MUARIK BULLETIN, Vol. 5. pp. 82-87, 2002
Printed in Uganda.
ISSN 1563-3721

Characterising low production patches in cropped fields of the Kigezi highlands, Uganda.

M.A. Mateete Bekunda and G. Manzi†
African Highlands Ecoregional Programme and Tropical Soil Biology and Fertility Programme, P.O. Box 239, Kabale, Uganda
†Department of Soil Science, Makerere University, P.O. Box 7062, Kampala, Uganda

Abstract

Intensification of land use has led to land degradation over much of the African highlands. One of the indicators of this degradation are the low production patches of land within cropped fields that have captured farmers' attention and desire for special know-how on their management. The farmers of the Kigezi highlands in south-western Uganda have a local name, *Ebeija,* describing the condition of crops growing on these land patches, and relating this condition to soil fertility. Soils from selected low production patches of land in the Kigezi highlands were characterised for their nutrient status by chemical analyses of soil and plant tissue samples, and the limiting nutrient approach in pot and field trials so as to identify the potential soil management needs for these patches. Nutrient concentration levels in soils and bean (*Phaseoulus vulgaris* L.) foliar tissues indicated that potassium was the deficient nutrient, averaging 0.23 cmol kg^{-1} and 0.94%, respectively. The limiting nutrient studies indicated best crop yield response (up to 156%) from the combined application of potassium, phosphorus and micronutrients. In smallholder farming systems, such nutrient combinations can best be achieved through integrated fertiliser management.

Key words: Bean, farmers, land patches, limiting nutrients, low fertility, potassium

Introduction

Intensification of land use in the East African Highlands in the absence of external nutrient inputs has led to soil nutrient depletion and land degradation mainly through the processes of erosion and harvest removal. Because of their mountainous nature, the nutrient depletion rates in the highlands probably exceed the depletion rate estimates for East Africa of 40 kg N, 7 kg P and 25 kg K ha^{-1} yr^{-1} (Stoorvogel and Smaling, 1990). The farmers of the Kigezi highlands have also recognised that the degree of soil fertility depletion within farms is variable and may result in patches of land within farms that are less productive (Anon., 1999). *Ebeija* is a local name used to invariably describe the stunting and yellowing appearance of crops growing on such lands or the infertility status of the soils themselves. Perhaps *ebeija* is equivalent to *Lunnyu* soils, a Luganda version describing patches of unproductive land recorded as early as 1954 to be common in Ssese Islands, Lake Victoria Crescent, Kigezi, Ankole and Busoga (Chenery, 1954). Similar low fertility land patches have been described in the western Kenya farming systems (Woomer *et al.*, 1998).

Rehabilitation of such low fertility areas by the smallholder farmers has predominantly depended on nutrient resources recycled within farm. There is growing interest in biological alternatives that can augment these resources, occasional supplementation with inorganic fertilisers, and also strategies of managing (integration) these resources to optimise crop response from them. This requires good diagnosis of the nature and extent of the problem. We, therefore, applied established methods of determining crop nutrient requirement including soil and plant tissue analyses, greenhouse and field experiments (Davidescu and Davidescu, 1982; Colwell, 1994) to determine the nutrient(s) that limit crop productivity in the low fertility patches.

Materials and methods

The impact of ebeija on yield

Land identified as having typical low fertility patches was prepared using the handhoe, sub-divided into twenty seven plots of 4.5 x 4.5 m each and planted to beans (var. K132) at a spacing of 50 x 10 cm. It was envisaged that the effect of soil fertility constraints on crop growth and yield would be variable in the different plots but that the relationship needed to be established. At pod formation (stunting, yellowing and curling of leaves, limited poding), when the *ebeija* symptoms are most prevalent, the affected beans per plot were counted and later plotted against the bean seed yield. *Rhizoctonia* root rot, which is common in the area and causes similar symptoms to beans as *ebeija,* was determined by recording lesions and cankers on lower stems of ten randomly selected plants in a plot. It was found to be minimal (0.9% infection).

Soil and plant tissue characterisation

Soil and bean leaf samples were obtained from 13 *ebeija* sites. At each site, six auger soil samples were taken randomly from bean fields and with low soil fertility patches to a depth of 20 cm and mixed into a composite sample. About 1 kg of the composite sample was processed for analysis according to Anderson and Ingram (1993). From the same low fertility patches, fully expanded upper leaves were randomly taken at flowering from several beans exhibiting *ebeija* symptoms, dried in the oven at 65°C for 48 hours, and ground to pass a 1 mm mesh. Samples were analysed for different nutrient elements at the Tropical Soil Biology and Fertility Programme's analytical laboratories in Nairobi.

Limiting nutrient pot trial

The study was conducted at Makerere University Agricultural Research Institute, in a glasshouse under natural conditions (light, temperature, humidity). The soil used in the study was from Rubaya, Kabale district, sampled from three *ebeija* sites, mixed, air dried, sieved (<2 mm), mixed with quartz sand in a ratio of 3:1 (soil:sand) and transferred to plastic pots (3 kg pot^{-1}). The trial consisted eight treatments; a control and nutrient elements (added at 50 kg ha^{-1}) being N, P, K, N+P, N+K, P+K and N+P+K, and replicated 8 times. The fertilisers were weighed and thoroughly mixed with the soil before potting. Four maize seeds (cv Longe 1) were planted in each pot, and the seedlings thinned to 2 per pot at two weeks after germination.

Moisture was maintained near field capacity by weighing and replacing the deficit with distilled water. However, four replicates also received weekly 20 ml aliquots of the Broughton and Dillworth nutrient solution (Somasegaran and Hoben, 1985), free of N, P and K.

Shoots were harvested by cutting 10 mm above the soil surface, after 10 weeks of growth. Samples were oven dried at 65°C for 48 hr and weighed to determine biomass. A second crop of maize was planted in the same pots without soil disturbance, to determine the residual effects of the treatments under similar management to that of the first crop.

Limiting nutrient field experiment

The study was conducted in Rubaya sub-county, Kabale district, south-western Uganda from February to December 2000. Kabale district lies approximately between latitudes 1°00' and 1°30'S, and longitudes 29°18' and 30°09'E, at an altitude of between 1500 – 2750 m above sea level. The mean annual rainfall ranges between 1000 and 1500mm in a bimodal distribution with peaks in March to April and October to November, allowing for two cropping seasons in a year. Average temperature ranges between 9 and 23°C (Kabale District Meteorological Office, 1999).

Like the rest of other parts in the district, Rubaya is made up of undulating hills with steep convex slopes of 10 – 60° with gentle (5 – 10°) foot slopes. About 10% of the cultivated area is on slopes of more than 20° (Lindblade *et al.*, 1996). The soils on these slopes are predominantly (>70% coverage) ferralitic sandy clay loams (Harrop, 1960). Historically, farmers have practiced terracing (Lindblade *et al.*, 1996) to counter the erosional effects of cropping on steep slopes. During the first rains of 2000 (season 1), treatments similar to those applied in the glasshouse experiment were also applied to six farmers' *ebeija* fields but without a micronutrient treatment. The farm fields constituted the replications. Fertilisers were spread by hand on the seedbeds and incorporated into the soil using a handhoe. Common bean (var. K132) was used as the test crop; it was planted in rows at a spacing of 50 by 10 cm. Plot sizes varied depending on the size of the low fertility patches, from 8 to 20m^2. The crops were weeded twice. During the second season, only the treatments involving the nutrient combinations (N+P, N+K, P+K, N+P+K), and the control, were applied to fresh fields.

Results

The impact of ebeija on yield

The relationship between yield and the number of plants exhibiting *ebeija* symptoms was significant (Fig.1); the yield declined sharply to less than 50% of that obtained in the plots without *ebeija* with about 10% of the plants bearing visual symptoms, and then gradually stabilising at about 30%.

Soil and plant tissue characteristics

The results in Table 1 show variation in ranges of the major soil nutrients determined. Potassium (K) was the only nutrient whose mean value was less than the critical value (only one sample had a value above the critical value) suggesting that K could be the limiting nutrient in the low fertility patches. Bean leaf sample analysis yielded K content values that were in the deficient range while P and N values were adequate (Table 2).

Pot trial

For the first crop, significant yield increases were obtained with fertiliser P, but were enhanced further by fertiliser P plus K (Fig. 2A). The effect of micronutrients was significant (P<0.05) and appeared to be more pronounced in the treatments where the plants responded to macronutrients. There were no

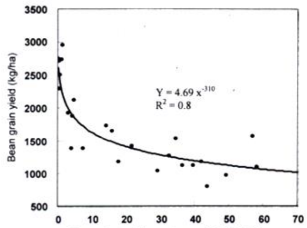

Figure 1. Relationship between bean grain yield and percent of bean plants with ebeija symptoms.

significant residual effects of the treatments (second crop, Fig. 2B). Here, the response to micronutrients was not residual because they continued to be applied.

Field trial

Treatment effects on bean yield were not significant in the first season (Table 3) but significant yield increases resulted from treatments with K and P combinations in the second season trial.

Discussion

In East Africa, the near universal response of crops to nitrogen and widespread deficiencies of phosphorus have led to the belief that these are the most severely depleted nutrients (Lekasi, 1998;

Table 1. Chemical characteristics of soils from the low fertility patches.

Characteristic	Mean value	Range	Critical value*
pH	5.3	4.5 - 6.0	5.5
Exchangeable calcium ($cmol_c\ kg^{-1}$)	6.1	3.3 - 7.7	2.6
Exchangeable magnesium ($cmol_c\ kg^{-1}$)	2.2	0.8 - 3.1	0.3
Exchangeable potassium ($cmol_c\ kg^{-1}$)	0.2	0.1 - 1.0	0.5
Extractable phosphorus ($mg\ kg^{-1}$)	7.7	2.8 - 19.8	5.0
Organic carbon (%)	2.5	1.2 - 3.5	1.5
Total soluble nitrogen (%)	0.28	0.15 - 0.35	0.12

*Source: Okalebo *et al.*(1993); the cut off value between the low and medium rating was adapted as the critical value.

Table 2. Chemical characteristics of leaves from bean plants growing on low fertility patches.

Characteristic	Mean value	Range	Critical value*
Nitrogen (%)	5.24	4.54 - 6.20	3.5
Phosphorus (%)	0.48	0.36 - 0.57	0.3
Potassium (%)	0.94	0.57 - 1.56	3.0
Calcium (%)	2.05	1.07 - 3.26	0.8

*Source: Okalebo *et al.* (1993).

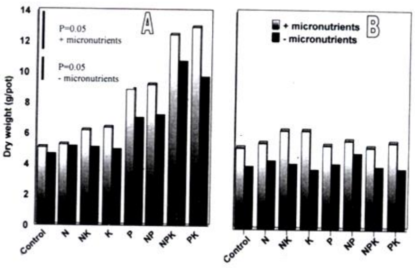

Figure 2. Growth response of maize seedlings to N, P, and K with and without micronutrients in first (A) and second (B) crops.

Woomer *et al.*, 1998). Indeed, rehabilitation of low fertility patches in the western Kenya highlands is based on a fertiliser kit formulated to restore fertility by contributing P from a Tanzanian phosphate rock and nitrogen from urea and rhizobial inoculants (Woomer *et al.*, 1998). For long, potassium application to soils has received least attention of the three major fertiliser elements.

The different methods used to characterise the low soil fertility patches suggest that the limitation to soil productivity on *ebeija* sites is a combination of K, P and micronutrients. In fact, the application of K alone may not result in appreciable crop responses, leading to increased yields even when limiting (as seen from soil and plant tissue analyses results), in conditions where it affects uptake of other nutrients (Anderson, 1972). This makes sense considering that farmers participating in the study claimed to have obtained yield responses on these sites with diammonium phosphate (DAP) fertiliser only when it was applied together with high rates of livestock manure. The DAP alone supplied N and P while the manure was a source of other nutrients, including potassium and micronutrients. But the use of high rates of manure in the highlands cannot be a widespread option given a limited livestock ownership rate of around 1-2 cattle per farm (Olson, 1995). The need for supplementary inorganic fertilisers is likely to increase. The analysis results of *Lunnyu* soils reported by Zake (1986) also showed potassium and phosphorus to be below the limiting nutrients for Ugandan soils.

Earlier studies indicated potential areas where potassium deficiency was to be expected as being on very sandy, very acid or calcareous soils (Evans and Mitchell, 1962; Anderson, 1967; Lock, 1969). The soils of the Kigezi highlands are acidic (Table 1), are continuously cultivated, receive high rainfall (>1000 mm per annum) and consequent greater leaching, all of which are conducive to potassium shortage. The test crops used in this study were responsive to this shortage but crops with relatively low nutrient demand may not act as indicator crops in the field. Soil and plant tissue analyses remain faster techniques for identifying limiting nutrients and correcting deficiencies before crops mature. In East Africa, early attempts to correlate soil analyses with crop response were mainly with phosphorus (Foster, 1972) and nitrogen (Robinson, 1968). It was observed that since the coefficients of variation with regard to nitrogen and potassium analysis in leaf tissue were low, this offered a useful guide to these nutrient requirements in crops (Robinson and Freeman, 1967). The introduction of high yielding but more nutrient-demanding crop varieties, increasing cropping intensity and improved cultural practices will probably result in an increase in demand for nutrients. The new developments and adaptations in analytical techniques (e.g., Anderson and Ingram, 1993) need to be considered and related to plant responses as a cheaper means of defining the constraints of the affected soils, increasing our knowledge of nutrient removal by crops, and applying of appropriate nutrient inputs to overcome the constraints.

Table 3. Bean yield response on ebeija sites to applied nutrients.

Treatment	season 1 yield t ha^{-1}	season 2 yield t ha^{-1}
Control	0.58	0.54
Nitrogen (50 kg ha^{-1})	0.55	nd
Phosphorus (50 kg ha^{-1})	0.53	nd
Potassium (50 kg ha^{-1})	0.69	nd
N + P	0.58	0.73
N + K	0.70	0.67
P + K	0.73	0.93
N + P + K	0.89	0.94
LSD(5%)	ns	0.21

nd, not determined; ns, not significant.

Acknowledgement

The funding for this study was through a grant to the African Highlands Ecoregional Programme by IDRC Canada. We are grateful to the farmers of Rubaya who participated in this study.

References

Anderson, G.D. 1967. Increasing coconut yields and income on sandy soils of the Tanganyika coast. East African Agriculture and Forestry Journal 32:310-314.

Anderson, G.D. 1972. Response of beans to fertilisers on Mt. Kilimanjaro in relation to soil and climatic conditions. Proceedings of the 12th East African Specialist Committee on Soil Fertility and Crop Nutrition. Morogoro, Tanzania. pp. 6-11.

Anderson, J.M. and Ingram, J.S.I. 1993. *Tropical Soil Biology and Fertility: A Handbook of Methods. CAB International.* Wallingford, UK. 221pp.

Anonymous, 1999. *Proceedings, Participatory Agroecosystem Workshop*, Kabale AHI Benchmark Site, Draft 1. African Highlands Ecoregional Programme, Kawanda, Uganda. 64pp.

Chenery, E.M. 1954. *Lunnyu soils.* Records of Investigations (1948-1954). Department of Agriculture, Entebbe, Uganda.

Colwell, J.D. 1994. *Estimating Fertiliser Requirements: A Quantitative Approach.* CAB International, Wallingford, UK. pp. 10-25.

Davidescu, V. and Davidescu, D. 1982. *Evaluation of Fertility by Plant and Soil Analysis.* Abacus Press, Turnbridge Wells, UK. 560pp.

Evans, A.C. and Mitchell, H.W. 1962. Soil fertility status in Tanganyika. 1. Improvement to crop and grass production on a leached sandy soil in Bukoba. East African Agriculture and Forestry Journal 27:189-196.

Foster, H.L. 1972. Correlation of groundnut responses to phosphate fertiliser with soil and leaf analysis. Proceedings of the 12th East African Specialist Committee on Soil Fertility and Crop Nutrition. Morogoro, Tanzania. pp. 1-5.

Harrop, J.F. 1960. *Soils of the Western Province of Uganda.* Memoirs of the Research Division, 1-6. Department of Agriculture, Uganda.

Lekasi, J.K. 1998. *Crop Residues as Mulches in Banana-Based Cropping Systems of Uganda.* MSc. Thesis, Makerere University, Uganda. 88pp.

Lindblade, K., Tumuhairwe, J.K., Carswell, G., Nkwiine, C. and Bwamiki, D. 1996. *More People, More Fallow: Environmentally favourable land-use changes in southwestern Uganda.* A Report. The Rockefeller Foundation, NY, USA. 67pp.

Lock, G.W. 1969. *Sisal.* 2nd Edition. Longmans, UK. 365pp.

Okalebo, J.R., Gathua, K.W. and Woomer, P.L. 1993. *Laboratory Methods of Soil and Plant Analysis: A working manual.* TSBF Programme, Nairobi, Kenya. 88pp.

Olson, J.M. 1995. *Natural resource management by farmers in Kabale District, Uganda.* RRA Report, AHI/ICRAF, Nairobi, Kenya. 18pp.

Robinson, J.B.D. 1968. Measuring soil nitrogen available to crops in East Africa. East African Agriculture and Forestry Journal 33:269-280.

Robinson, J.B.D. and Freeman, G.H. 1967. Sources of variation in leaf analysis in East Africa. East African Agriculture and Forestry Journal 33:8-13

Somasegaran, P. and Hoben, H.J. 1985. *Methods in Legume-Rhizobium Technology.* NifTAL Project and MIRCEN, University of Hawaii, USA 366pp.

Stoorvogel, J.J. and Smaling, E.M.A. 1990. Assessment of soil nutrient depletion in sub-Saharan Africa: 1983-2000: Vol. 1, Main Report. The Winand Staring Centre, Wageningen, The Netherlands. 101pp.

Woomer, P.L., Bekunda, M.A., Karanja, N.K., Moorehouse, T. and Okalebo, J.R. 1998. Agricultural resource management by smallhold farmers in East Africa. Nature and Resources 34:22-33

Zake, J.Y.K. 1986. Preliminary findings on the investigations of causes of infertility (Lunnyu) in some Uganda soils. *Proceedings, 8th Annual General Meeting of the Soil Science Society of East Africa,* Kampala, Uganda. pp.115-120.