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Effects of potassium deficiency, drought and weevils on banana yield and economic performance in Mbarara, Uganda

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Abstract

This paper reports results from a 6-year long-term fertilizer X banana weevil trial for highland banana in Mbarara, Uganda. The objective of the study was to quantify the effect of mineral fertiliser (100 kg N, 50 kg P, and 100 kg K ha^{-1} yr^{-1}) on crop and economic performance and weevil pest status. Soil and foliar analyses, and visual observations (i.e. yellowing of leaves) revealed that potassium deficiency was the major soil fertility constraint and a function of slope. Topsoil (0-15 cm) exchangeable K content was low down slope (<0.3 mmol$_c$ 100g^{-1} dm), but higher upslope (>0.6 mmol$_c$ 100g^{-1} dm). As a result, annual yields in the lower block (9 t ha^{-1}) were much lower than in the upper block (17 t ha^{-1}). Yield increase due to fertilizer application (4 t ha^{-1} yr^{-1}) was independent of initial soil fertility status. This observation was in line with foliar analysis, which revealed that K concentrations (2.0 %) were still at deficiency level in fertilized plots, suggesting that 100 kg K ha^{-1} yr^{-1} is too little to correct for the deficiency. K deficiency did not only reduce bunch weight, but also increased cycle length, resulting in a significant (r^2 = 0.57) correlation between these two crop parameters. Mean weevil pressure was too low (< 4%) to result in significant yield loss, but maximum bunch weight was less than 50% in plants with large corm damage (>8%). Overall, the applied fertilizer dose was not profitable; i.e. the mean benefit-cost ratio was 0.7. Probably, application of N and P fertilizer did not increase yields, but the mean benefit-cost ratio is still low (1.6) when N and P fertilizer costs are omitted, and drought-related risks are high. We recommend testing the use of mulch to decrease drought risk and enhance fertilizer use efficiency.

Key words: *Cosmopolites sordidus*, fertilisers, Musa spp.

Introduction

In Uganda, actual highland banana yields (5-30 t ha^{-1}yr^{-1}) are small when compared to potential yield (70 t ha^{-1}yr^{-1}) due to high pest- and disease pressure, soil fertility decline, and poor management (Van Asten et al., 2004). Although it is generally accepted that soil exhaustion is a major cause of low and declining yields, there are almost no data to demonstrate this relationship (Van Asten et al., 2004). But even if soil fertility is not a problem already, it may become a major problem in the near future. The increasing commercialization of banana increases the export of plant nutrients from the farms to the urban centers (Bekunda and Manzi, 2004). A 25 ton bunch yield will export approximately 42 kg N, 5 kg P, and 143 kg K (Van Asten et al., 2004). Contrary to commercial banana farmers elsewhere in the world, Ugandan banana growers do not use mineral fertilizers to replenish soil nutrient stocks (Bekunda and Woomer, 1996). Instead, they only rely on organic amendments, causing further soil fertility decline of annual cropped fields and grassland (Wortmann and Kaizzi, 1998). With increasing land pressure, the availability of organic inputs is decreasing. Although nutrient losses can be minimized with improved organic matter management, sustaining long-term soil fertility without the judicious use of external inputs seems unlikely in market-oriented banana systems (Van Asten et al., 2004).

High fertilizer prices, poor availability of credit (Bekunda et al., 2001; Sseguya et al., 1999), and a lack of knowledge on how and what mineral fertilizer are best used, currently hamper adoption of mineral fertilizers in EA highland banana systems. Furthermore, the efficiency of (in)organic fertilizers is greatly reduced if pest pressure is high. Ssali et al (2003) found very little effect of applying chemical fertilizers (NPKMg 50 15 50 12.5 kg ha^{-1} yr^{-1}) in weevil-infested fields. Similarly, Smithson et al. (2001) found that chemical fertilizers only increased yields significantly when nematode and weevil pressure were low. There is further evidence showing that pest and disease pressure are closely related to soil fertility and plant nutrient uptake. Okech and Gold (1996) concluded from a literature review that phytophagous insects are sensitive to nutritional changes in host plants.

Bosch et al. (1996) suggested that weevil damage might be related to plant and soil phosphorus and cation concentrations, with special emphasis on the K/Mg ratio. Bosch et al. (1996) cited earlier studies by Borges Perez et al. (1983), who had suggested similar relationships between plant and soil P, Zn, Mg and K content on the one hand, and the ability of a plant to close off infected or damaged cells with pectin and tylose (gel substances) on the other hand. However, this relationship between plant nutritional status and damage by weevil infection has never been confirmed.

We conducted long-term fertilizer X banana weevil (*Cosmopolitus sordidus*) trials for highland banana (AAA-EA, cv Enyeru) in Mbarara, Uganda. The objectives of this study were: (i) to quantify the impact of mineral fertilizer and weevils on yields and foliar nutrient concentrations, and (ii) to quantify the cost/benefit ratios of fertilizer applications for different fertilizer X weevil scenarios.

Material and Methods

The trials was located on at the NARO-IITA research farm on the outskirts of Mbarara town (S 0.33, E 30.36, altitude 1380m). The climate is typical for the mid-altitude African Higlands, with fairly constant and moderate temperatures throughout the year; i.e. the mean daily maximum and minimum temperature is 26 and 14 °C, respectively. The rainfall distribution shows a strong bimodal pattern with dry spells from June-August and December-February. The annual rainfall totals around 950 mm yr^{-1} (NARO, unpublished). Bananas are a major food and cash crop in Mbarara district. In 1996, a PRA in the Namuyanja valley, close to the trial site, revealed that farmers considered banana weevils and declining soil fertility as their major constraints (Gold et al., 1997).

The trial started in October 1996 and measurements continued up to June 30, 2002. The trial consisted of the following four treatments: (T1) fertilizer with weevils, (T2) no fertilizer with weevils, (T3) fertilizer without weevils, (T4) no fertilizer without weevils. Each treatment was repeated four times (i.e. 4 blocks) following a randomized complete block design. Fertilizer doses comprised 100 kg N (Urea 46%), 50 kg P (Triple Supper Phosphate (46%), and 100 kg K (Muriate of Potash 52%) per hectare per year. Fertilizers were manually spread on the soil surface, with split K fertilizer applications at the onset of each wet season (March, October), and with N fertilizer applications at the onset and in the middle of each wet season (March, May, August, November). P was applied once (October). Prior to the installation of the trial, the site was under natural fallow (i.e. grass and shrubs). Hence, no or few banana weevils were present, so weevils were introduced in the trial in two splits. The first batch was released in the first week of February 1997 (3 months after emergence of the suckers) at the rate of 10 adults per mat (5 females and 5 males). The second batch was released 5 months later (July 1997) at the rate of 20 adults per mat (10 females and 10 males). Weevil control plots were protected with "Dursban" granular insecticide at the rate of 180g per mat (twice a year, at the start of each wet season).Plot sizes were 21m X 21m. Each plot had 49 mats at a spacing of 3m X 3m. Plots were separated by 20m wide allays to safe guard against fertilizer drift and weevil movement from infested plots to the uninfected plots. The field was on a gentle slope (4-5%). Trial blocks were laid across the slope with block 1 being at the top and block 4 at the lower end of the slope.

Composite soil samples (4 samples per plot) from were taken at each plot at 0-15cm and 15-30cm depth at the beginning of each trial. The soil samples were analyzed at Kawanda Agricultural Research station. Samples were air dried, ground and sieved (<2mm). Analyses comprised pH (1:2.5 suspension), soil texture (Bouyoucos, 1936), organic matter (Walkley, 1947), and total N% (Bremner, 1960). Available P and exchangeable bases (Ca, Mg, K, Na) were measured in a single ammonium lactate extract (Egner et al., 1960). P in the extract was estimated using a colorimeter, K using a flame photometer, and the other bases using an AAS. Values obtained with the lactate method can be converted to exchangeable cation values based on ammonium-based extractants (Foster, 1971). However, the difference between the methods (e.g. between the lactate and Melich-3 method) is generally small (<15%), with the lactate method giving slightly lower values (John Wendt, personal communication).

Each mat was marked and monitored individually for date of flowering. At harvest, date and bunch weight were recorded. Mean annual bunch yields per plot were determined graphically; i.e. for each plot, cumulative yield was plotted as a function of time with linear interpolation between harvest points, and annual yield being equal to the difference in interpolated cumulative yield at January 1 and December 31 of each year.

Corm damage due to weevils was assessed using the method described by Gold et al. (1994). Bunches were exported from the field. Foliar samples at large sucker stage were taken of the 3rd last expanding leaves of large suckers in September 1997. Foliar samples were oven-dried (70 °C), grind (< 1 mm) and subsequently analyzed for N, P, K, Ca, and Mg (Parkinson and Allen, 1975) at the ICRAF laboratory in Nairobi.

Rainfall was recorded daily. The mean expected daily rainfall for each day of the year was calculated as the total cumulative rainfall during the trial period, divided by the number of days. The cumulative rainfall deficit was calculated as the expected minus the actual cumulative rainfall, and was considered as an indicator to identify dry and wet periods.

Partial budget analysis

A partial budget analysis was used to quantify the cost-benefit ratio of fertilizer applications. The budget analysis calculations were done on a yearly basis, using yearly cumulative yield data for each plot. Harvested bunches were sold at the farm gate and bunch prices were recorded. Using a linear regression between bunch price and bunch weight, the prices of bunches consumed locally and the total income per plot per year were estimated. The benefits of fertilizers were calculated as the difference between treatment T1 and T2 (with weevils), and T3 and T4 (without weevils).

Data analysis

Statistical analyses were conducted using the software package SPSS for Windows (Version 10.0). Significance of factors and interactions on yield were analyzed for each season using multiple factorial ANOVA. Means for yields were compared using least square difference (LSD) test. Considering the strong gradient in exchangeable K^+ of the topsoil (0-15cm) and its potential effect on yield, the same statistical analysis were also conducted using exchangeable K^+ as a covariate.

Results

Agronomic and soil data

Statistical analysis showed that the factor weevils and its interaction with other factors had no significant effect on yield. Hence, the weevil factor was excluded from further statistical analysis and treatments T1 and T3 (with fertilizer), and T2 and T4 (without fertilizer) were considered equal. Annual and cumulative yield data for fertilized and non-fertilized treatments are shown in Table 1. Analysis of variance (ANOVA) revealed that fertilizer, year, block, year x fertilizer and year x block all were significant factors ($p<0.01$), but fertilizer x block and fertilizer x year x block were not ($p>0.05$). We suspected that the block effect was related to a soil characteristic. Basic soil characteristics for 0-15 cm and 15-30 cm depth are shown in Table 2. A correlation matrix between cumulative yield and soil parameters at 0-15 cm and 15-30 cm depth (Table 2) revealed that yields were best related to the exchangeable K^+, Ca^{2+} and Na^+ content at 0-15cm depth. Visual observations (i.e. yellowing of the leaf margins), and foliar analysis (Table 2) showed that K deficiency, and not Ca or Na deficiency was most likely to explain the high correlation coefficient between exchangeable soil K^+ and yield. The high correlation between Ca^{2+}, Na^+ and yield was explained by the very high correlation ($r^2 >0.98$) between exchangeable K^+, Ca^{2+} and Na^+. A map of the trial layout with exchangeable K^+ content, treatment and yields clearly shows that there is a strong K^+ gradient in the trial (Figure 1), with moderate exchangeable K^+ content in the upper plots (> 0.6 meq/100g dry soil) and very low exchangeable K^+ content in the lower plots (<0.3 meq $100g^{-1}$ dry soil). Similarly, clay content in the upper plots was much higher (>20%) than in the lower blocks (11%). Available P content showed an opposite trend with low values (< 4 mg kg^{-1}) in the upper plots and higher values (> 8 mg kg^{-1}) in most of the lower plots. Even though available P values of 4 mg kg^{-1} are considered low, and P foliar concentrations were low too (Table 3) plant P concentration were not related to yield, nor to soil p content.Although fertilizer had a significant effect on yield, this factor did not affect foliar nutrient concentrations, even when initial differences in exchangeable soil K^+ content were taken into account as a covariate in the analysis of variance. Foliar concentrations were not significantly related to soil parameter, with the exception of plant K concentrations, which were significantly positively correlated to 0-15cm exchangeable K^+ ($r = 0.69$), Ca^{2+} ($r =0.65$), Na^+ ($r =0.66$), and to 15-30cm clay content ($r =0.58$), and plant P concentrations, which were significantly positively correlated to 15-30cm exchangeable Mg^{2+} content ($r = 0.58$).

From the ANOVA it followed that the factor ‘year’ had a significant effect on yield. Annual yields in all plots showed strong temporal variation, with maximum yields below 9 t ha^{-1} in 1999 (year 3), but with maximum yields exceeding 23 t ha^{-1} in 2001 and 2002 (year 5 and 6). We hypothesized that this strong temporal variation could be related to climate factors. Since inter annual fluctuations in temperature are negligible (results not shown), fluctuations in rainfall were most likely to cause the temporal variation in annual yields. Mean annual rainfall during the trial period was 1006 mm, but rainfall in 1999 was only 678 mm, while 1027, 943, 1230, 1219 and 1022 mm were recorded in 1997, 1998, 2000, 2001 and 2002, respectively. The low rainfall in 1999 resulted in a large cumulative rainfall deficit and corresponded with low mean bunch yields (Figure 2 and Table 1). Cumulative rainfall deficit was significantly ($p<0.01$) negatively correlated ($r = -0.38$) with mean bunch weights of all treatments (results not shown).

In figure 2, one can recognize almost vertical clusters of bunch harvest; i.e. the first cluster represents the harvest of the mother plant and subsequent clusters represent those of the following ratoons. Although the data points within each cluster are almost vertically positioned, there is a slight tendency for smaller mean bunches to be harvested later. This tendency increases over the years. When the crop cycle duration (i.e. the number of days between two subsequent harvests of the same mat) increases, bunch size decreases significantly ($r^2 = 0.57$) (Figure 3).

As indicated earlier, weevils had no significant effect on yield. This was related to the fact that mean total corm damage in the weevil infected plots was still low to moderately low (<4 %) in all years. Nonetheless, maximum bunch weight of plants that had substantial corm damage (>8%) was substantially lower (<50%) than of plants that had no weevil damage (Figure 4).

Partial budget analysis

Based on the partial budget analysis, fertiliser costs averaged 400,000 USh (1,900 USh H” 1.0 USD) per hectare per year, with Muriate of Potash (K) being 20% more expensive than TSP or Urea per 50kg bag. The mean price per kg bunch during the trial period was 64 USh. The financial benefit

Table 1 Mean annual and cumulative banana yield (t ha^{-1}) for fertilized and non-fertilized treatments. The letters represent LSD-test significant differences between rows at different p-levels with topsoil exchangeable K^+ content included as a co-variate.

	1997	1998	1999	2000	2001	2002	Cumul
fertilized	11.3a	17.0	8.5	14.2a	24.1a	23.3a	86.7a
non-fertilized	10.2b	13.8	6.8	9.8b	15.6b	15.1b	63.8b
p-level	<0.05	n.s.	n.s.	<0.01	<0.01	<0.01	<0.05

Table 2. Mean soil characteristics at 0-15 cm and 15-30 cm depth at the onset the trial and their correlation with cumulative yield.

	Depth	pH	OM	N	P	Ca^{2+}	Mg^{2+}	K^+	Na^+	Clay	Silt
	cm		%		mg/kg	mmol$_c$/100 g dry soil				%	%
Mean	0–15	4.3	2.5	0.14	5.2	1.2	0.6	0.5	0.2	19	73
St.Dev	0–15	0.2	0.3	0.02	2.3	0.4	0.1	0.2	0.1	5	6
CC[1]	0–15	.00	.61*	.47*	-.50*	.77**	.35	.76**	.77**	.63**	-.59*
Mean	15–30	4.1	1.8	0.10	3.1	0.8	0.5	0.3	0.2	21	72
St.Dev	15–30	0.3	0.3	0.03	2.7	0.2	0.1	0.1	0.0	4	5
CC[1]	15–30	-.37	.23	.15	-.53*	.48	-.04	.55*	.53*	.52*	-.63*

[1] Pearson bivariate correlation coefficient with cumulative yield of individual plots; = significant at $p < 0.05$; ** = significant at $p < 0.01$

Table 3: Mean foliar nutrient concentrations (± standard deviation) in September 1997, their correlation coefficient (CC) with annual yields in 1997 and critical nutrient concentrations below which yield reduction is expected.

	N	P	Ca	Mg	K
Sep 97	3.21 ± 0.16	0.16 ± 0.01	0.96 ± 0.25	0.44 ± 0.08	1.95 ± 0.41
Crticical[1]	3.1	0.25	0.5	0.3	3.0
CC[2]	-0.30	-0.03	-0.14	-0.21	0.55*

[1] Crtical nutrient concentrations according to Wortmann et al. (1994); [2] Pearson bivariate correlation coefficient
* = siginificant at $p < 0.05$; ** = significant at $p < 0.01$

Fig 1: A schematic overview of the trial layout, indicating treatment and block position (in *italic*), the slope direction, mean annual yield, and initial topsoil (0-15 cm) exchangeable K$^+$ content.

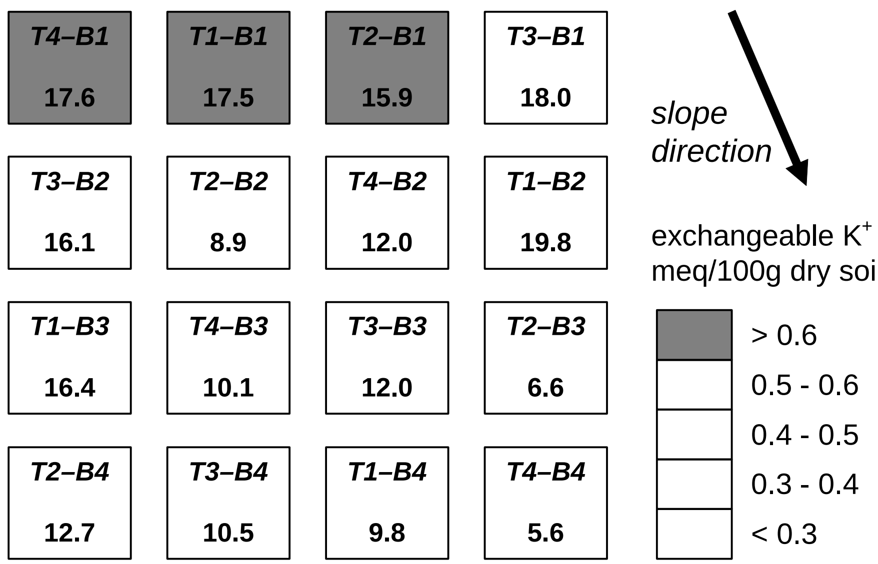


Figure 2. Cumulative rainfall deficit (line) and mean bunch weight of fertilized (black squares) and non-fertilized (grey dots) plots during the trial period.

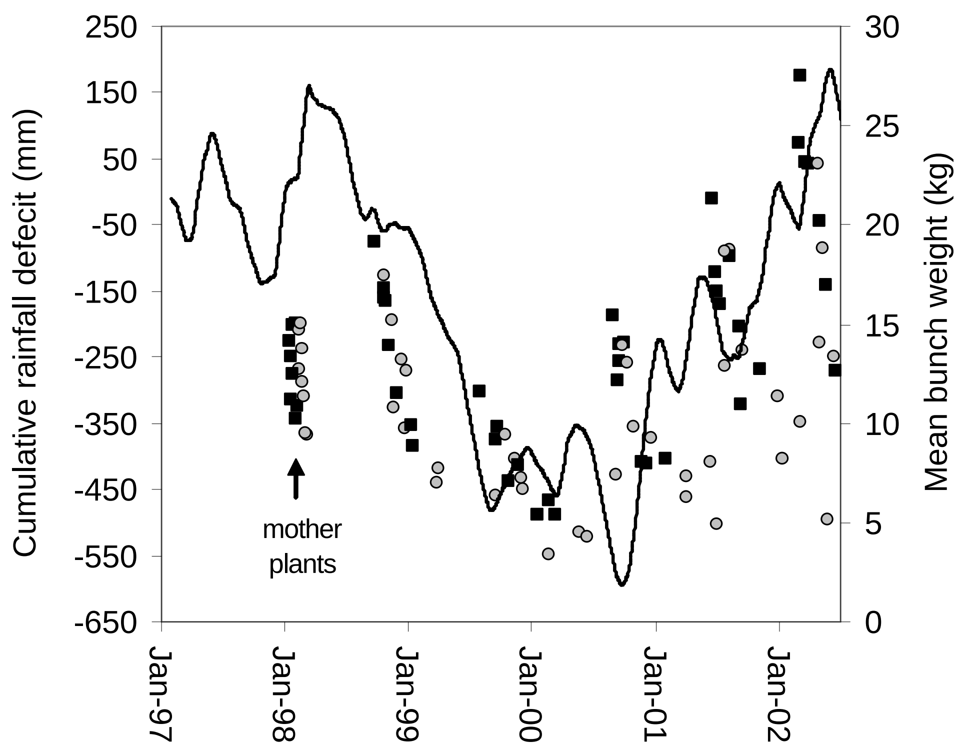


Figure 4. Mean bunch weight per plot per harvest as a function of the number of days between two subsequent harvests.

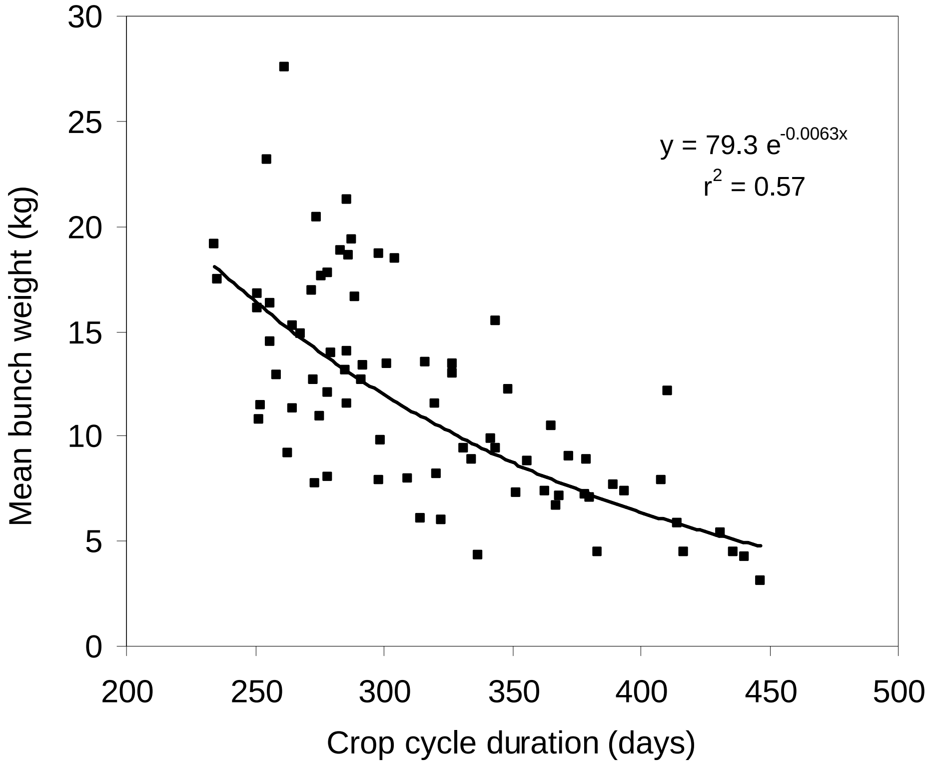
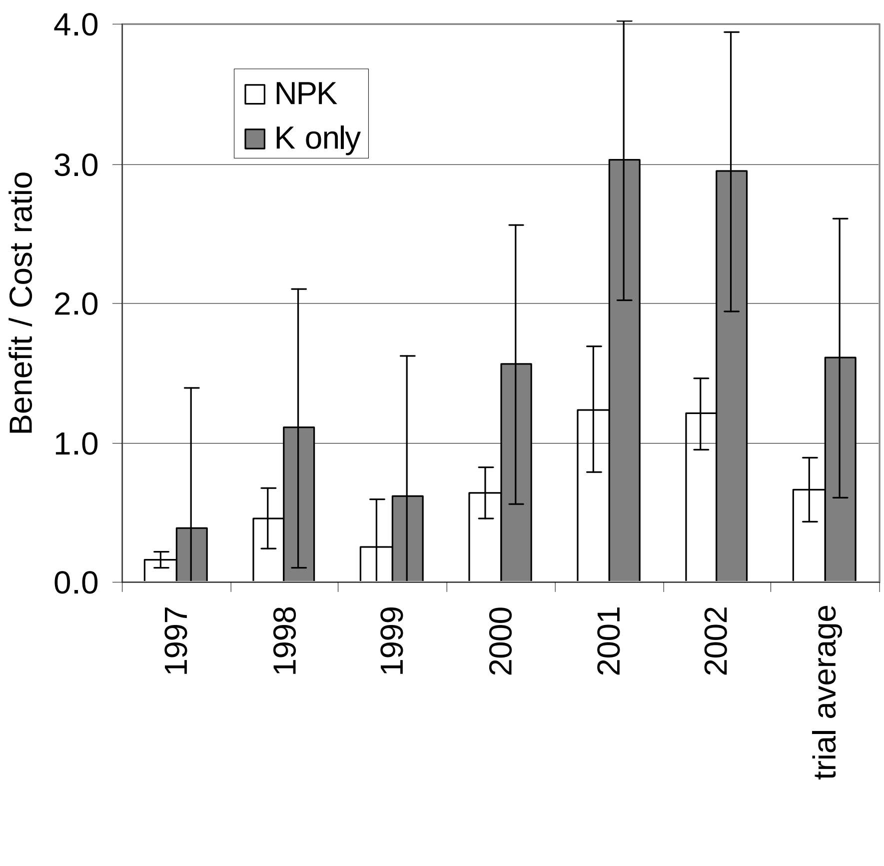


Figure 5. Benefit-cost ratios of fertilizer of the NPK fertilizer rates used in the trial, and for a scenario where we assume that only K fertilizer increased yields



related to fertilizer applications increased from 64,000 USh in the first year to over 480,000 USh in year 5 and 6. Averaged over the trial period, the used NPK fertilizer doses would lead to a net annual loss of 136,000 USh, or a benefit-cost ratio of 0.7 (Figure 5). If we assume that the fertilizer yield increase was entirely the result of K fertilizer, then N and P fertilizer (costs) can be omitted. In that case, annual fertilizer costs reduce to 164,000 USh per year and the mean annual net profit over the trial period would be 100,000 Ush, which corresponds to a benefit-cost ratio of 1.6. In a 'K fertilizer only' scenario, annual net profit would be -100,000 USh in 1997 and -62,000 USh in 1999, but would exceed 320,000 Ush in year 2001 and 2002. The fluctuations of benefit-cost ratios over time for a 'NPK fertilizer' and 'K fertilizer only' scenario are presented in Figure 5.

Discussion

Nutrient deficiencies

The soil and foliar analysis, in combination with visual observations, all indicate that potassium deficiency was the main yield-limiting factor. The potassium deficiency was related to the soil's low exchangeable K content (0.2-0.7 $mmol_c$ $100g^{-1}$ dry soil), especially in the lower block. The soils are classified as Haplic and Plinthic Ferralsol at the upper plots, but as Gleysol at the lower plots (Ssendiwanyo, unpublished). The strong variation in exchangeable K content caused low annual yields (9 t ha^{-1}) in the lower block when compared to the upper block (17 t ha^{-1}) (Figure 1). Average literature values suggest that a minimum exchangeable K^+ content of 1.0 meq 100g-1 dry soil is required to sustain optimum banana growth. The mean foliar K concentration (2 %) was also much lower than the 3%, which is considered as the minimum concentration to sustain optimum growth (Wortmann et al., 1994). Although fertilizer application increased yields by 4 t ha^{-1} yr^{-1} on average, this increase was independent of initial soil fertility status. This is in line with the observation that foliar K concentrations were not higher in fertilized plots, which means that K was still deficient in fertilized plots. Hence, yields could probably further have increased with increasing K fertilizer dose. When using an average literature value of 20 kg total above-ground plant K uptake per ton fresh bunch harvest for AAA cultivars (Van Asten et al., 2004), a 4 t yr^{-1} yield increase would be equal to an increased plant K uptake of 80 kg yr^{-1}, which would signify a K fertilizer recovery efficiency of 80%. This corresponds well to the high K fertilizer recovery efficiency of 75% that have been found in some other banana fertilizer studies (Lopez and Espinoza, 2000). Hence, the observed yield increase corresponds to the expected yield increase if K was a major growth limiting factor. Despite the soil's low available P content and the low foliar P concentrations (0.16 %), when compared to the critical limit (0.25 %) (Wortmann et al., 1994), there are no indications that P deficiency was a main yield limiting factor. On the contrary, the soil's available P content was negatively correlated with yields (Table 2). Foliar concentrations of N (3.1%) were above the deficiency level (Wortmann et al. 1994). Poor annual yields were not only caused by a decrease in bunch weight, but also by a substantial increase in crop cycle duration, as indicated by the negative correlation between bunch weight and crop cycle duration. An increase of delay in flower initiation is typical for potassium deficiency (Lahav, 1995) and is the likely reason for the observed increase in relationship between bunch weight and crop cycle duration.

Weevils

Weevils pressure at the site was too low (mean total corm damage < 4%) to result in significant yield loss. However, maximum bunch weight of plants with large corm damage (> 8%) was less than 50% of plants with no corm damage, which indicates that weevils can reduce yields significantly if the pest pressure is high. Corm damage was low due to the small weevil populations (results not shown), despite early efforts to establish a sizeable weevil population. We did not investigate why large weevil populations could not be sustained, but suspect that the lack of mulch in the trial did not create the humid micro-climate in which weevils thrive (Gold et al., 2003). It is very likely that yield losses due to weevils would be higher if additional mulch were to be applied. The low weevil pressure in the trial is in line with the findings of Gold et al. (1997), who found weevils to be a minor problem in the nearby Namuyanja valley, in contrast to farmers' complaints. Speijer et al. (1997) observed that nematodes (*P. goodeyi*) were a major constraint at survey sites in Mbarara, but since the trial was established on 'virgin' soil, it is unlikely to have played a major role at the trial site.

Drought

Annual rainfall during the trial period averaged 1000 mm yr^{-1}, which is less than the 1300 mm yr^{-1} that is required for ideal banana production according to Purseglove (1985). It is, however, likely that minimum rainfall requirement for the trial site are somewhat lower than 1300 mm yr^{-1}, since temperatures and evapotranspiration rates at 1200 m altitude are lower than at sea level. Nonetheless, the low annual rainfall in 1999 (678 mm) reduced yields by around 50% (see Table 1) and substantially reduced the absolute yield increase due to fertilizer application.

Partial budget analysis

The fertilizer rates used in this trial did not appear to be economic. Annual fertilizer costs (400.000 USh) exceeded annual fertilizer-related profits (264.000 USh). However, N and P fertilizer did probably not, or little, contribute to the observed yield increase; i.e. we found no or little evidence for P and N deficiency. Moreover, foliar analysis showed that K deficiency was still a major yield-limiting factor, even when K fertilizer was applied. Hence, it is very likely that the economic picture would improve a lot, if only K fertilizer was applied. This would basically decrease fertilizer costs by 60%. The mean benefit-cost ratio over the trial period would be 1.6 in a ‘K fertilizer only’ scenario. However, it is generally believed that a benefit-cost ratio of 2 is minimal in order to ensure farmer adoption of mineral fertilizers (Mokwunye et al., 1996). In 1997 and 1999, the yield increase due to K fertilizer application was not sufficient to justify the investment. The small yield difference between fertilized and non-fertilized treatments in 1997 might be explained by the fact that it was a mother plant harvest; i.e., (i) mother plants harvest are often smaller leading to smaller absolute yield differences, and (ii) mother plants partly rely on the nutrient stock of the sucker at the time of planting, making them less sensitive for differences in soil nutrient stock and soil fertility management. The small yield increase due to fertilizer in 1999 was explained by the drought, which reduced yields by 50%.

Conclusion

Potassium deficiency was the major yield limiting factor in this long-term banana trial. This was related to the soil’s low exchangeable K^+ content (0.2 - 0.7 $mmol_c$ $100g^{-1}$ dry soil). Potassium deficiency did not only lead to a reduced bunch weight, but also prolonged the crop cycle duration. We found no or little evidence to suggest that N, P, Mg or Ca deficiencies occurred.

Weevil pressure was too low (4%) to significantly reduce yields, but maximum yields for plants with substantial corm damage (> 8%) were more than 50% lower than that of plants with no or little weevil damage. Application of K fertilizer (Muriate of Potash) increased annual yield by 4.0 t ha^{-1}, and this increase was independent of initial soil fertility status. This is in line with foliar analyses results and suggests that K deficiency was still the main limiting factor, even when K fertilizer was applied. Hence, a further yield increase can be expected if K fertilizer dose would be increased. The K fertilizer recovery efficiency was estimated to be equal to what is generally considered ‘normal’ worldwide (i.e. 25%).

The combined application of N, P and K fertilizer was not economic and the application of K fertilizer alone was only marginally beneficial, with an average benefit-cost ratio of 1.6 and a net loss in 2 out of 6 years. A drought in 1999 reduced yields and the benefits of fertilizers by 50% or more. Hence, the low average benefit-cost ratio and drought-related risks make that the use of mineral fertilizers can not be recommended to farmers at sites where fertilizer response and farm-gate bunch prices are similar to that of the Mbarara trial site, despite severe deficiency symptoms. Hence, sustaining the soil fertility of banana system with mineral fertilizers at similar sites is only possible if (i) fertilizer prices drop, and/or (ii) bunch prices increase, and/or (iii) plant fertilizer response improves. To improve plant fertilizer response, it will be useful to test a combination of mineral fertilizer and mulch applications. The common grass mulches are generally rich in K, which might partly explain why grass mulches tend to do well, besides reducing drought stress (Ssali et al. 2003). With increased moisture availability, the health and efficiency of the root system is likely to improve, which can increase nutrient uptake and lead to better nutrient recyling. On the downside, mulch could lead to an increase in weevil population, but the overall effect of mulch on yield is likely to be positive.

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