Fertilizer Management of Highland Banana in East Africa

By Kenneth Nyombi

East African highland bananas showed substantial yield increases with balanced fertilizer application. However, very high fertilizer cost and low banana market value in the region resulted in only small returns on investment. This poses a challenge to fertilizer use in remote areas in Uganda at this time.

East Africa highland banana (*Musa* spp., AAA-EAHB) or 'matooke' is a major staple crop grown for food and sale by smallholder farmers in Uganda. Banana yields in farmers' fields average 15 t/ha fresh weight (FW), and have remained small compared with yields of 60 to 70 t/ha/yr achieved at a research station with fertilizer application (Tushemereirwe et al., 2001; Smithson et al., 2001). Low banana yields achieved by smallholder farmers are attributed to poor soil fertility, low fertilizer use and increasing pest pressure (especially the banana weevil - *Cosmopolites sordidus*) and moisture stress (NARO, 2000). Very few (<5%) banana farmers in Uganda use mineral fertilizers due to perceived high cost, poor availability, and lack of knowledge related to its use. Past research has highlighted the large extent of soil fertility decline. For most soils in Uganda, soil pH, extractable P, Ca and K are below critical concentrations for most crops (Ssali, 2002). Increased agricultural productivity, mainly through increased fertilizer use, is recognized as key to alleviating poverty and ensuring food security in rural parts of Uganda. To increase banana productivity in a profitable way, there is a need to develop fertilizer recommendations for balanced application of nutrients.

Two nutrient omission trials were established at Kawanda (near Kampala) in central Uganda and Ntungamo in southwest Uganda to: (i) identify limiting nutrients and nutrient interactions in banana production; (ii) quantify banana yield responses to mineral fertilizers; and (iii) assess agronomic and economic efficiency of fertilizer use in banana production. Soils at Kawanda are Haplic Ferralsols, while soils at Ntungamo are Lixic Ferralsols. Soil pH was 5.5 at Kawanda and 4.8 at Ntungamo. Average soil organic matter and total N values were higher at Kawanda (2.6 and 0.1%, respectively) than at Ntungamo (0.7 and 0.07%, respectively). Average Mehlich-3 extractable P was higher at Ntungamo (3.5 mg/kg), but exchangeable K and Mg were low at both sites. Rainfall at both sites averages 1,258 mm/yr and follows a bimodal pattern with dry periods from June to July and January to March.

The trials were laid out in a completely randomized block design with four replicates. Treatments consisted of the following nutrient applications (kg/ha/yr): (1) 0N-0P-0K; (2) 0N-50P-600K; (3) 150N-50P-600K; (4) 400N-0P-600K; (5) 400N-50P-0K; (6) 400N-50P-250K, and (7) 400N-50P-600K. With the exception of the control, all plots received 60Mg-6Zn-0.5Mo-1B kg/ha/yr. Nitrogen and K were applied in 8 splits each year, while P, Mg, Zn, Mo and B were applied in two splits at the start of each rainy season. All fertilizers were applied in a circle at 0.4 to 0.5 m from the base of the plant. A plant spacing of 3 x 3 m was used resulting in a density of 1,111 plants/ha.

Abbreviations and notes: N = Nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; B = boron; Mo = molybdenum; Zn = zinc.

Under good management planting, one banana corm results in 3 production cycles. Yields from crop cycles 2 and 3 better represent a stable state. The development rate for banana at Kawanda was faster than at Ntungamo probably because of the difference in average temperatures (22 vs. 20°C, respectively). It was assumed that cycle 3 at Kawanda is reaching a stable state and would be comparable with cycle 2 from Ntungamo. The nutrient conversion efficiencies [CE; kg finger (dry matter)/kg nutrient in plant] for individual banana plants at harvest were calculated. Bunch yields (t/ha/yr) were calculated based on the duration from planting to harvest, but yields of successive crop cycles were based on the duration between consecutive harvests.

Banana Yields

Bunch yields (t/ha/yr) differed significantly among fertilizer treatments and sites (p = 0.001) (**Table 1**). Maximum bunch yield increases over the control plot yields were 7.2 t/ha/yr at Kawanda and 29.5 t/ha/yr at Ntungamo. Poor yields observed in control plots at both sites can be attributed to poor soil fertility. Potassium applications increased bunch yields, particularly at Ntungamo, where the soil K level of 0.09 $cmol_c$/kg was far below the critical value of 0.2 $cmol_c$/kg. Attainable yields and yield increases with fertilizer were smaller at Kawanda than at Ntungamo (**Table 1**) due to low available soil water and clay

Table 1. Yields of East africa highland banana as affected by mineral fertilizer application at Kawanda and Mbarara, Uganda.

	----------- Bunch yield, t/ha/yr -----------				
	Kawanda			Ntungamo	
	C1*	C2*	C3*	C1	C2
0N-0P-0K	5.4	18.2	15.3	2.1	13.7
0N-50P-600K	7.6	25.4	22.9	7.6	33.8
150N-50P-600K	6.1	19.2	22.4	8.9	39.6
400N-0P-600K	5.9	23.7	26.5	7.4	27.9
400N-50P-0K	5.7	19.7	18.9	2.6	13.0
400N-50P-250K	5.5	22.9	22.2	7.9	36.4
400N-50P-600K	5.7	22.1	22.5	9.1	43.2
Mean	6.0	21.6	21.5	6.5	29.7
S.E.D.**	0.4	1.63	1.63	0.5	2.53

*C1, C2 and C3 denote banana crop cycles 1, 2 and 3, respectively.
**S.E.D. denotes standard error of difference.

Potassium deficiency in banana plants supplied with N, P and micronutrients at Ntungamo, south-western Uganda.

Balanced banana nutrition - A trial plot well supplied with N, P, K, Mg and other micronutrients at Ntungamo, south-western Uganda. Note the mat management, i.e., a mother plant (C1), daughter (C2) and grand daughter (C3).

accumulation in the B-horizon, which limits root exploration of this soil layer. The larger yield responses to added fertilizer at Ntungamo can be explained by the coarser soil texture and lower bulk density, resulting in better root distribution (data not published) and improved soil moisture availability.

The N, P and K yield gaps at Ntungamo for cycle 2 plants were 9.4, 15.4 and 30.2 t/ha/yr, respectively, indicating that K was the most limiting nutrient followed by P and N. Increasing fertilizer N application rate from 150 to 400 kg/ha/yr resulted in a small yield increase (3.6 t/ha/yr), while increasing fertilizer K rate from 250 to 600 kg/ha/yr resulted in a yield increase of 6.8 t/ha/yr. In Uganda, the official mineral fertilizer reccomendation (kg/ha/yr) for banana is 100N-30P-100K-25Mg. From our experimental results, it is clear that the amount of K in the official reccomendation should be raised to at least 200 kg/ha/yr. Information from this work can be used to develop specific multi-nutrient fertilizers for banana, which are currently not avialable.

Total Nutrient Uptake and Apparent Fertilizer Recovery Efficiency

Total N, P and K uptake values determined at the time of harvest were significantly different (p = 0.001) among fertilizer treatments and sites. Average nutrient uptakes were greater at Ntungamo than at Kawanda, with averages of 113 vs. 74 kg N/ha, 13.2 vs. 8.8 kg P/ha, 353 vs. 280 kg K/ha (**Table 2**). The apparent fertilizer recovery efficiencies for N (<10%) and P (<5%) calculated in this study were small. Larger K recovery efficiencies (36 to 49%) at both trial sites indicate the importance of K nutrition in banana growth. However under intensive management in south America (Costa Rica and Honduras), maximum recovery efficiencies are estimated at 50% N, 30% P and 75% K (Lopez and Espinosa, 2000).

Table 2. Average N, P and K uptake (kg/ha) for banana (crop cycles 1, 2 and 3) at the harvest stage of cycle 1 and recovery efficiency for highland banana plants at harvest stage at Kawanda and Ntungamo.

	-------- Kawanda --------			-------- Ntungamo --------		
Treatment/site	N	P	K	N	P	K
0N-0P-0K	70.5	7.40	204	62.6	6.70	121
0N-50P-600K	78.3	9.50	332	111	13.2	420
150N-50P-600K	79.6	9.20	316	138	17.3	487
400N-0P-600K	74.7	8.90	303	121	13.9	415
400N-50P-0K	66.2	8.30	237	73.5	7.90	147
400N-50P-250K	70.9	8.50	256	136	15.7	367
400N-50P-600K	78.9	9.70	312	149	17.6	510
Mean	74.2	8.80	280	113	13.2	353
S.E.D.	3.67	0.43	15.5	6.90	0.85	21.1
Fertililizer recovery efficiency, %	2	1	14	10	5	49

*S.E.D. denotes standard error of difference.

Profitability of Fertilizer Use

Since banana is a perennial crop, with yields increasing with sucessive harvests to a stable state, yields (t/ha/yr) for cycle 3 plants at Kawanda and cycle 2 plants at Ntungamo were used to calculate the profitability of fertilizer use.

Application of fertilizer at rates targeting high yields without improved soil moisture management (e.g., mulching) at Kawanda in central Uganda resulted in mostly negative gross margins. This was due to the small yield response to fertilizer application. At Ntungamo, fertilizer use was profitable, with highest gross margins of about US$1,000/ha with moderate rates of N and P application and high rates of K application (**Table 3**). However, very high fertilizer costs and low banana market value at these sites, because of poor access to major banana markets in Uganda, meant that the added economic benefits over control plots were low or negative. To make fertilizer use attractive among smallholder banana farmers in central Uganda, agronomic efficiency of the applied fertilizer has to be increased. Supporting farmers access to markets that offer higher prices for banana will be crucial to ensure profitable banan production intensifi-

Table 3. Profitability of fertilizer use in two nutrient ommission trials calculated for cycle 3 plants at Kawanda and cycle 2 plants at Ntungamo.

	Kawanda				Ntungamo			
Treatment	Yield–C3, t/ha/yr	Fertilizer cost, US$/ha/yr	Profits*, US$/ha/yr	Benefit over control, US$/ha/yr	Yield–C2, t/ha/yr	Fertilizer cost, US$/ha/yr	Profits, US$/ha/yr	Benefit over control, US$/ha/yr
0N-0P-0K	15.3	0	1,101	-	13.7	0	986	-
0N-50P-600K	22.9	1,616	32	-1,069	33.8	1,616	817	-169
150N-50P-600K	22.4	1,847	-234	-1,335	39.6	1,847	1,003	17
400N-0P-600K	26.5	1,992	-84	-1,185	27.9	1,992	16	-970
400N-50P-0K	18.9	1,349	11	-1,090	13.0	1,349	-413	-1,399
400N-50P-250K	22.2	1,716	-118	-1,219	36.4	1,716	904	-82
400N-50P-600K	22.5	2,231	-611	-1,712	43.2	2,231	878	-108

*Profits were calculated using the farm gate price of US$72/t (fresh weight) of banana and costs in US$ of 1 kg Urea = 0.7; 1 kg MOP = 0.76; 1 kg TSP = 0.95; 1 kg magnesium sulphate = 0.48; 1 kg of zinc sulphate = 3.34; 1 kg of borax = 19 and 1 kg of sodium molybdate = 71.
1US$ = 2,090 Ugandan Shillings. Labor and transport to Ntungamo costs were not included in the calculations.

cation. Encouraging practices that increase soil organic matter and soil moisture availability, such as mulching, improve fertilizer recovery in banana production systems (McIntyre et al., 2000). Use of fertilizer rates targeted at maximizing economic benefits may also provide an entry point to support smallholder farmers to intensify banana production in Uganda.

Summary

Results from nutrient omission trials in Uganda showed that K was the most limiting nutrient for banana growth. Drought stress played an important role in crop response to fertilizer input and affected sink filling, especially at Kawanda. Fertilizer recovery efficiencies measured in this study were low, far below the values published for bananas in Latin America, particularly for N and P. Profitable fertilizer use depends largely on fertilizer treatments and site conditions, with the highest gross margins obtained in well-drained soils. However, the results of this study showed that the economic benefit from fertilizer use was low because of high fertilizer cost and low market price for bananas. BC

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