

# Mineral Fertilizers Improve the Sensory Quality of East African Highland Bananas (*Musa* AAA-EA, cv. 'Kisansa')

Godfrey Taulya<sup>1\*</sup> • Piet van Asten<sup>1</sup> • Kephas Nowakunda<sup>2</sup> • Phoebe Kaddu-Mukasa<sup>2</sup>

<sup>1</sup> International Institute of Tropical Agriculture, P.O Box 7878, Kampala, Uganda

<sup>2</sup> National Banana Research Programme, P.O Box 7065, Kampala, Uganda

Corresponding author: \* g.taulya@iita-uganda.org

## ABSTRACT

Some farmers in Uganda believe that fertilizers negatively affect the sensory attributes of cooking type bananas. This belief may hamper the adoption of fertilizers. To verify the validity of this belief, bunches (*Musa* AAA-EA, cv. 'Kisansa') from fertilized (i.e. N-P-K-Mg-Zn-S-B-Mo) and non-fertilized plots were harvested from on-station trials in central (Wakiso) and southwestern (Ntungamo) Uganda. Samples were anonymously tagged for preparation (boiled or steamed) and sensory evaluation by farmers from southwestern (n=33) and central Uganda (n=35). Data were analyzed in STATA using Tau-b rank test for proportions, median ranks and odds ratios. The frequency of evaluators ranking fertilized steamed bananas highly (i.e. 'Best' or 'Second-best') was significantly ( $P \leq 0.05$ ) higher (60%) than for non-fertilized bananas (42%). The opposite was true for boiled bananas (fertilized, 43% vs. non-fertilized, 60%). Irrespective of site of cultivation and evaluators' origin, gender or age, fertilizers significantly ( $P \leq 0.05$ ) improved the appearance, odor, softness and acceptability of steamed bananas. For boiled bananas, attributes did not significantly differ between fertilizer treatments, except for appearance, which was significantly inferior ( $P \leq 0.05$ ) for fertilized bananas. This study shows that the belief that fertilizers negatively affect the sensory attributes of cooking type bananas is generally incorrect. Only when boiled, fertilized bananas appeared less attractive than non-fertilized bananas. The dominant and traditional way of preparing cooking type bananas in Uganda is through steaming (i.e., *matooke*). We recommend the application of fertilizer, as it will not only positively affect yield, but also the sensory quality of cooking type bananas.

**Keywords:** *matooke*, odor, softness, taste, Uganda

## INTRODUCTION

Bananas (*Musa* sp.), especially the cooking type East African Highland (AAA-EA) cultivars (*Matooke*), constitute a major staple food crop in Uganda. Cultivated in rural areas on smallholdings averaging less than 0.5 ha (Gold *et al.* 2002a), Uganda's annual production (9.9 million Mt) was the highest globally as of 2005 (FAO 2008). Furthermore, Uganda's per capita consumption of bananas, estimated at between 220 and 460 kg year<sup>-1</sup> was also the highest globally (FEWSNET 2004). The increasing commercialization of banana production over the past two decades is escalating nutrient exports through the transport of fresh bunches from the rural areas to the urban centers. Annual nutrient exports from the rural areas to Kampala City were estimated at 1.5 million tons of potassium and 0.5 million tons of nitrogen (van Asten *et al.* 2004). In the banana-based cropping systems of Uganda, farmers preferentially apply organic residues to banana fields (Bekunda and Woomer 1996) for soil fertility management. This, however, is unsustainable in the long-run because nutrients are added to the banana fields at the expense of those fields from which the residues are exported. External nutrient inputs in the form of mineral fertilizers are thus a prerequisite for sustaining the system in the long-run (van Asten *et al.* 2004).

Some farmers in Uganda believe that the use of mineral fertilizers leads to inferior sensory quality of *matooke*. If this is true, then this poses a serious threat to the adoption of mineral fertilizers and hence sustainability of the banana cropping system in light of the importance *matooke* consumers in Uganda attach to its sensory quality (Gold *et al.* 2002b). However, independent reviews of various studies from different parts of the world revealed conflicting re-

ports concerning mineral fertilizers' effect on the sensory quality of various fruits and vegetables (Woese *et al.* 1997; Bourn and Prescott 2002). For example, Bourn and Prescott (2002) cite the finding by Johansson *et al.* (1999), in which consumers preferred one variety of tomatoes that was grown conventionally (with application of mineral fertilizers and/or crop protection chemicals) and another variety that was grown organically (without application of mineral fertilizers and/or crop protection chemicals).

Woese *et al.* (1997) and Bourn and Prescott (2002) came to a conclusion that there was no evidence supporting the claim that organic production practices led to foods with better sensory quality than conventional practices. Nonetheless, based on the weaknesses they identified in the methodologies used in the studies they reviewed, Bourn and Prescott (2002) conceded that genuine differences in the sensory quality of foods produced organically compared to those produced conventionally may indeed exist.

The objective of this study was to assess the effect of mineral fertilizers on the sensory quality of *matooke* originating from two major production and consumption zones in Uganda.

## MATERIALS AND METHODS

The experimental sites at which the AAA-EA cultivar (*Kisansa*) was grown for this study are located in Wakiso (00° 25'N, 32° 31'E; 1,156 meters above sea level or m.a.s.l) and Ntungamo (00° 54'S, 30° 14'E; 1,405 m.a.s.l) districts in central and southwestern Uganda, respectively. Both sites have bimodal rainfall distribution, with the first rains coming between March and June, and the second rains between September and October. Over the duration of the current study, the mean total annual rainfall received at the

central Uganda site was 1,200 mm while that for the southwestern Uganda site was 1,115 mm. The mean annual minimum and maximum temperature at the central Uganda site are 17.0 and 27.38°C, respectively, while those for the southwestern Uganda site are 13.0 and 27.16°C, respectively. The soil type at the central Uganda site is classified as Ferralsol, while that at the southwestern Uganda site is classified as Acrisol according to the FAO classification.

There were 2 treatments for this study; one to which an assortment of mineral fertilizers were applied and another which received no mineral fertilizers at all in RCBD with 4 replicates. The fertilized crop received N, P, K, Mg, Zn, B and Mo at the respective rates of 300, 50, 460, 60, 6, 1 and 0.5 kg of the element ha<sup>-1</sup> year<sup>-1</sup> supplied as urea, triple super phosphate (TSP), muriate of potash, magnesium sulphate, borax and sodium molybdate, respectively. Neither of the treatments received any chemical pesticide applications.

Focus group discussions and resource person interviews were conducted to identify the attributes that determine the sensory quality of bananas among banana consumers in Uganda. The identified attributes were appearance, odor, softness, taste and overall acceptability of the cooked product. These were then used to design a checklist for ranking the sensory quality of the bananas in this study. A 5-point hedonic scale was used to rank the attributes in which 1 was 'Poor'; 2, 'Fair'; 3, 'Good'; 4, 'Very Good' and; 5, 'Excellent'. The checklist also required the evaluators to give an overall rating of each sample relative to the other samples as either 1 ('Best'), 2 ('Second Best'), 3 ('Second Worst') or 4 ('Worst').

A bunch was harvested from the first ratoon crop at the horticultural maturity stage (with at least one finger ripe) from each treatment at each site to obtain 4 samples. Each sample was taken to proportionately include fingers from the top, middle, and lower clusters (i.e. hands) of the bunch. The samples were anonymously labeled and then offered to a group of 33 farmers from Ntungamo for preparation in 2 ways, namely steaming and boiling after peeling the fresh fruits as commonly practiced by banana consumers in Uganda. Each banana sample to be steamed was separately wrapped in banana leaves (with the corresponding label sealed in water-proof polythene bag inserted in the wrap) but cooked in the same pan supported above the water on split pieces of peduncle. After cooking to readiness, each sample was mashed to a puree within its banana leaf wrappings, and then steamed for 2 h prior to tasting. The boiled banana samples were cooked in water using different pans for each sample containing the corresponding label for the sample. Each evaluator (farmer) was presented with all the four coded samples prepared in the same method at the same time on the same plate. The evaluators were encouraged to give their respective opinions on the checklist without discussing with any other person present during the exercise. The above procedure was repeated 2 days later with another set of banana samples harvested and prepared as described above for a group of 35 farmers from Wakiso district. At both sites, the samples were prepared and tasted within 36 h from harvest.

The median and Pearson  $\chi^2$  tests were used for assessing influence of site, gender, treatment, origin of evaluators and mode of banana preparation on assignment of ranks by evaluators for a given sensory quality attribute. The likelihood  $\chi^2$  rank test for proportions and trends in proportions were used for assessing trends, while for each sensory quality attribute, Tau-b statistic was used in assessing whether high ranks when boiled or steamed differ according to type of treatment. Odds ratios (based on ordinal logistic regression/ordinal GLM) and their 95% confidence intervals were used for multivariate assessment (adjusting for site, sex jointly in evaluating effect of treatment on sensory quality attribute evaluation) of factors associated with the ranking. STATA (version 9) software was used for analysis.

## RESULTS

### Overall rating

The frequency with which farmers assigned superior scores ('Second Best' or 'Best') to fertilized bananas was significantly ( $P \leq 0.05$ ) higher than the corresponding one for non-fertilized ones when steamed. However, the reverse was true for the boiled bananas (Fig. 1). These trends were

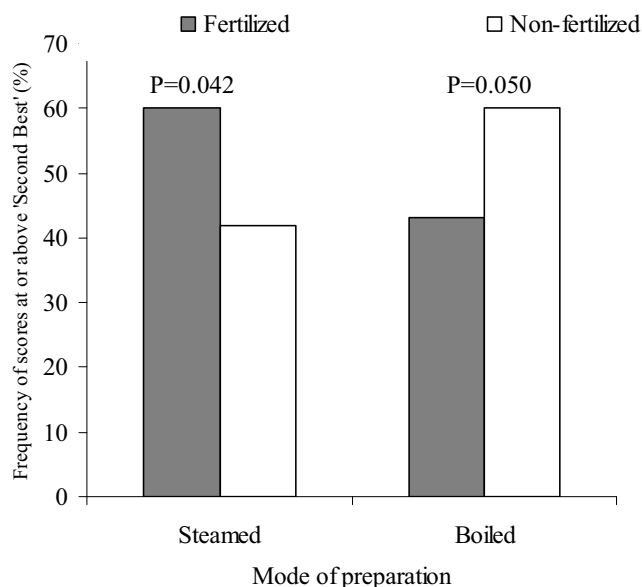


Fig. 1 Consumers' overall rating of fertilized and non-fertilized bananas by mode of preparation. P values relate to differences between fertilized and non-fertilized bananas.

Table 1 Effect of fertilizer application on sensory qualities of East African Highland bananas in Central and Southwestern Uganda by odds ratios.

Sensory attribute	Steamed	P-level	Boiled	P-level
	†Adjusted Odds Ratio ± SE		†Adjusted Odds Ratio ± SE	
Appearance	0.64 ± 0.16	0.08	1.83 ± 0.44	0.01
Odour	0.57 ± 0.15	0.03	0.87 ± 0.21	0.57
Softness	0.41 ± 0.11	0.00	0.10 ± 0.26	0.69
Taste	0.44 ± 0.12	0.00	1.30 ± 0.32	0.28
Acceptability	0.57 ± 0.12	0.03	1.59 ± 0.13	0.01

†Base category = 'Fertilized'; SE = standard error

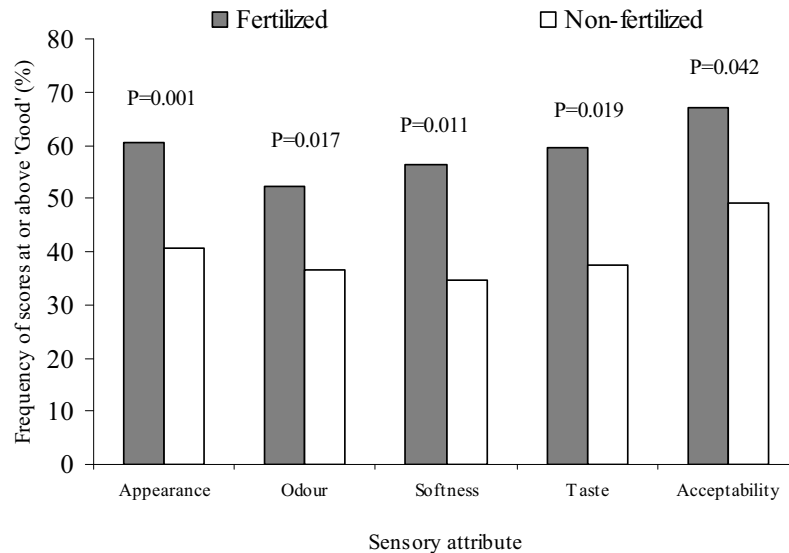
confirmed by the odds ratio analysis. Site of cultivation and the origin, gender and age of evaluators had no significant ( $P > 0.05$ ) influence on the overall ratings, implying that mineral fertilizer application clearly improved the consumers' appreciation of the banana sensory quality when steamed.

### Sensory attributes driving overall rating

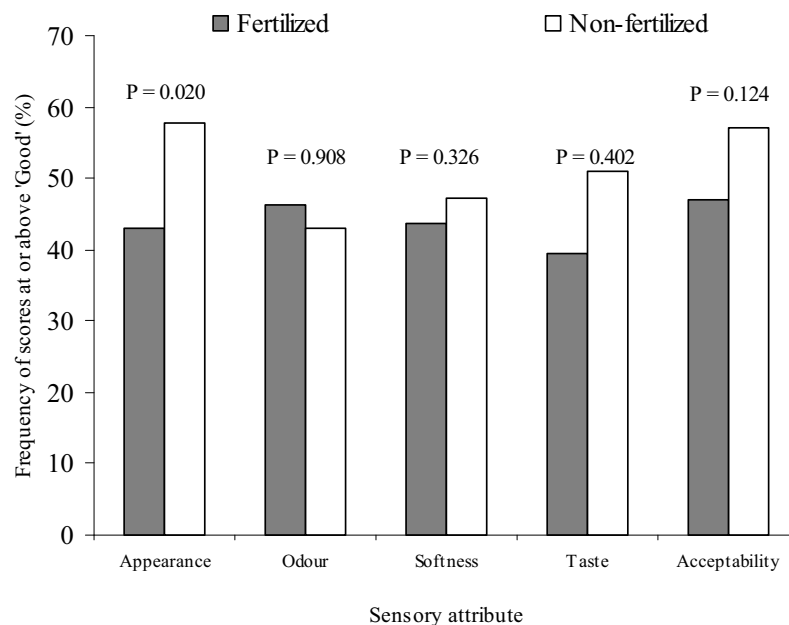
The frequencies with which farmers respectively assigned superior ranks (at or above the score of 'Good') for the appearance, odor, softness and acceptability of fertilized bananas were significantly ( $P \leq 0.05$ ) greater than those for the respective sensory attributes for the non-fertilized bananas when steamed (Fig. 2). On the contrary, the appearance of the non-fertilized boiled bananas was better appreciated than that for the fertilized bananas (Fig. 3). The odds ratio analysis revealed the same trends, except that the acceptability of non-fertilized boiled bananas was significantly ( $P < 0.05$ ) greater than that for the steamed fertilized bananas (Table 1). These results show that the factors responsible for the superior ratings of non-fertilized boiled bananas were better appearance and acceptability compared to the corresponding parameters for the fertilized boiled bananas.

### Evaluators' and cultivation sites' influence on scores

Some interactions with the evaluator's profile and site of cultivation of the bananas were observed. Evaluators from central Uganda were significantly ( $P \leq 0.05$ ) more discerning of the appearance, softness, taste and overall acceptability of the bananas in relation to fertilizer application than their counterparts from southwestern Uganda. The central Uganda evaluators judged the fertilized steamed bananas to



**Fig. 2** Effect of mineral fertilizer application on consumers' ranking of sensory attributes of steamed bananas in Uganda. P values relate to differences between fertilized and non-fertilized bananas.



**Fig. 3** Effect of mineral fertilizer application on consumers' ranking of sensory attributes of boiled bananas in Uganda. P values relate to differences between fertilized and non-fertilized bananas.

be significantly ( $P < 0.05$ ) better than the non-fertilized ones in terms of appearance, softness and taste. However, they judged the non-fertilized boiled bananas to be significantly ( $P < 0.05$ ) better than the fertilized boiled ones in terms of appearance and acceptability. There was no significant difference ( $P > 0.05$ ) in the way evaluators from either gender tended to assign ranks for any of the sensory parameters.

The site of cultivation of the bananas was significant ( $P < 0.05$ ) only in determining farmers' ranks for appearance, taste and overall acceptability of the bananas but not for softness and odor in relation to fertilizer application. The appearance and taste of fertilized steamed bananas grown in southwestern Uganda were significantly ( $P > 0.01$ ) better appreciated than for the non-fertilized ones unlike for the respective sensory attributes for the steamed bananas grown in central Uganda. Fertilized steamed bananas grown in central Uganda had significantly ( $P < 0.01$ ) higher acceptability than non-fertilized ones while the reverse was true ( $P < 0.05$ ) for boiled bananas.

## DISCUSSION

The overall rating (**Fig. 1**) indicates that mineral fertilizer application improved consumers' appreciation of the steamed bananas. This finding disputes farmers' beliefs concerning the deterioration of *matooke* sensory quality due to mineral fertilizer application, since the dominant and preferred mode of *matooke* preparation in Uganda is steaming. Farmers may have developed negative expectations regarding the sensory attributes of bananas grown with mineral fertilizer application due to the widely publicized claims to that effect by organic farming proponents.

It has been demonstrated that information about the mode of production (organic vs. conventional) of a food product influences consumers' judgement of its sensory quality (Schutz and Lorenz 1976; Johansson *et al.* 1999). These authors reported that consumers rated the sensory attributes of organically produced fruits and vegetables higher than for conventionally produced ones when appropriately labeled. However, the consumers in the same studies exhibited indifference between the sensory quality of conventional vs. organic fruits and vegetables when the

food products were anonymously labeled, signifying more of random chance than effects due to the mode of production in the latter case's relative ratings. Although the samples in the current study were anonymously labeled, consumers consistently distinguished between the sensory attributes of fertilized steamed *matooke* and those for the non-fertilized steamed *matooke* (Fig. 2), thus triangulating the significance of the treatment effects on overall rating of sensory quality (Fig. 1).

Fertilized boiled *matooke* were less appreciated compared to the non-fertilized ones (Fig. 1) due to the latter's inferior appearance (Fig. 2) and overall acceptability (Table 1). This trend in appearance and overall acceptability may have been due to the fact that fertilized *matooke* appeared soggy, which undermined its overall acceptability. However, consumers were indifferent regarding the odour, softness and taste of the boiled *matooke* across fertilizer treatments (Fig. 2). The apparent loss of integrity, as deduced from its soggy appearance, of fertilized *matooke* when boiled may have masked its sensory attributes, which may explain why sensory attributes were rated superior for fertilized bananas when steamed, but not when boiled. This reflects the effect of postharvest handling/processing on the nutritional attributes of the food product (Nagy and Wardowski 1988).

The most important factors that can influence the nutritional quality of fruits and vegetables besides fertilizer application are the genotype (Baldwin *et al.* 1991), harvest maturity (Baldwin *et al.* 1999), climatic variables and soil type (Somers and Beeson 1948; Hornick 1992). In the current study, the same cultivar (*Kisansa*) of AAA-EA at the same stage of horticultural maturity was used. It is thus probable that the observed interactions between site of cultivation and fertilizer effect on the sensory quality of *matooke* may have been due to pre-harvest influence of climatic variables such as temperature, light, humidity and rainfall, as well as soil quality characteristics (Somers and Beeson 1948; Hornick 1992). Both sites were primarily deficient in potassium but the deficiency and response to K was stronger at southwestern Uganda site than the central Uganda site (Nyombi *et al.* 2010). The fertilizer effect observed in this study can therefore probably most strongly be attributed to differences in plant K nutrition. Potassium plays a major role in the activation of enzymes involved in photosynthesis and carbohydrate metabolism besides facilitating the translocation of photosynthates, primarily carbohydrates, from the leaves to the storage organs (Tisdale *et al.* 1993). This perhaps explains why evaluators were certain about the superior appearance and taste of fertilized steamed bananas compared to those for the non-fertilized ones grown in southwestern Uganda. However, the evaluators were indifferent to the respective sensory attributes between the fertilized and non-fertilized steamed bananas grown in central Uganda.

The greater discerning ability of farmers from central Uganda for the sensory quality of *matooke* on the other hand may be related to the reported variation in human perception of sensory attributes with ethnic or geographical background (O'Mahony 1995). *Matooke* constituted the primary staple food for the people from central Uganda for centuries, whereas it has only become the dominant staple in southwestern Uganda during the past decades, where it replaced other food crops such as finger millet (Gold *et al.* 1999).

## CONCLUSIONS

This study shows that contrary to farmers' belief, mineral fertilizers improve the sensory quality of cooking type bananas when prepared by steaming (*matooke*). Fertilized bananas are less appreciated by consumers when prepared

by boiling due to the fact that they appear soggy than non-fertilized bananas. Since the dominant and preferred mode of *matooke* preparation is by steaming, we recommend the application of fertilizer, as it will not only positively affect yield, but also sensory quality of cooking bananas.

## ACKNOWLEDGEMENTS

We are grateful for the funding from the Flemish Association for Development Co-operation and Technical Assistance, Flanders (VVOB) and the International Institute of Tropical Agriculture. We also extend our gratitude to Mr. Symon Wandiembe for the statistical analysis and to Mr. Mugaga K Thuai (RIP) and Mr. Serubiri Isaac for their technical input in the field work. We thank all the farmers from Ntungamo and Wakiso districts for their participation in this study.

## REFERENCES

- Baldwin EA, Malundo TMM, Bender R, Brecht JK (1999) Interactive effects of harvest maturity, controlled atmosphere and surface coatings on mango (*Mangifera indica* L.) flavor quality. *Horticultural Science* 34, 514
- Baldwin EA, Nisperos MO, Moshonas MG (1991) Quantitative analysis of flavor and other volatiles and for other constituents of two tomato varieties during ripening. *Journal of the American Society of Horticultural Science* 116, 265-269
- Bekunda MA, Woomer PL (1996) Organic resource management in banana-based cropping systems of the Lake Victoria Basin, Uganda. *Agriculture, Ecosystems and Environment* 59, 171-180
- Bourn D, Prescott J (2002) A comparison of the nutritional value, sensory qualities and food safety of organically and conventionally produced foods. *Critical Reviews in Food Science and Nutrition* 42 (1), 1-34
- FAO (2008) FAO Statistics. Food and Agricultural Organization of the United Nations Available online: <http://faostat.fao.org/site/339/default.aspx>
- FEWSNET (2004) Uganda Food Security Update November - December 2004. Increased movement hampers aid efforts. Available online: <http://www.fews.net/centers/innerSections.aspx>
- Gold CS, Karamura EB, Kiggundu A, Bagamba F, Abera AMK (1999) Geographic shifts in highland cooking banana (*Musa* spp., group AAA-EA) production in Uganda. *International Journal of Sustainable Agriculture and World Ecology* 6, 45-59
- Gold CS, Kiggundu A, Abera AMK, Karamura D (2002a) Diversity, distribution and farmer preference of *Musa* cultivars in Uganda. *Experimental Agriculture* 38 (1), 39-50
- Gold CS, Kiggundu A, Abera AMK, Karamura D (2002b) Selection criteria of *Musa* cultivars through a farmer participatory appraisal survey in Uganda. *Experimental Agriculture* 38 (1), 29-38
- Hornick SB (1992) Factors affecting the nutritional quality of crops. *American Journal of Alternative Agriculture* 7, 63-68
- Johansson L, Haglund A, Berglund L, Lea P, Risvik E (1999) Preferences for tomatoes, affected by sensory attributes and information about growth conditions. *Food Quality and Preferences* 10, 289-298
- Nagy S, Wardowski, WF (1988) Effects of agricultural practices, handling, processing, and storage on fruits. In: Karmas E, Harris RS (Eds) *Nutritional Evaluation of Food Processing* (3<sup>rd</sup> Edn), New York, USA, pp 73-100
- Nyombi K, van Asten PJA, Corbeels M, Taulya G, Leffelaar PA, Giller KE (2010) Mineral fertilizer response and nutrient use efficiencies of East African highland banana (*Musa* spp., AAA-EAHB, cv. *Kisansa*) in Uganda. *Field Crops Research* 117, 38-50
- O'Mahony M (1995) Sensory measurement in food science: fitting methods to goals. *Food Technology* April, 72-82
- Schutz HG, Lorenz OA (1976) Consumer preferences for vegetables grown under 'commercial' and organic conditions. *Journal of Food Science* 41, 70-73
- Somers GF, Beeson KC (1948) The influence of climate and fertilizer practices upon the vitamin and mineral content of vegetables. *Advances in Food Research* 1, 291-324
- Tisdale SL, Nelson WL, Beaton JD, Havlin JL (1993) *Soil Fertility and Fertilizers* (5<sup>th</sup> Edn), Prentice Hall, New Jersey, USA, 634 pp
- van Asten PJA, Gold CS, Okech SH, Gaidashova SV, Tushemereirwe WK, De Waele D (2004) Soil quality problems in East African banana systems and their relation with other yield loss factors. *InfoMusa* 13 (2), 20-25
- Woese K, Lange D, Boess C, Bogl KW (1997) A comparison of organically and conventionally grown foods - results from a review of relevant literature. *Journal of the Science of Food and Agriculture* 74, 281-293