in the leaves; Mbwazi= Mbwazirume.

for desert, this reduces post-harvest losses (Nowakunda et al., 2000). Most of the differences were in FHIA17, this could be because of its genetical make up because it is

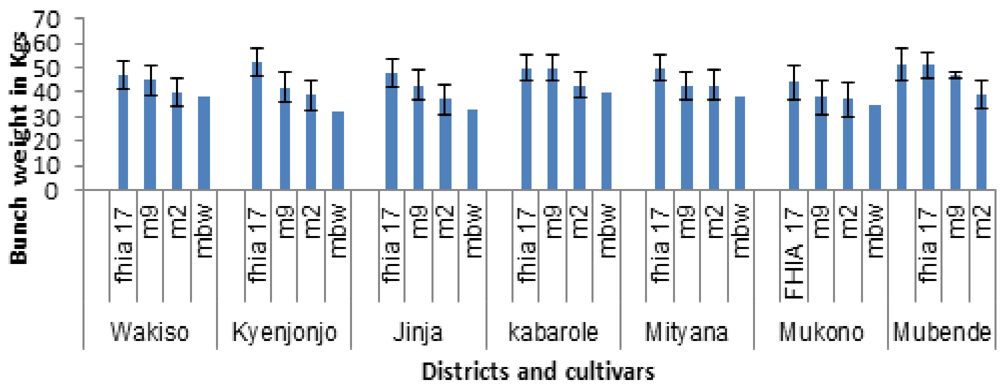

Figure 6. Bunch weights (kgs) for the various cultivars in the different districts.

an AB while the rest are not. M9, M2 and Mbwazirume did not have major differences, this is probably because, they are genetically related since the two hybrids were bred from the east African highland bananas (AAA) and Mbwazirume is one of the AAA cultivars (Barekye et al., 2002).

The few significant differences, could probably be because the mechanism of nutrient uptake is similar for all the cultivars. The results showed that FHIA 17 had the highest nutrient concentrations meaning that its nutrient uptake is higher than the rest of the cultivars. Total nutrient uptake and concentration does not depend on the cultivars but other factors which may include, soil moisture, management practices and soil ph. Most nutrients in the plant were found to be below average, average or just slightly above average, probably because sampling was done at harvest stage.

Generally, the concentration of plant nutrients fell with age. It was also established that all nutrients reach the same proportion in the fruits irrespective of the amounts supplied, (Esguerra, 2009). Insufficient potassium supply reduces the total dry matter production of Banana plants and the distribution of dry matter within the plant. The bunch is the most drastically affected organ and hence the importance of potassium in banana growing. Turner and Barkus (1980) found that while low potassium supply halved the total dry matter produced, the bunch dry matter was reduced by 80% and the roots were unaffected. It was suggested that of the various organs competing for potassium, those nearest to the source of supply is the most successful in obtaining their requirements. Studies of the ontogenic course of potassium uptake under field conditions have shown an overall decrease in whole plant concentration of potassium in the dry matter from sucker to fruit harvest. The potassium uptake is proportionally greater than dry matter accumulation early in the life of the plant. Under restricted potassium supply, the highest potassium uptake rate occurs during the first half of the vegetative phase. It is redistributed within the plant (Vorm and Diest, 1982) to allow further accumulation of dry matter.

Where potassium supply is abundant, large amounts of potassium is absorbed during the latter half of the vegetative phase Twyford and Walmsley (1973) and have a special effect on the maturation process (Fox, 1989). Even when potassium supply is abundant, potassium uptake during the life cycle is appropriate to meet the needs of the main plant crop but it is not relevant to ratoons, since in stools the mother plant and followers are present at the same time.

In general, M2 had the lowest nutrient use efficiency (Table 1). This suggests that cultivar FHIA17, which was the best in terms of nutrient use efficiency has a greater ability of converting absorbed nutrients into fruits (Ortiz-Monasterio et al., 2003). FHIA17 was followed by M9 in terms of nutrient use efficiency. FHIA17 nutrient concentration is significantly different from that of other cultivars, it means that, it is able to utilize acquired nutrients into fruits/bunch more than any other cultivar.

The results also showed high N and P use efficiency for FHIA 17 in Kamuli as compared to Kyenjojo, meaning there are less N and P in Kamuli. There was also higher K nutrient use efficient by FHIA17 in Wakiso as compared to Mityana. The results also showed high Ca use efficiency by FHIA17 in Mityana as compared to Wakiso, and high Mg use efficiencies in Kyenjojo as compared to Mityana (Table 1). M2 had higher N nutrient use efficiency in Kamuli than in Kyenjonjo and there was higher P use efficiency in Kamuli than in Mubende.

The results also showed higher K, Mg and Ca use efficiency in Kabarole than in Kyenjojo. M9 had a higher N, K, Mg and Ca use efficiency in Mubende as compared to other districts and higher P use efficiency in Mukono as compared to Kyenjojo. M9 had a higher N and P use efficiency in Kamuli and higher K, Mg and Ca use effiency in Kabarole as compared to other districts. Mbwazirume had a higher N, K, Mg and Ca nutrient use efficiency in Mubende as compared to other districts and

Table 1. Nutrient use efficiencies of different banana cultivars in different districts.

Cultivars	District	Average NUE (N) (%)	Average NUE (P) (%)	Average NUE (K) (%)	Average NUE (Ca) (%)	Average NUE (Mg) (%)
	Jinja	38.1	270.5	10.4	56.5	72.2
	Kamuli	83.8	750.7	18.2	170.1	85.8
FHIA 17	Kyenjojo	30.0	185.4	5.7	41.8	60.5
	Mukono	63.1	430.6	16.1	111.8	117.3
	Wakiso	41.2	499.1	8.9	107.2	114.8
Total average NUE (%)		49.4***	388.5***	12.0***	89.0**	89.0***
CV (%)		11	9	18	14	10.3
	Kyenjojo	33.2	290.5	11.9	53.1	73.9
M2	Mityana	78.7	1009.1	7.3	107.2	34.4
	Mubende	35.9	246.7	9.6	80.7	68.2
	Mukono	38.3	328.3	8.4	100.4	59.9
	Wakiso	31.3	287.2	24.2	60.2	34.3
Total average NUE (%)		39.3*	353.9**	11.0***	79.1**	61.3*
CV (%)		8.5	13.7	18	8	17
	Jinja	43.9	364.2	9.7	107.8	129.3
	Kabarole	46.9	240.9	34.3	179.1	88.9
	Kamuli	55.8	486.8	13.8	117.2	198.5
M9	Kyenjojo	32.0	288.2	8.1	85.9	33.8
	Mityana	33.2	245.0	9.9	141.5	62.0
	Mubende	40.2	239.8	12.8	90.6	111.3
	Mukono	50.5	394.7	12.4	120.0	86.1
	Wakiso	37.1	290.9	10.3	91.3	64.4
Total average NUE (%)		41.9**	316.6*	13.3***	117.8***	87.0***
CV (%)		14	15.4	15	19	12
	Jinja	47.7	359.6	7.0	79.0	68.7
	Kyenjojo	46.8	241.0	10.3	112.2	98.3
Mbwazi	Mityana	47.7	339.2	10.3	178.3	62.7
	Mubende	51.6	299.3	12.1	230.5	119.3
	Mukono	49.1	396.7	9.9	68.6	96.3
	Wakiso	41.7	248.1	9.6	107.9	48.4
Total average NUE (%)		47.8***	331.9**	9.7*	110.6***	85.5**
CV (%)		11.6	17	9.1	9.7	13

*, ** and *** denotes significant differences at p≥0.05, 0.01 and 0.001 respectively, between districts. Mbwazi =Mbwazirume.

higher P use efficiency in Mukono district as compared to other districts. Generally, there was high nutrient use efficiency in the districts of Kabarole, Kyenjojo and Mubende and these are the districts that had bigger bunches, meaning that the farms in the above districts have average nutrients. These three districts are found in the agroecological zone of western mid altitude farmlands, this zone has got a combination of soil types namely Andosols, Histosols and Chernozems, these are all dark soils formed from volcanic materials and rich in organic matter**,** the farms in zone are fairly managed compared to farms in the districts of Wakiso, Jinja, Kamuli, Mukono and Mityana that belong to zones of southern and eastern lake Kyoga and lake Victoria crescent which had plants with low nutrient use efficiency. These agro ecological zones have Acrisols type of soil that has got clays with low cation exchange capacity **(**FAO 1988).

High nutrient use efficiency for elements suggests deficiency for those various elements in the different areas, while low nutrient use efficiency suggests sufficiency of these nutrients (Ortiz-Monasterio et al., 2003).The variations in the elements use efficiency is probably generally due to the different soil types, soil management, altitude and climate among others.

The bunch weights for the various cultivars between the districts were not significantly different. These results support results for the nutrient use efficiencies of various cultivars in the different districts**.**

Table 2. Correlation matrix of soil properties and plant nutrient concentration.

Variables	N (%)	P (ppm)	K (cmolc/kg)	Ca (cmolc/kg)	Mg (cmolc/kg)	pH	OM	Total N	Total P	Total K	Total Ca	Total Mg
N (%)	1											
P (ppm)	0.41*	1										
K cmolc/kg	0.34 *	0.521	1									
Cacmolc/kg	0.63*	0.383	0.602	1								
Mg cmolc/kg	0.64 *	0.411	0.53	0.848	1							
pH	-0.19	-0.03	0.265	0.368	0.24	1						
OM	0.73*	0.34*	0.29*	0.60*	0.62*	0.04*	1					
Total N	0.004	0.171	0.095	0.089	0.0059	-0.03	0.070	1				
Total P	0.116	0.15	0.20	0.23	0.11	0.15	0.15		1			
Total K	-0.317	-0.17	-0.00	-0.13	-0.17	0.14	-0.2	0.55	0.46	1		
Total Ca	-0.05	-0.00	-0.12	-0.04	-0.05	-0.17	-0.0	0.64	0.44	0.61	1	
Total Mg	-0.07	-0.08	-0.14	0.00	-0.03	-0.11	0.3	0.450	0.283	0.372	0.338	1

OM= Organic matter; NS=not significant.

Correlation between soil nutrients and plant nutrient concentrations in banana plants

The results showed a negative correlation coefficient of total Potassium in the plant and Nitrogen in the soil -.0.317 ($p<0.012$) (Table 2) suggesting that high Nitrogen in the soil leads to maximum dilution of Potassium in the plant (Bolvin et al., 2004). All the nutrient concentrations in the plant were significantly positively correlated to each other. Similarly, the entire nutrients in the soil were positively correlated to each other, this is because, different nutrient elements affect the uptake of others as reflected in (Table 2).

On the other hand, N and P in the plants are also positively correlated to all the other studied nutrients in the soil but the correlation is not significant, whereas K, Ca and Mg in the plants are negatively correlated with all the studied nutrients in the soil, except for Mg in the plant and Ca in the soil which are positively correlated, It was observed that pH was low in most places. At acidic pH values, phosphate ions react with aluminum (Al) and iron (Fe) to again form less soluble compounds. The uptake, translocation and perhaps assimilation of cations and anions by plants depend not only on the concentration and availability of these ions in the nutrient medium but also on the presence of other cations and anions. The absorption of ca, for instance, may be depressed by excessive amounts of potassium or magnesium but favored by nitrate. The mechanism of these interactions is not always clear; in many cases it depends on ion competition on colloidal surfaces either at the surface of a cell or within the cytoplasm.

Organic matter was shown to be significantly positively correlated with all the nutrients. The higher the organic matter, the higher the nutrient elements in the soil and vice versa. This is because organic matter serves as a revolving nutrient bank account, meaning that it holds nutrients (Cations Exchange Capacity). Organic matter also improves on soil structure, maintains tilth and minimizes erosion; it prevents soil compaction, improves water infiltration and releases nutrients in an available form (Rietberg, 2008).

Conclusion and Recommendations

It was observed that nutrient use efficiency depends on other factors such as soil type, altitude, farm management and nutrient interactions (antagonism) and many others other than cultivar.

Fhia 17 was the best in terms nutrient use efficiency. M2 proved to be the poorest in terms of nutrient use efficiency, this means that it does well in areas with fertile soils and good management like Kabarole and Kyenjojo districts that are found in agroecological zone of Rwenzori footslopes and fortportal. Cultivars with high nutrient use efficiency like FHIA 17 do better in marginal land compared to the rest of the cultivars because FHIA 17 has the potential to convert the available nutrients into fruit unlike the other cultivars and farmers should be provided with suckers for those cultivars.Total nutrient uptake and concentration does not depend on the cultivars but other factors which may include, soil moisture, management practices and soil ph.

All the nutrient concentrations in the plant were significantly positively correlated to each other. Similarly, the entire nutrients in the soil were positively correlated to each other and therefore better soil management practices are recommended.

Conflict of interest

The authors did not declare any conflict of interest.

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Appendix 1. Source of funding and time frame.

Activity	Time frame	Item	Amount	Source of funds
Data collection	20012 February- June	Fuel (L)	600,000	BECANET
		SDA	200,000	BECANET
		Labor	100,000	BECANET
Sample analysis	2012 July-August	Sample analysis	550,000	Becanet
		Total	1,450,000	

Becanet, Biosciences for eastern and central Africa.