THE BANANA-BEAN INTERCROPPING SYSTEM IN KAGERA REGION OF TANZANIA--RESULTS OF A DIAGNOSTIC SURVEY

by

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PREFACE

This document reports results of a diagnostic survey of the banana-bean intercropping system in Kagera Region of Tanzania. The survey concentrated on crop nutrition aspects, and their interactions with pests and diseases of bananas. The survey was a collaborative effort of the Centro Internacional de Agricultura (CIAT), the Maruku Agriculture Research Institute and the Netherlands Farming Systems Research Project of the Lake Zone of Tanzania.

This volume is the sixth in a working document series that serves research on beans (*Phaseolus vulgaris*) in Africa. This publication series forms part of the activities of the pan-African bean research network, which aims to stimulate, focus and co-ordinate research efforts on this crop.

The network is organized by the Centro Internacional de Agricultura Tropical (CIAT) through three independent research projects, for the Great Lakes region of Central Africa, for Eastern Africa and, in conjunction with SADCC, for the Southern Africa region.

Working documents will include bibliographies, research reports and network discussion papers. These publications are intended to complement an associated series of Workshop Proceedings.

Support for the regional bean projects comes from the Canadian International Development Agency (CIDA), the Swiss Development Corporation (SDC) and the United States Agency for International Development (USAID).

Further information on regional research activities on common beans in Africa, and additional copies of this publication, are available from:

Pan-Africa Coordinator, CIAT, P.O. Box 23294, Dar es Salaam, Tanzania.

Coordinateur Regional, CIAT, Programme Regional pour l'Amelioration du Haricot dans la Region des Grands Lacs, B.P. 259, Butare, Rwanda.

PUBLICATIONS OF THE NETWORK ON BEAN RESEARCH IN AFRICA

Workshop Series

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No. 2. Bean Research in Eastern Africa, Mukono, Uganda, 22-25 June, 1986.

No. 3. Soil Fertility Research for Bean Cropping Systems in Africa, Addis Ababa, Ethiopia, 5-9 September, 1988.

No. 4. Bean Varietal Improvement in Africa, Maseru, Lesotho, 30 January - 2 February, 1989.

No. 5. Troisieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Kigali, Rwanda, 18-21 Novembre, 1987.

No. 6. First SADCC/CIAT Regional Bean Research Workshop, Mbabane, Swaziland, 4-7October, 1989.

No. 7. Second Regional Workshop on Bean Research in Eastern Africa, Nairobi, Kenya, 5-8 March, 1990.

No. 8. Atelier sur la Fixation Biologique d'Azote du Haricot en Afrique, Rubona, Rwanda, 27-29 Octobre, 1988.

No. 9. Quatrieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Bukavu, Zaire, 21-25 Novembre, 1988.

No. 10. National Research Planning for Bean Production in Uganda, Makerere University, Kampala, Uganda, 28 January - 1 February, 1991.

No. 11. Proceedings of the First Meeting of the Pan-Africa Working Group on Bean Entomology, Nairobi, Kenya, 6-9 August, 1989.

No. 12. Ninth SUA/CRSP Bean Research Workshop and Second SADCC/CIAT Regional Bean Research Workshop. Progress in Improvement of Common Beans in Eastern and Southern Africa, Sokoine University of Agriculture, Morogoro, Tanzania, 17-22 September, 1990.

No. 13. Virus Diseases of Beans and Cowpea in Africa, Kampala, Uganda, 17-21 January, 1990.

No. 14. Proceedings of the First Meeting of the SADCC/CIAT Working Group on Drought in Beans, Harare, Zimbabwe, 9-11 May, 1988.

No. 15. First Pan-Africa Working Group Meeting on Anthracnose of Beans, Ambo, Ethiopia, 17-23 February, 1991.

No. 16. Cinquieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Bujumbura, Burundi, 13-17 Novembre, 1989.

No. 17. Sixieme Seminaire Regional sur l'Amelioration du Haricot dans la Region des Grands Lacs, Kigali, Rwanda, 21-25 Janvier, 1991.

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INTRODUCTION

The banana-bean (Musa spp. - Phaseolus vulgaris L.) intercropping system is the major food production system in parts of Bukoba, Muleba and Karagwe districts in Kagera Region of Tanzania. The system has been sustained with continuous production for well over 100 years (Anon., 1989). Meanwhile cassava and maize-based systems have not been sustainable without frequent periods of grass fallow. However, the banana-bean system apparently is in decline due to reduced productivity of the banana component. Reasons for the decline may include soil fertility problems and damage to the banana plants by banana weevil, nematodes and diseases (Tibiajuka, 1984, Sebasigari and Baert, 1989). The importance of these problems has not been quantified, nor have the interactions between these problems been studied. This study was conducted to determine which constraints are most important to the productivity of the system and to evaluate interactions between these constraints.

MATERIALS AND METHODS

Observations were made on 25 farms in Bukoba District and 10 each in Karagwe and Muleba Districts. The villages surveyed were Kagondo, Kaibanja, Buhekela, Ruhoko and Kanyangereko in Bukoba District, Bugene and Kituntu in Karagwe District, and Ilemera and Nshamba villages in Muleba District. Farms with old (>20 years) banana stands were selected for this survey, but in Karagwe District some of the banana fields were established more recently. Bukoba sandstone is the predominant parent material of the soils of farms survey in Bukoba and Muleba districts. Ruhoko village is an exception with alluvial soils predominating. Soils in Karagwe developed primarily from old argillaceous sediments of the Karagwe-Ankolean geological system.

Observations were made near and farther (>20 m) from the house on each farm. Bean variety trials were conducted on most of these farms and yield was determined for the beans grown with bananas. Observations were made on pests, banana and bean yield, soil fertility and banana plant nutrition. Nematode damage was assessed as the percentage of root necrosis found in the first three main roots encountered (15-25 cm segments) for three banana plants. Damage due to banana weevils was assessed by visually rating the degree of tunneling found in lower cross-sections of four recently harvested pseudostems on a 1-9 basis, with 9 indicating very severe damage.

Banana yield varies with years and reliable estimates of productivity would require several years of yield data. Therefore, farmers' estimates of yield components were used in estimating productivity. Farmers gave estimates for fingers per hand, hands per bunch and bunch height for each part of the farm. Bunch weight was estimated using a relationship between weight and height based on a sample of 30 bunches, i.e.

Bunch wt. = 14.73 + 0.19 x Bunch ht. ($R^2 = 0.38$).

A value of 135 grams was used throughout for the weight of one finger. Pseudostems taller than 1.5 m were counted in 16 m^2 blocks to estimate pseudostem density. In calculating banana yield estimates from these components, it was assumed that 50% of the pseudostems would produce fruit in one year. The yield estimates of bananas used in this study is the mean of the banana yield estimates based on fingers per bunch and on bunch height. Accuracy of the yield estimates is debatable, but inaccuracies are expected to be systematic and tests of relationships of banana yield to other factors are expected to be valid.

Pseudostem girth gave another estimate of banana performance but this was not measured in all villages. Proportions of cooking and brewing banana cultivars were estimated for each part of the farm.

Bean yield was measured on those farms where bean variety trials were conducted. Soil samples were taken from the trial sites for chemical and textural analysis. Foliar samples were collected from the internal laminae of the third banana leaf when the banana plants were growing rapidly in an early reproductive stage (Martin-Prevel, 1987).

Results of the foliar analyses were interpreted according to the critical nutrient levels (CNL) (Lahav and Turner, 1983) and according to the Diagnosis and Recommendation Integrated System (DRIS; Walworth and Sumner, 1987). The DRIS norms were estimated using the results of analyses of 78 foliar samples of AAA, AAB and ABB types (Turner and Hunt, 1984). Mn and Fe were excluded from the DRIS analysis because their levels were abnormally high in these 78 samples. Soil nutrient levels and estimated N, P and K availability according to the QUEFTS model (Janssen et al., 1990) were related to banana and bean yield.

Alternative CNL's for some nutrients and a set of DRIS norms were estimated for East Africa highland bananas. Proposed CNL's are those that correspond with the 90% yield level relative to the mean yield associated with the optimal nutrient level. DRIS values are based on the relationship of banana yield and pseudostem girth with nutrient concentrations or ratios. When there was no relationship, mean values are given as the new DRIS norm.

RESULTS

Effects of distance from the house

The means determined for various traits near and far from the house are presented in Tables 1 & 2. The degrees of freedom were few and differences often were not significant at $= 0.05$. The differences, however, were often consistently large as indicated by the F-values. Cooking types of bananas made up over 60% of the plant stands in all villages and increased relative to brewing types near to the house. Differences due to proximity to houses in nematode and weevil damage were generally small and inconsistent. Farmers estimated yield components to be highest near the house. Pseudostem density was not consistently affected by proximity to the house. Estimated banana yield was consistently higher near to the house.

With the exception of Ruhoko village in Bukoba District, mean N levels in banana leaves were highest near to the houses. B levels were higher near to the house on most farms. The levels of P, K, Ca, Mg, Fe, Mn, Zn and Cu varied inconsistently with proximity to the house. The ratios of K/(K+Ca+Mg), Ca/(K+Ca+Mg) and Mg/(K+Ca+Mg) (expressed in *milli*-equivalents) were not much affected by distance from the house and are not reported here.

Critical nutrient levels (CNL) in banana leaf tissue

Results of foliar analyses were interpreted using CNLs of 2.6% N, 0.2% P, 3.0% K, 0.5% Ca, 0.3% Mg, 0.23% S, 25 ppm Mn, 80 ppm Fe, 18 ppm Zn, 11 ppm B and 9 ppm Cu (Lahav and Turner, 1983). The overall frequency of distribution of foliar nutrient concentrations are given in Figure 1. The frequencies of occurrence by village of nutrient levels below the CNLs are given in Table 3. N levels were above the CNL on most farms. P levels were generally above the CNL except in Kituntu and in the two villages of Muleba District. K levels were generally low in all villages. CNL interpretations of the foliar analyses indicate that Ca, Mg, Mn and Fe were usually adequate. S levels were low on some farms, especially in Karagwe District. Zn, Cu and B levels were generally low in all areas surveyed. Mn levels observed in Kagondo and Nshamba villages were high but probably not within the toxicity range for bananas (Martin-Prevel, 1987).

Martin-Prevel (1987) reported the optimal ranges for K/(K+Ca+Mg), Ca/(K+Ca+Mg) and Mg/(K+Ca+Mg) to be approximately 50-57%, 28-34% and 14-19%, respectively. The values of K/(K+Ca+Mg) were generally below the optimum range. The Ca/(K+Ca+Mg) ratio occasionally indicated Ca deficiency and the Mg/(K+Ca+Mg) ratio always indicated adequate Mg.

DRIS interpretation of foliar analyses results for bananas

When DRIS indices were applied in the interpretation of the foliar analyses results, N and K occurred frequently as the most limiting nutrients (Table 4). N deficiency was identified as the major constraint in Kagondo, Buhekela and Ruhoko villages in Bukoba District, in both Ilemera and Nshamba in Muleba District and in Bugene in Karagwe District. K deficiency was diagnosed to be very serious in Nshamba, but also a serious problem in Kagondo, Ruhoko and Kaibanja. The results indicate widespread sulfur deficiencies, but of less severity than N and K deficiencies. Sulfur does not appear to be a problem in Buhekela and Nshamba. The DRIS interpretation finds B deficiency to be a major constraint to banana productivity in Kanyangereko. It is also of concern in Kaibanja and Kituntu. Cu and Zn deficiencies were generally diagnosed as secondary in importance to other nutritional problems but occurred in all of the surveyed villages as potentially serious problems. Cu and Zn deficiencies were always associated with B deficiency.

Foliar nutrient levels and banana yield

A model with districts, percentage cooking types and concentrations of nutrients as independent variables found the coefficients for N, Ca, Mg and Fe to be significant (Table 5) in accounting for variation in banana yield. The coefficient for Fe, however, was negative. The model also suggests weak positive relationships of K and Zn and weak negative relationships of Cu and B concentrations with banana yield.

The relationships indicated in Table 5 are not consistent with those in Tables 3 and 4. The weak relationship between K concentration in the leaf tissue and banana yield is unexpected considering the low levels found in the leaves. Similarly, the positive relationships of Ca and Mg with yield were unexpected as the foliar analyses indicate adequacy of these nutrients. The results do not confirm the importance of improved Cu and B nutrition to increased banana yield as indicated by the CNL and DRIS interpretations.

The correlation coefficients presented in Table 6 give indications of possible constraints for specific areas. N deficiency is indicated as an important constraint in most villages. Other constraints indicated are P deficiency in Ruhoko, Nshamba and Ilemera villages; K deficiency in Buhekela and Kanyangereko; Ca deficiency in Kaibanja, Buhekela, Ruhoko, Bugene and Ilemera; Mg deficiency in Kagondo, Kaibanja, Buhekela, and Kituntu; S in Kanyangereko; Zn in Kanyangereko and Kituntu; Cu in Nshamba; B in Kaibanja, Ruhoko and Kanyangereko. The high correlation coefficients in these cases could be due to coincidental distributions, but observation of the distribution of the plotted points shows that outlying values are not very important. The case for Mg in Bugene village is an exception.

Relevance of available CNL values

The linear relationships of yield with N, Ca, Mg, Zn and B concentrations, and the ratios of K/(K+Ca+Mg), Ca/(K+Ca+Mg) and Mg/(K+Ca+Mg), in banana leaf tissue were examined (Table 7). The linear relationships were positive for the complete range of values for N (2.1 - 3.6%), Mg (0.26 - 0.65%), and Zn (9.9 - 21.5 ppm). Apparently the CNLs of N, Mg and Zn determined for Cavendish cultivars grown at low altitudes are too low for the East Africa highland cultivars. Yield tended to increase: with Ca concentration to 1.13% Ca in foliar banana tissue, and thereafter increased at a lower rate; and with B concentration to 10.0 ppm B after which there was no relationship between yield and B concentration. Alternative CNL values proposed are 3.1% N, 1.13% Ca, 0.48% Mg, 18.4 ppm Zn and 10.0 ppm B.

Yield increased with the Ca/(K+Ca+Mg) ratio to the ratio value of 0.36 and the optimal range was predicted to be 0.33-0.40 by the equation:

$$\text{Banana yield} = -5906 + 39341 \times (Ca/(K+Ca+Mg) - 11997 \times (Ca/(K+Ca+Mg)^2$$

Similarly, the Mg/(K+Ca+Mg) was linearly related to yield below the ratio value of 0.25. The optimal range for this range was estimated to be 0.25-0.30 according to the equation:

$$\text{Banana yield} = -34623 + 427220 \times (Mg/(K + Ca + Mg) - 775370 \times (Mg/(K + Ca + Mg)^2$$

The optimal range for K/(K+Ca+Mg) was estimated to be 0.34-0.40.

The alternative set of DRIS norms estimated from the Kagera data is presented in Table 8.

Results of soil sample analyses

Soil samples were collected in the area of the bean trials. Estimated amounts of N, P and K available to the crop during a growing season as estimated using the QUEFTS model (Janssen et al, 1990) ranged from 36 to 283 kg N ha^{-1}, 4 to 85 kg P ha^{-1} and 4 to 762 kg K ha^{-1}. Also, the productivities of the farms as estimated with the QUEFTS model with the results expressed in terms of kilograms of maize per hectare ranged from 1000 to 8845.

There was not a significant relationship between soil test values or the QUEFTS values and banana yield. A model with dummy variables for districts and soil pH, available N, P and K as estimated with QUEFTS as the independent variables did not account for a significant amount of variation in banana yield. Another model with actual soil test values for N, P and K as independent variables also was not significant in accounting for variation in banana yield. There was a significant relationship between bean yield and QUEFTS estimated N ($r = 0.33$) and P ($r = 0.36$) availability. Bean yield was not related to QUEFTS productivity estimates.

Pest damage

No direct relationship was detected between either damage due to banana weevils or nematodes and banana yield.

In a multiple regression model which included dummy variables for districts and with percent cooking varieties and foliar nutrient concentrations as independent variables, 34% the variation in percent root necrosis was explained (Table 5). Root necrosis was more severe in cooking types than in brewing types of bananas. As foliar N increased, root necrosis decreased. A weak relationship existed between iron concentration and root necrosis. A similar model was not significant for banana weevil damage. Correlations of nutrient values with levels of nematode and weevil damage for each village were generally weak and gave little additional evidence for interactions between pest damage and plant nutritional status.

DISCUSSION

Banana yield was consistently higher near the house as was expected because of the heavier application of organic manures near to the house. Only N and B concentrations were consistently higher near the houses but other nutritional traits and pest damage were not consistently affected by proximity to the house. These results suggest that inadequacy of N and B nutrition constrain yield. Low N and B availability are also suggested as constraints by the DRIS interpretation of foliar analysis results. The regression analysis supports the importance of improving N nutrition but does not indicate B deficiency as a problem.

CNL and DRIS indicate K deficiency to be a major problem and S, Cu and Zn deficiencies to be secondary problems. This is supported neither by effects of proximity to house nor by the regression analysis. No reason is apparent for the lack of relationship of K levels with banana yield. The over-riding effects of other nutritional disorders may have prevented the variation in S, Cu and

Zn levels from affecting yield. Alleviation of other nutritional constraints may result in increased importance of the S, Cu and Zn deficiencies.

Ca and Mg deficiencies are suggested by the correlation and regression analyses but CNL and DRIS indicate that these are generally adequate. The Ca/(K+Ca+Mg) ratios indicate occasional Ca deficiency. The inconsistencies may be due to poor applicability of the CNLs, which were determined for Cavendish bananas grown in Australia, to the East African highland conditions and cultivars.

Results from the various interpretations of foliar tissue analyses were inconsistent in regards to P, but generally indicate adequate P nutrition, with possible exceptions in Ruhoko, Nshamba, Ilemera and Kituntu villages.

All results indicate that Fe and Mn are not deficient. The Mn levels observed in Kagondo and Nshamba villages were high but probably not toxic to the banana plants (Martin-Prvel, 1987). They may indicate the occurrence of Mn toxicity in beans intercropped with the bananas (Wortmann et al., 1992).

The results raise serious doubts about the applicability of available CNL's for the East Africa highland bananas. Comparison of foliar nutrient levels for bananas in this study with those of Turner and Hunt (1984) show considerably higher Ca and Mg levels in the East African highland bananas, but lower K and micro- nutrient levels. Therefore, the results of the DRIS interpretations of nutrient levels may also be mis-leading. The nutrient to nutrient ratios used in the DRIS indices would be high for Ca and Mg, but low for K and micro-nutrients, resulting in failure to detect Ca and Mg deficiencies and over-prediction of K and micro-nutrient deficiencies.

The optimum values for foliar concentrations of B and Zn are in agreement with those determined by Lahav and Turner (1983) and Martin-Prvel (1987). The results indicate that the CNLs for N, Ca and Mg are too low. The lack of relationships of P, S, and Cu with yield indicate that other stresses constrained yield more than deficiencies of these nutrients, or that these nutrients were adequately available and the published CNLs are too high for the East Africa highland bananas. The published CNL's for Fe and Mn appear to be correct. The optimum values as suggested by our results are lower for K/(K+Ca+Mg) and higher for Ca/(K+Ca+Mg) and Mg/(K+Ca+Mg) than those reported by Martin-Prvel (1987).

Failure to find stronger relationships for soil test values and nutrient availability with banana yield were disappointing. As Turner et al. (1989) pointed out however, the nutrient concentration at the root surface is only one of several factors influencing nutrient uptake. Extent of the root system and rate of above ground growth are important factors. Inadequacies of interpretation and inaccuracies in applying the methods may have contributed to the weak relationships.

QUEFTS estimates appear to be of value in estimating N and P availability for bean production, but not for bananas.

Relationships of levels of banana weevil and nematode damage with nutritional factors and banana yield were generally weak and inconsistent. The methods of assessing pest damage may not allow for adequate precision to detect some relationships. Main roots were sampled for nematode damage while sampling of feeder roots may be preferable. Observations on weevil damage to cross sections of the corm may have been more accurate than observing the lower pseudostems. Alternatively, counts of tunnels in the corm at a specific stage of pseudostem growth may be a better indication of weevil damage.

RECOMMENDATIONS

Final conclusions cannot be drawn from the results but they suggest the existence of problems that should be further investigated. A follow-up survey with better assessment of weevil and nematode damage, and more consideration to varietal and growth stage effects, is needed to further investigate assess the importances of the pests and their relationships to plant nutritional disorders.

Simple diagnostic trials are needed to confirm the existence of the problems indicated. These might be conducted first on fields in villages likely to have a specific problem (Table 8) and even on those farms which appear to be most seriously affected. Failure to show a response to corrective treatments under those conditions may be adequate justification to neglect a potential problem in favor of other problems. A significant response would suggest that the problem should be further investigated.

Fertilizer treatments to test for specific nutrient deficiencies may be as follow.

1. Nitrogen—applied as urea four times per year at 60 kg N/ha.
2. Phosphorus applied as TSP or SSP at 80 kg P/ha once a year.
3. Potassium applied twice per year at 80-100 kg K/ha as KCl.
4. Calcium applied once as 500 kg lime/ha ??
5. Magnesium applied as dolomite or $MgSO_4$ to soil at 30 kg Mg/ha or foliar application of $MgSO_4$ in four applications of 2 kg Mg / ha.[1]
6. Sulfur applied as $MgSO_4$, $(NH_4)_2SO_4$ or K_2SO_4 applied at rate of 20 kg S/ha in 2 applications per year.[1]
7. Zinc applied to the leaves with a spray of 0.5% $ZnSO_4$ at 1 kg/ha two times per year.
8. Copper applied as a neutralized 0.5% $CuSO_4$ spray to leaves at 0.1 kg Cu/ha two times per year.
9. Boron applied as a single application of 12 kg of borax per ha.

[1] Application of compound fertilizers will complicate interpretation of results.

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Table 1. Means according to proximity to houses for various traits measured in farmers'banana fields in Kagera Region.

Prox. to house	Cooking %	Root Nec. %	Weevil 1-9	Hands/ bunch	Fingers/ hand	Stem girth	Pseudo./ ha.	Bunch wt.	Banana yield
				Kanyangereko village, Bukoba District					
Far	61.2	30.0	3.2	4.2	9.0		2042	22.6	19860
Near	73.7	21.2	3.0	8.2	14.5		2752	26.1	26109
F-value	3.6	0.2	1.0	32.0	12.5		3.7	225.0	7.7
				Buhekela village, Bukoba District					
Far	65.0	29.0	3.6	6.5	13.6	60.0	2070	23.1	18291
Near	86.0	31.0	3.4	11.0	17.2	68.8	2093	28.2	28920
F-value	2.7	0.3	0.2	101.0	10.3	3.7	0.0	25.9	1.3
				Kagondo village, Bukoba District					
Far	70.0	17.0	3.4	7.7	13.5	60.3	1876	24.1	18115
Near	93.0	16.0	4.2	10.4	20.0	72.8	2023	28.5	28231
F-value	5.0	0.1	1.9	27.1	32.5	29.5	0.1	33.1	5.6
				Kaibanja village, Bukoba District					
Far	62.0	27.0	3.4	5.2	8.4		1985	22.7	14563
Near	88.0	26.0	3.8	9.0	17.2		1991	26.3	24048
F-value	2.9	0.0	0.2	26.7	15.7		0.0	10.0	9.4
				Ruhoko village, Bukoba District					
Far	86.0	40.0	3.0	8.0	15.5		1669	24.3	16690
Near	100.0	42.5	3.0	9.5	17.0		1905	25.2	22347
F-value	3.3	0.1	0.0	2.4	1.6		0.3	1.7	2.8
				Ilemera village, Muleba District					
Far	70.0	49.2	5.8	6.6	10.0	66.6	2083	22.5	16784
Near	81.0	57.0	6.4	8.0	13.2	73.5	2399	25.9	24209
F-value	2.1	0.9	0.7	3.5	2.3	1.3	0.3	28.2	3.2
				Nshamba village, Muleba District					
Far	82.5	28.0	2.6	10.0	12.0	55.8	1867	24.4	17517
Near	100.0	23.0	2.4	11.0	15.0	55.5	1970	29.0	29399
F-value	3.0	1.3	0.1	0.8	15.0	0.0	0.3	8.8	12.4
				Bugene village, Karagwe District					
Far	72.0	34.0	8.8	7.6	11.4	50.4	2186	24.8	19391
Near	93.2	54.0	2.8	10.6	16.4	61.1	2139	28.1	28373
F-value	15.9	6.4	0.7	1.3	2.8	6.6	2.5	0.0	2.6
				Kituntu village, Karagwe District					
Far	78.0	48.0	1.4	7.6	12.0	48.9	1633	25.2	16411
Near	80.8	43.0	2.6	11.2	17.6	59.3	1602	30.3	22541
F-value	0.1	0.3	4.2	7.8	10.6	0.1	0.0	81.0	2.1

Table 2. Means according to proximity to households for foliar nutrient levels measured in farmers banana fields in Kagera Region.

Proximity to house	N %	P %	K %	Ca %	Mg %	S %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
Kanyangereko village, Bukoba District											
Far	2.79	0.29	2.19	1.09	0.40	0.22	139	179	13.8	6.75	9.2
Near	3.16	0.25	2.45	1.05	0.39	0.23	134	181	15.2	4.67	9.9
F-value	13.7	1.4	4.5	0.3	0.1	3.1	0.8	0.3	9.5	11.4	1.5
Buhekela village, Bukoba District											
Far	2.70	0.34	2.69	1.20	0.36	0.28	132	377	16.6	7.52	11.0
Near	3.10	0.25	2.87	1.26	0.48	0.29	150	315	18.1	6.60	11.9
F-value	3.5	2.4	2.3	0.2	4.1	1.7	2.3	2.4	1.3	1.4	3.0
Kagondo village, Bukoba District											
Far	2.83	0.24	2.61	1.15	0.43	0.22	143	612	14.5	7.70	10.0
Near	3.21	0.23	2.41	1.36	0.49	0.27	171	735	16.3	7.96	10.6
F-value	6.8	0.1	1.6	3.2	3.3	6.4	2.6	2.6	2.4	0.1	1.7
Kaibanja village, Bukoba District											
Far	2.85	0.30	2.73	0.90	0.36	0.25	125	444	14.4	8.18	10.2
Near	3.15	0.25	2.72	1.14	0.42	0.24	142	463	14.7	6.20	11.0
F-value	3.9	1.8	0.0	7.3	3.7	0.0	13.2	0.0	0.1	2.7	1.9
Ruhoko village, Bukoba District											
Far	3.32	0.22	2.54	0.90	0.54	0.26	184	632	15.4	9.15	10.3
Near	3.16	0.23	2.44	0.94	0.48	0.23	146	504	14.7	7.60	11.1
F-value	0.7	0.1	0.1	0.2	0.2	3.2	0.8	0.7	0.8	3.3	4.4
Ilemera village, Muleba District											
Far	2.83	0.28	2.74	0.84	0.37	0.24	169	430	14.8	9.86	10.0
Near	3.23	0.27	2.83	0.92	0.45	0.25	232	353	14.4	6.60	10.5
F-value	11.6	0.0	0.1	1.1	3.3	0.0	1.8	1.3	0.2	0.7	1.0
Nshamba village, Muleba District											
Far	3.05	0.19	1.94	1.03	0.41	0.25	123	627	13.7	8.54	9.6
Near	3.24	0.19	2.05	0.99	0.39	0.26	133	796	13.7	7.54	9.7
F-value	2.7	0.0	3.9	0.1	0.4	2.6	3.8	1.5	0.0	3.0	0.0
Bugene village, Karagwe District											
Far	2.63	0.21	2.32	0.92	0.43	0.21	130	283	16.1	5.82	10.5
Near	2.84	0.24	2.55	1.04	0.45	0.22	144	259	16.4	5.86	10.0
F-value	2.5	1.5	1.0	0.8	0.3	1.3	3.9	0.3	0.1	0.0	3.4
Kituntu village, Karagwe District											
Far	2.68	0.29	2.41	1.07	0.45	0.23	128	325	13.7	6.44	10.6
Near	2.87	0.22	2.29	1.13	0.42	0.22	142	487	15.1	5.34	10.8
F-value	3.3	0.6	0.2	0.4	0.3	0.1	2.6	2.5	0.4	1.2	0.1

Table 3. Frequencies of nutrient levels being below published critical nutrient levels for bananas.

	N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu	B	K/[1]	Ca/[1]	Mg/[1]
								Bukoba District						
Kanyang.	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0
Buhekela	0.3	0.1	0.7	0.0	0.1	0.0	0.0	0.0	0.6	0.9	0.2	1.0	0.0	0.0
Kagondo	0.0	0.2	1.0	0.0	0.1	0.2	0.0	0.0	1.0	0.8	1.0	0.9	0.1	0.0
Kaibanja	0.0	0.0	0.8	0.0	0.1	0.2	0.0	0.0	1.0	0.9	0.5	0.9	0.3	0.0
Ruhoko	0.0	0.1	0.7	0.0	0.0	0.4	0.0	0.0	0.9	0.6	0.5	1.0	0.4	0.0
								Muleba District						
Ilemera	0.0	0.4	0.5	0.0	0.1	0.3	0.0	0.0	0.9	0.8	0.8	0.9	0.1	0.0
Nshamba	0.0	0.9	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.8	1.0	1.0	0.0	0.0
								Karagwe District						
Bugene	0.3	0.1	1.0	0.0	0.0	1.0	0.0	0.0	0.6	1.0	0.9	0.9	0.1	0.0
Kituntu	0.3	0.6	0.9	0.0	0.0	0.8	0.0	0.0	0.7	1.0	0.7	1.0	0.2	0.0

[1] Ratios of milliequivalents of K, Ca and Mg to sum of K, Ca and Mg.

Table 4. Frequencies of banana foliar nutrient levels being diagnosed as deficient according to the DRIS interpretation.

	N	P	K	Ca	Mg	S	Zn	Cu	B
					Bukoba District				
Kanyang.	0.4	0.0	0.5	0.0	0.0	0.3	0.0	0.3	0.6
Buhekela	1.0	0.0	0.4	0.0	0.0	0.0	0.3	0.4	0.6
Kagondo	0.7	0.1	0.7	0.0	0.0	0.2	0.2	0.2	0.3
Kaibanja	0.7	0.0	0.4	0.0	0.0	0.4	0.4	0.5	0.7
Ruhoko	0.4	0.0	0.5	0.0	0.0	0.0	0.2	0.2	0.2
					Muleba District				
Ilemera	0.6	0.0	0.2	0.0	0.1	0.3	0.3	0.4	0.7
Nshamba	0.2	0.0	1.0	0.0	0.0	0.0	0.2	0.1	0.3
					Karagwe District				
Bugene	0.7	0.0	0.4	0.0	0.0	0.4	0.0	0.2	0.2
Kituntu	0.8	0.0	0.6	0.0	0.1	0.5	0.2	0.5	0.5

Table 5. Regression estimates of banana yield and percent root necrosis of bananas on district effects and foliar nutrient concentrations.

	Yield	% root necrosis
Bukoba[1]	-4778**	-10.1*
Karagwe	-2441	1.6
% Cooking types	147***	0.3***
Nitrogen	7186***	-16.5*
Phosphorus	8373	-41.0
Potassium	4192	6.9
Calcium	11959***	-12.3
Magnesium	35077***	28.6
Sulfur	2900	-40.4
Iron	-47**	0.1*
Manganese	0	0.0
Zinc	582	0.5
Copper	-532	0.2
Boron	-1346	0.7
R-square	0.46	0.34
F-value	87	87
Sample size	4.43	2.64
Intercept	-33372	39.3

[1] The variables for districts are dummy variables. Muleba district is the omitted district variable.

[2] *, ** and *** indicate significance at P > 0.10, 0.05 and 0.01, respectively.

Table 6. Simple correlation coefficients for foliar nutrient concentrations and mean banana yield.

	N %	P %	K %	Ca %	Mg %	S %	Mn ppm	Fe ppm	Zn ppm	Cu ppm	B ppm
			Bukoba District								
Kanyang.	0.57	-0.32	0.45	-0.13	-0.02	0.44	0.26	-0.33	0.81	-0.79	0.42
Buhekela	0.42	-0.11	0.61	0.47	0.59	0.12	-0.52	-0.07	0.32	-0.21	-0.01
Kagondo	0.55	0.29	-0.33	0.20	0.81	0.47	-0.01	0.67	0.03	0.13	-0.17
Kaibanja	0.34	-0.16	-0.26	0.50	0.60	-0.14	0.39	-0.17	0.20	-0.08	0.52
Ruhoko	0.55	0.42	0.14	0.72	0.27	-0.37	-0.37	0.01	-0.02	-0.36	0.64
			Muleba District								
Ilemera	0.26	0.68	0.06	0.41	-0.05	-0.37	-0.19	-0.18	-0.43	-0.02	0.18
Nshamba	0.44	0.49	0.07	0.14	0.32	0.20	-0.36	0.11	0.30	0.54	-0.40
			Karagwe District								
Bugene	0.21	-0.34	0.03	0.53	0.86	0.19	-0.12	0.18	0.10	0.31	-0.06
Kituntu	0.44	-0.15	-0.20	-0.13	0.47	0.07	0.45	0.52	0.71	-0.19	-0.38
			Over all locations								
	0.33	-0.05	0.04	0.31	0.37	0.09	-0.08	-0.00	0.24	-0.05	0.05

Table 7. Coefficients of correlation of foliar nutrient concentrations[1] with banana yield at apparent non-optimal and optimal nutrient levels.

	Sub-optimal			Above CNL for deficiency		
Nutrient	Range of Conc.	r	no.[2]	Range of Conc.	r	no.
N	2.07 - 3.64	0.33[3]	87	--	--	--
Ca	0.64 - 1.13	0.48	55	1.13 - 1.59	0.26	32
Mg	0.26 - 0.65	0.38	87	--	--	--
Zn	9.9 - 21.5	0.24	87	--	--	--
B	8.1 - 10.0	0.38	30	10.0 - 12.8	0.01	57
K/(K+Ca+Mg)	0.28 - 0.37	0.35	30	0.38 - 0.59	-0.45	57
Ca/(K+Ca+Mg)	0.23 - 0.36	0.44	49	0.37 - 0.47	-0.22	38
Mg/(K+Ca+Mg)	0.17 - 0.25	0.32	62	0.25 - 0.36	-0.06	25

[1] Linear relationships of banana yield with P, K, S, Fe, Mn, and Cu were not significant and are not presented.

[2] no. is the number of samples.

[3] The linear relationship is significant at P = 0.05 and 0.01 if the correlation coefficent (r) exceeds 0.21 and 0.27, respectively.

Table 8. DRIS norms and coefficients of variability for Eastern Africa Highland bananas estimated from the Kagera data.

	DRIS norms	CV
N	3.15	10.3
P	0.25	32.8
K	3.04	17.1
Ca	1.13	19.2
Mg	0.48	17.3
S	0.25	12.8
Fe	152	26.8
Mn	400	69.0
Zn	16.0	15.9
Cu	7.10	37.8
B	10.0	9.9
N/P	12.5	25.6
N/K	1.2	20.7
N/Ca	2.8	25.6
N/Mg	7.0	21.6
N/S	12.5	14.9
N/Fe	0.021	19.0
N/Mn	0.009	55.6
N/Zn	0.20	17.5
N/Cu	0.50	26.8
N/B	0.30	13.3
P/K	0.09	34.4
P/Ca	0.24	47.5
P/Mg	0.50	55.0
P/S	1.06	31.4
P/Fe	0.002	50.0
P/Mn	0.001	100.0
P/Zn	0.016	43.7
P/Cu	0.040	37.5
P/B	0.025	32.0
K/Ca	2.40	32.7
K/Mg	5.2	31.5
K/S	10.4	19.2
K/Fe	0.018	22.2
K/Mn	0.008	50.0
K/Zn	0.16	23.1
K/Cu	0.40	31.5
K/B	0.24	17.9
Ca/Mg	2.50	23.1
Ca/S	4.80	23.4

Table 8. Continued.

Ca/Fe	0.008	25.0
Ca/Mn	0.003	66.6
Ca/Zn	0.072	25.0
Ca/Cu	0.17	37.1
Ca/B	0.11	18.2
Mg/S	2.00	21.0
Mg/Fe	0.003	33.3
Mg/Mn	0.001	50.0
Mg/Zn	0.031	19.4
Mg/Cu	0.070	31.4
Mg/B	0.045	17.8
S/Fe	0.002	41.0
S/Mn	0.001	64.0
S/Zn	0.018	16.7
S/Cu	0.039	25.6
S/B	0.039	10.3
Fe/Mn	0.35	70.6
Fe/Zn	9.9	28.2
Fe/Cu	23.0	38.8
Fe/B	14.6	28.2
Mn/Zn	25.0	76.0
Mn/Cu	62	53.5
Mn/B	42	64.4
Zn/Cu	2.6	26.2
Zn/B	1.15	17.1
Cu/B	0.67	20.8

Table 9. Probable villages in which to conduct diagnostic trials to confirm the presence of problems indicated by this study.

	N	P	K	Ca	Mg	S	Zn	Cu	B
				Bukoba District					
Kanyang.	x		x	x	x	x	x	x	x
Buhekela	x						x	x	x
Kagondo	x		x						
Kaibanja			x			x	x	x	x
Ruhoko			x						
				Muleba District					
Ilemera	x						x	x	x
Nshamba		x	xx						
				Karagwe District					
Bugene	x		x	x	x				
Kituntu	x		x				x	x	x

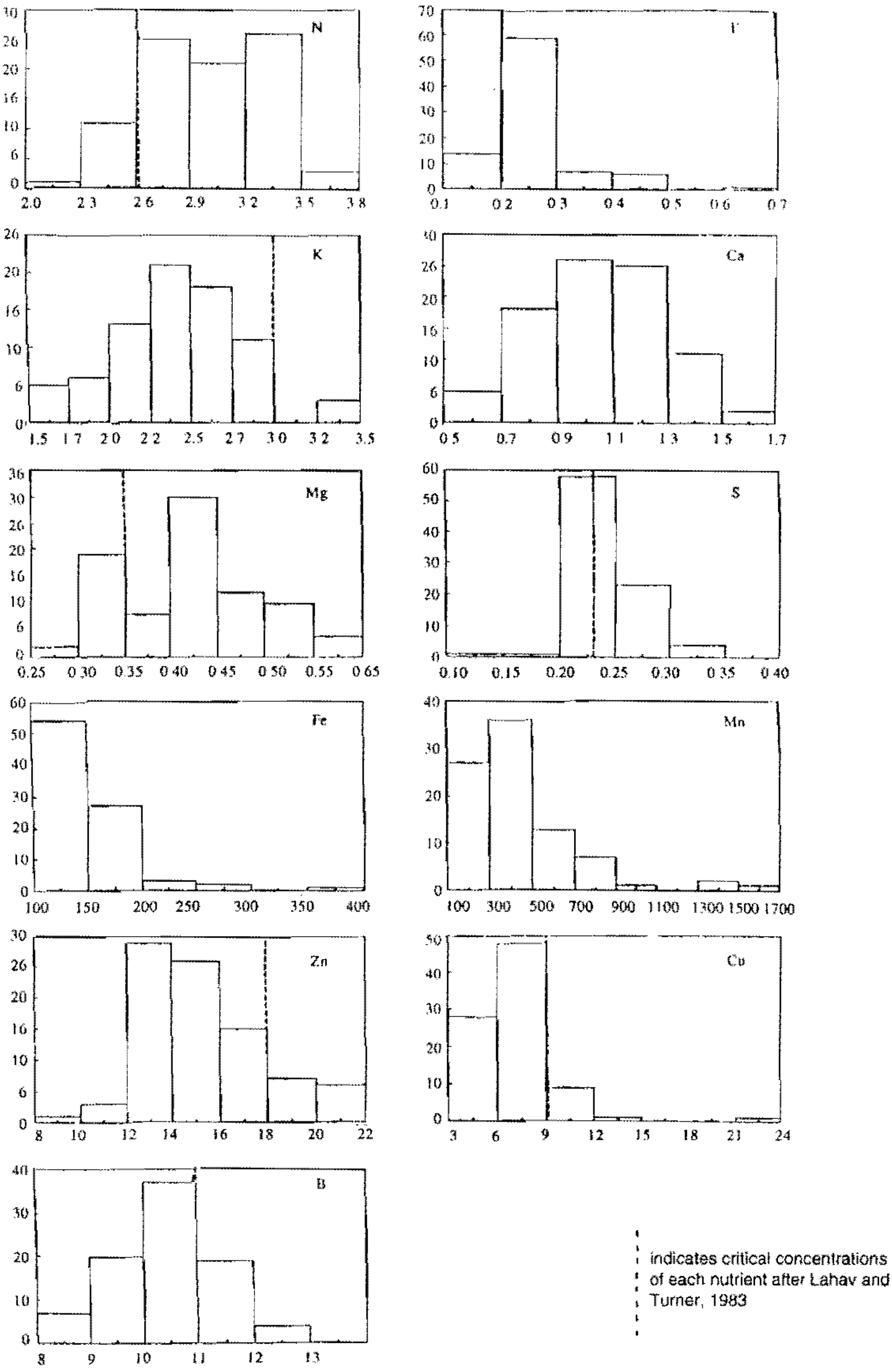

Figure1. Frequency of occurence of foliar nutrient concentrations in Bananas in Kagera Region of Tanzania. Nutrient concentrations are given on the X axis and Frequency of occurence on the Y axis.

APPENDIX

Table A1. Foliar nutrient concentrations of bananas near (N) and far (F) from the house on farms in Kagera Region of western Tanzania.

Name		N %	P %	K %	Ca %	Mg %	S %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
					Mikoni, Bukoba							
I. Abdallah	F	2.88	0.23	2.44	1.35	0.41	0.14	123	304	9.9	5.1	10.3
	N	3.19	0.23	2.02	1.17	0.52	0.24	220	538	14.6	7.5	10.2
P. Nicolus	F	2.63	0.22	2.43	1.16	0.43	0.23	133	399	15.8	6.1	9.9
	N	3.58	0.28	2.79	1.40	0.52	0.30	157	411	16.9	6.8	9.9
N. Kayego	F	2.69	0.27	2.63	1.32	0.51	0.27	166	637	16.2	8.5	10.5
	N	2.97	0.21	2.17	1.42	0.43	0.26	185	479	15.7	5.7	10.9
C. Pangani	F	2.72	0.28	2.89	1.13	0.44	0.25	166	340	13.7	8.8	8.8
	N	2.94	0.24	2.85	1.59	0.46	0.27	147	574	18.0	8.4	10.9
P. Ngaiza	F	3.22	0.19	2.67	0.80	0.29	0.22	127	1382	16.9	10.0	10.7
	N	3.36	0.19	2.22	1.22	0.52	0.29	145	1672	16.2	11.4	10.9
					Kaibanja, Bukoba							
T. Grabawa	F	2.97	0.26	2.85	0.74	0.42	0.23	121	399	14.4	13.6	9.2
	N	3.42	0.30	2.97	1.13	0.39	0.28	134	481	14.2	7.1	11.6
J. Muganyizi	F	3.00	0.25	3.02	0.69	0.33	0.28	144	454	14.7	8.3	9.1
	N	3.50	0.26	3.15	0.96	0.44	0.24	152	303	15.3	6.6	10.3
S. Karumuna	F	2.86	0.41	2.61	0.91	0.32	0.30	119	307	15.2	7.6	11.2
	N	2.58	0.20	2.39	1.32	0.45	0.20	154	595	13.7	5.9	11.0
R. Rugalabamu	F	2.74	0.25	2.42	1.00	0.42	0.19	113	625	14.4	6.5	10.3
	N	3.02	0.28	2.29	1.23	0.46	0.25	125	477	16.9	6.3	11.7
E. Alexander	F	2.66	0.35	2.77	1.14	0.33	0.23	127	435	13.5	4.9	11.2
	N	3.22	0.23	2.82	1.05	0.36	0.24	145	457	13.3	5.1	10.2
					Buhekela, Bukoba							
E. Ishashi	F	2.55	0.32	2.78	1.53	0.48	0.26	111	307	16.0	6.2	11.7
	N	3.36	0.24	3.08	1.30	0.44	0.30	146	354	20.3	6.9	11.5
N. Balingilaki	F	2.80	0.20	2.51	0.90	0.26	0.28	124	451	17.7	7.6	9.7
	N	3.19	0.25	2.94	1.47	0.36	0.30	166	455	19.6	8.6	12.8
M. Muyunga	F	3.22	0.25	2.40	1.37	0.34	0.28	118	474	16.1	9.3	12.0
	N	3.25	0.27	2.74	1.26	0.60	0.29	170	341	20.3	7.8	12.2
B. Muliro	F	2.46	0.50	3.15	1.34	0.38	0.28	154	307	17.1	7.3	11.5
	N	3.25	0.29	3.13	1.46	0.62	0.28	133	142	17.0	5.7	11.4
B. Thadeo	F	2.74	0.41	2.62	0.86	0.33	0.29	151	345	16.0	7.2	10.2
	N	2.55	0.21	2.44	0.79	0.36	0.27	133	282	13.3	4.0	11.7
					Ruhoko, Bukoba							
H. Ibrahimu	F	3.39	0.29	3.30	0.95	0.49	0.29	144	339	14.8	10.8	10.4
	N	3.14	0.26	2.54	0.98	0.50	0.20	137	387	14.0	7.1	11.3
H. Abedi	F	3.28	0.21	2.35	0.86	0.55	0.26	163	675	14.7	8.0	11.4
	N	3.64	0.28	3.13	1.03	0.50	0.24	156	244	13.9	6.1	11.8
M. Sentamu	F	3.30	0.21	2.10	0.88	0.65	0.25	282	583	19.3	10.7	10.4
	N	3.08	0.19	1.61	1.07	0.61	0.23	169	853	17.0	9.7	12.3
L. Kashunga	F	3.30	0.20	2.59	0.95	0.45	0.22	147	730	12.8	7.1	9.0
	N	2.77	0.20	2.47	0.67	0.32	0.25	124	533	14.1	7.5	9.1

Table A1. Cont

Name		N %	P %	K %	Ca %	Mg %	S %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
					Kanyangereko, Bukoba							
J. Kagurusi	N	2.49	0.40	2.06	1.15	0.42	0.20	114	207	16.0	6.1	10.2
W. Tigwera	F	3.11	0.24	2.34	0.97	0.30	0.24	173	161	14.4	6.1	10.9
	N	3.22	0.24	2.57	1.11	0.42	0.25	134	179	15.1	3.7	10.0
B. Mulinda	F	2.80	0.22	2.17	1.17	0.41	0.21	143	165	13.9	5.1	8.9
	N	3.39	0.21	2.29	0.83	0.33	0.24	148	220	16.1	4.8	9.8
C. Rugomora	F	2.35	0.48	1.65	1.24	0.52	0.22	114	165	13.5	8.2	8.5
	N	2.74	0.32	2.27	1.20	0.41	0.21	131	167	14.1	6.0	9.8
E. Sebastian	F	2.69	0.24	2.60	0.99	0.34	0.21	153	195	13.3	5.7	8.6
	N	3.28	0.23	2.68	1.06	0.38	0.24	122 1	60 1	5.7	4.2 1	0.0
					Bugene, Karagwe							
E. Kanyangaro	F	2.97	0.24	3.01	0.64	0.40	0.20	127	209	15.8	7.1	11.1
	N	2.80	0.23	2.49	1.41	0.53	0.23	122	189	12.6	3.7	9.9
F. Mutabazi	F	2.86	0.21	2.42	0.93	0.43	0.20	121	462	12.5	5.9	10.3
	N	2.80	0.33	2.82	0.98	0.36	0.22	122	486	14.0	5.6	10.4
O. Kabendera	F	2.80	0.20	1.59	1.26	0.45	0.22	147	140	20.5	4.6	9.9
	N	3.30	0.24	2.50	1.00	0.40	0.20	162	200	21.2	6.0	9.0
O. Gabagambi	F	2.44	0.19	2.20	0.80	0.40	0.20	121	462	12.5	5.9	10.3
	N	2.88	0.20	2.52	1.12	0.54	0.21	151	274	20.0	8.5	10.5
B. Nkoborelwa	F	2.07	0.23	2.37	0.98	0.46	0.22	134	146	19.6	5.6	10.8
	N	2.44	0.22	2.44	0.91	0.41	0.22	163	146	14.2	5.5	10.0
					Kituntu, Karagwe							
M. Babara	F	2.94	0.21	2.13	1.08	0.59	0.22	162	500	19.8	5.0	10.0
	N	2.94	0.19	2.28	1.08	0.51	0.21	160	718	19.7	6.7	10.3
N. Bigimbwa	F	2.72	0.18	2.06	1.22	0.47	0.21	157	279	12.9	7.1	10.5
	N	2.86	0.20	2.10	1.18	0.38	0.22	150	391	12.1	4.8	11.4
F. Kamugisha	F	2.38	0.20	2.67	1.25	0.33	0.20	111	195	12.8	5.2	10.7
	N	2.32	0.20	2.52	1.33	0.41	0.24	143	262	10.4	3.7	10.0
I. Mugeni	F	2.58	0.19	1.76	1.12	0.53	0.21	101	487	11.0	6.8	11.6
	N	3.00	0.23	2.17	0.96	0.42	0.23	136	383	21.5	7.7	10.1
J. Murondo	F	2.80	0.69	3.45	0.68	0.32	0.29	109	166	12.1	8.1	10.1
	N	3.25	0.26	2.40	1.10	0.40	0.20	120	680	11.9	3.8	11.8
					Ilemera, Muleba							
A. Kamugisha	F	2.63	0.26	2.73	0.70	0.32	0.28	251	534	14.5	6.4	8.1
	N	3.19	0.28	2.56	0.97	0.50	0.24	203	254	13.1	4.3	10.7
W. Shabani	F	3.16	0.25	3.27	0.79	0.48	0.26	161	564	18.4	24.7	11.8
	N	3.28	0.25	3.12	0.76	0.54	0.27	235	282	16.1	6.3	11.9
Kifaru	F	2.69	0.41	2.74	0.85	0.30	0.23	165	286	12.6	6.6	10.9
	N	3.36	0.27	3.10	0.87	0.43	0.25	397	382	15.3	5.8	10.9
E. Mnyagante	F	2.74	0.33	2.77	0.88	0.35	0.21	124	452	13.3	5.9	9.2
	N	3.30	0.27	2.20	1.14	0.43	0.25	147	405	13.9	10.6	9.9
C. Bombo	F	2.94	0.17	2.21	0.98	0.41	0.24	146	314	15.3	5.7	9.8
	N	3.00	0.36	3.15	0.88	0.34	0.22	177	443	13.7	6.0	9.2

Table A1. Cont.

Name		N %	P %	K %	Ca %	Mg %	S %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
						Nshamba, Muleba						
A. Rwakatare	F	2.94	0.19	1.94	1.07	0.43	0.25	155	710	13.6	8.5	10.6
	N	3.22	0.20	1.98	1.13	0.44	0.28	165	707	12.3	6.4	10.2
A. Rwakatare	F	3.33	0.20	1.91	1.00	0.41	0.23	124	347	12.4	9.5	8.5
	N	3.36	0.20	1.98	1.06	0.47	0.29	139	403	14.9	10.2	9.5
Igabiro	F	2.97	0.17	1.96	0.76	0.40	0.27	110	885	13.0	8.7	9.5
	N	3.30	0.18	2.29	0.78	0.35	0.25	115	707	12.3	6.4	10.2
D. Timanya	F	3.22	0.17	1.64	1.06	0.31	0.24	105	921	13.6	8.4	9.1
	N	3.02	0.18	1.71	1.22	0.32	0.25	132	1496	13.5	8.3	9.8
D. Kaduugu	F	2.77	0.21	2.25	1.26	0.49	0.24	120	273	15.8	7.6	10.3
	N	3.30	0.18	2.29	0.78	0.35	0.25	115	669	15.4	6.4	8.8