EVALUATION OF LEGUMES AS COMPONENTS OF INTEGRATED SOIL NUTRIENT MANAGEMENT FOR KALE PRODUCTION

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ABSTRACT

Declining soil fertility as a result of nutrient depletion is a major constraint to crop production in smallholder farms in northwestern Kenya. The use of legumes could play an important role in improving soil productivity of these production systems. Sunhemp (*Crotolaria juncea* L.) locally known as mito and mucuna [*Mucuna pruriens* var. Utilis (L) DC] were evaluated for soil fertility improvements as preceding rotation crops for subsequent kales (*Brassica oleracea var. acephala*) when herbage above 10 cm was removed as vegetable or feed. Eight treatments were evaluated using a randomized complete block design replicated five times in two seasons. The treatments were: (1) defoliated sunhemp, (2) defoliated mucuna, (3) defoliated sunhemp + 5 t/ha farm yard manure (FYM), (4) defoliated sunhemp + 30 kg/ha P_2O_5 + 30 kg/ha N, (5) defoliated mucuna + 5 t/ha FYM, (6) defoliated mucuna + 30 kg/ha P_2O_5 + 30 kg/ha N ha, (7) 60 kg/ha P_2O_5 + 60 kg/ha N and (8) No fertilizer (control). Legume dry matter yields and fresh kale leaf yields were measured. Sunhemp yielded greater (P<0.01) lower canopy stem stubble than mucuna. There were no significant differences (P>0.05) in herbage removed as food or feed, which ranged from 2.2 to 3.4 t/ha. The combination of stubble legume residue and either FYM or inorganic fertilizer yielded greater (P<0.05) kale leaf than no fertilizer control. The yields under the combination of stubble legume residue and half the recommended inorganic fertilizer were not significantly different (P>0.50) from those for recommended inorganic fertilizer. The remaining stubble legume residue after defoliating top canopy herbage as food or fodder can substitute for 30 kg/ha P_2O_5 + 30 kg/ha N. Despite the greater stubble residue incorporated under the sunhemp treatments, kale yields under mucuna treatments were similar to those from sunhemp treatments, suggesting that nutrient use by succeeding kale was enhanced under mucuna treatments. Farmers preferred the combination of legume stubble with FYM because it was associated with larger kale leaf, low cost of production and good persistence of the kales.

Key words: Fresh leaf yields, Kale, Legume green manure, Rotation

INTRODUCTION

Low soil fertility, particularly nitrogen (N) and phosphorus (P) deficiencies, is recognized as one of the major biophysical causes for declining per capita food production in sub-Saharan Africa (Sanchez et al., 1997), including the smallholder farms in northwestern Kenya. The use of green manures from legumes in cropping systems offers considerable benefits because of their ability to fix atmospheric nitrogen (N_2) that is available after senescence of legume residue to an associated sequentially cropped non-legume (Tian et al., 2000; Nyambati et al., 2006). Cattle manure that is an integral component of soil fertility management in many areas of the tropics (Powell and Williams, 1993) is not available in sufficient quantity and the quality is low in most smallholder farms.

The low biomass yields when top-canopy green manure herbage is defoliated as food or fodder (Nyambati and Sollenberger, 2003) and the limited quantity and quality of cattle manure suggest the need for integrated nutrient management (INM) approach which seeks to maximize the complementary effects of mineral and organic nutrient sources in improving soil productivity of smallholder farming systems (Fanzlaebbers et al., 1998). The efficiency of transferring N from a legume green manure to the succeeding crop depends on synchronizing the N release from the legume residue with the demand of the recipient crop. Factors influencing the synchrony and therefore N recovery value from organic manures by annual crops include type of species, biomass quality, method and time of application (Mafongoya et al., 1997). The use of these legumes in many parts of the tropics is limited and it has been shown that farmers tend to adopt them when they have other benefits in addition to soil fertility improvement (Versteeg et al., 1998).

Legume managed as green manures has the potential to furnish all or part of the N needed by a succeeding non-legume crop (Bowen et al., 1993). Mucuna also known as velvetbean [*Mucuna pruriens* var. Utilis (L) DC (Wright) Burck] is a legume green manure that has been successfully used in intercropping systems (Wortman et al., 2000). It is one of the legumes identified having potential for soil fertility improvement in northwestern Kenya. Sunnhemp (*Crotolaria juncea L.*) is also one of the most promising species for short duration cover cropping that is also used as a vegetable by some communities in western Kenya (Woomer and Imbumi, 2003). Kale (*Brassica oleracea var. acephala*) is a nutritious green leafy vegetable (Lisiewska et al., 2008) that is commonly consumed in most households. It is also a source of income for smallholder farmers in Kenya. Previous research in Kenya has shown that the yields of *Brassica* spp. vegetables can be increased by inorganic and organic fertilizer application (Muriuki et al., 2002, Wambani et al., 2006). The broad objective of this study was to evaluate legumes for soil fertility improvements, food and feed production when used as preceding rotation crop for subsequent kales. The specific objectives of the study were to: (1) determine the effect of combining sunhemp and mucuna residue with FYM or inorganic fertilizer on yields of subsequent kales when part of the herbage is removed as food or feed on low soil fertility farmers' fields, and (2) assess farmer evaluation of the economic benefits of legume inclusion into the farming systems.

MATERIALS AND METHODS

The study was conducted during the 2004 and 2005 growing seasons in Matunda and Kaisagat in Trans-Nzoia District in northwestern Kenya in Upper midland 4 (UM_4) agro-ecological zone (Jaetzold and Schmidt, 1983). Agro-ecological zone UM_4 is located at an altitude range of 1600 to 2000 m with annual mean temperature of 18^oC to 20^oC and receives annual average rainfall of 950 to 1600 mm. The zone has a long cropping season with 60% reliability growing period of 230 to 280 days. The major soils are humic Ferralsols (FAO-UNESCO, 1974). Farmer Participatory Research (FPR) approach (Farrington and Martin, 1988) was used in the research process. The FPR focuses on groups of farmers (i.e. farmer research groups and expert panels) instead of individual farmers during the implementation of research and dissemination activities so as to enhance sharing of ideas, leading to greater impact and adoption of technologies. Participatory Rural Appraisal (PRA) techniques and tools (Nabasa et al., 1995) were used to (1) understand the main characteristics and farming systems of the communities, (2) diagnose and prioritize production constraints, and (3) identify and prioritize constraints and potential solutions to address those constraints using problem and cause analysis techniques. The farmers were actively involved in testing and evaluating the identified interventions.

In this study the farmers focused on use of legume green manure as a component of soil fertility improvement for kale production. Eight treatments were evaluated in a legume green manure-kale rotation using a randomized complete block design on five farms and each farm serving as a replicate. The treatments included: (1) defoliated sunhemp, (2) defoliated mucuna, (3) defoliated sunhemp + 5 t/ha FYM, (4) defoliated sunhemp + 30 kg/ha P_2O_5 + 30 kg/ha N, (5) defoliated mucuna + 5 t/ha FYM, (6) defoliated mucuna + 30 kg/ha P_2O_5 + 30 kg/ha N, (7) 60 kg/ha P_2O_5 + 60 kg/ha N and (8) no fertilizer (control). Experimental plots measured 4.5 m by 6 m. The legumes were planted at the beginning of the growing season in April and defoliated in early September.

The seeds of mucuna and mito were obtained from KARI's Legume Research Network Project. Mucuna was planted at a spacing of 45 cm by 30 cm and mito was spaced at 45 cm by drill. In the defoliated treatments, top-canopy foliage above 10 cm from the ground was harvested as edible vegetables or fodder. The remaining stem stubble residue was incorporated into the soil. The kale was planted as a rotation crop immediately after stem stubble residue incorporation. The kale seeds were obtained from Kenya Seed Company and were established in a seedling nursery before transplanting to experimental plots. Kale was planted at an inter- and intra-row spacing of 45 cm by 45 cm. Fresh kale leaf harvesting started in October and continued to early February. Measurements were made on legume DM yields and kale fresh leaf yields. The general linear models procedure of SAS was used to test treatment effects on legume DM and kale fresh leaf yields (SAS, 2001).

RESULTS AND DISCUSSION

At the time of legume defoliation (112 days after planting) sunhemp had started forming flower pods, but mucuna had not reached physiological maturity. There were no treatment by year and treatment by location interactions (P>0.05) for both the lower and upper canopy herbage; therefore the data were pooled across the years and sites (Table 1). Sunhemp yielded greater (P<0.01) lower canopy stem stubble than mucuna. There were no differences (P>0.05) in biomass removed, which ranged from 2.2 to 3.4 t/ha. Sunhemp yielded (4.4 t/ha) greater (P<0.01) total herbage than mucuna (3.4 t/ha) probably due to its fast growth. Defoliation of mucuna removed a greater proportion (75%) of residue than sunhemp (65%), thus leaving greater amounts of residue to be incorporated under the Sunhemp treatments.

Table 1. Dry matter (t/ha) of green manure legumes before soil incorporation for kale production during the 2004 and 2005 growing seasons combined

Treatment	Lower canopy (soil incorporated)	Upper canopy (fodder/food)	Total
Sunhemp + 5 t/ha FYM	2.0	3.4	5.4
Sunhemp + 30 kg/ha P_2O_5 + 30 kg/ha N	1.3	2.2	3.5
Sunhemp + No fertilizer	1.3	3.0	4.3
Mucuna + No fertilizer	1.0	2.6	3.6
Mucuna + 5 t/ha FYM	0.8	2.4	3.2
Mucuna + 30 kg/ha P_2O_5 + 30 kg/ha N	0.7	2.7	3.4
$LSD_{0.05}$	0.7	1.2	1.6
CV (%)	48	33	32

This is probably because mucuna was still growing and spreading, whereas sunhemp had reached maturity and has uniform upright growth. The greater proportion of top canopy of mucuna herbage removed after defoliation is in agreement to Nyambati and Sollenberger (2003) who showed that defoliation of mucuna to 10 cm-stubble removed 76% of top canopy.

There were also no treatment by year and treatment by location interactions ($P>0.05$); therefore kale fresh leaf yield data were pooled across the two years and locations. The combination of stubble legume residue and either 5 t/ha FYM or 30 kg P_2O_5 + 30 kg/ha N yielded significantly greater ($P<0.01$) kale fresh leaf than no fertilizer control. This is in agreement with Wambani et al. (2006), who showed that the use of either inorganic or organic fertilizer increased kale yields. The yields under the combination of stubble legume residue and half the recommended inorganic fertilizer (30 kg/ha P_2O_5 + 30 kg/ha N) were similar ($P>0.05$) to those for recommended inorganic fertilizer (60 kg/ha P_2O_5 + 60 kg/ha N).

The results suggest that after defoliating part of the legume top canopy herbage as food or fodder, the remaining stubble legume residue can substitute for half of the recommended rate of fertilizer. Harvesting top-canopy herbage lowers the residue quality of the remaining stubble (Nyambati and Sollenberger, 2003) and improves the nitrogen uptake of subsequent crop (Nyambati, 2002). Despite the fact that sunhemp yielded greater lower canopy DM than mucuna (Table 1), defoliated mucuna without fertilizer yielded 1.6 t/ha greater fresh leaf than the no fertilizer control, whereas sunhemp without fertilizer yields were the same as those for control without fertilizer, suggesting that immobilization of nutrients could have taken place and could require supplemental fertilizer.

Table 2. Kale fresh leaf yields (t/ha) from various fertilizers treatments during the 2004 and 2005 growing seasons

Treatments	Yield
Defoliated Sunhemp + 5 t/ha FYM	12.4
Defoliated Mucuna + 5 t/ha FYM	11.9
Defoliated Mucuna + 30 kg/ha P_2O_5 + 30 kg/ha N	11.2
Defoliated Sunhemp + 30 kg/ha P_2O_5 + 30 kg/ha N	9.5
60 kg/ha P_2O_5 + 60 kg/ha N	8.5
Defoliated Mucuna + No fertilizer	7.4
Control (No Fertilizer)	5.8
Defoliated Sunhemp + No fertilizer	5.7
$LSD_{0.05}$	4.4
CV (%)	35

Farmers' evaluation indicated that a combination of defoliated legume stubble and FYM was more preferred in terms of leaf size, leaf colour and good persistence of the kales (Table 3), but it is associated with extra cost of labour for collecting and applying FYM. For increased adoption of legume based food and forage technologies in smallholder farms, these legumes must fit into overall farming strategy based on food production for the family household. This study has shown that mucuna or sunhemp grown as a preceding rotation crop with kales and defoliating to 10 cm-stubble can provide nutritious vegetable from sunhemp (Woomer and Imbumi, 2003) and fodder from mucuna that could be a valuable protein supplement (Nyambati and Sollenberger, 2003). This could reduce the trade-off associated with the introduction of green manure legumes for soil fertility improvement alone and increase the adoption. Farmers bulked both Sunhemp and Mucuna seeds, suggesting that they are willing to adopt the technology.

Table 3. Farmers ranking of various fertilizer treatments on kale production on farmers' fields during the 2004 and 2005 growing seasons

Treatment	Farmers' criteria					
	Establishment	Leaf size	Colour	Labour	Cost	Persistence
Mucuna + 5 t/ha FYM	4	4	3	1	2	4
Sunhemp + 5/t ha FYM	3	4	3	1	2	4
Mucuna + 30 kg/ha P_2O_5 + 30 kg/ha N	4	4	3	3	2	4
60 kg/ha P_2O_5 + 60 kg/ha N	3	3	3	3	3	3
Sunhemp + 30 kg/ha P_2O_5 + 30 kg/ha N	3	3	3	3	2	3
Sunhemp + No fertilizer	2	2	3	4	4	2
Mucuna + No fertilizer	2	2	2	4	5	2
Control (No Fertilizer)	2	2	2	5	5	2

Key: 1 = Poor establishment, very small leaf, yellowish leaves, very poor persistence, more labour and cost; 5 = Very good establishment, large leaf size, dark green, very good persistence, less labour and cost of production.

CONCLUSION AND RECOMMENDATIONS

Sunhemp yielded 1 t/ha greater biomass than mucuna because of its fast growth. Defoliation of legumes to 10 cm stubble removed 65% and 75% biomass of sunhemp and mucuna, respectively, providing 2.2 to 3.4 t/ha of edible vegetable or feed. Incorporation of legume stubble combined with 5 t/ha FYM yielded greater kale leaf compared to no fertilizer control. Also, mucuna stubble biomass combined with half of recommended inorganic fertilizer yielded as much as the recommended rate of inorganic fertilizer, which yielded higher than no fertilizer control. Despite the greater stubble residue incorporated under the sunhemp treatments, kale yields under mucuna treatments were similar to those from sunhemp treatments suggesting that the synchrony of nutrient release from legume residue and uptake by succeeding kale was better under mucuna treatments. Although the use of FYM requires more labour than use of inorganic fertilizer, farmers preferred the combination of legume stubble with FYM because it was associated with larger kale leaf, low cost and good persistence of the kales. Using part of legume biomass as vegetable or feed could enhance the adoption of these legumes in the farming system. Further research should focus on quantifying the N contribution from legume stubble residue and its uptake by kales.

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REFERENCES

Bowen, W.T., J.W. Jones, R.J. Carky, and J.O. Quntana. 1993. Evaluation of the nitrogen sub-model of CERES-maize following legume green-manure incorporation. Agron. J. 85:153-159.

FAO-UNESCO. 1994. Soil map of the world. Revised legend. Technical Paper No. 20. FAO/Rome and ISRIC/Wageningen, the Netherlands.

Farrington, J., A.M. Martin. 1988. Farmer participation in agricultural research: A review of concepts and recent field work. Agricultural Research and Administration 29:247-264.

Franzluebbers, K., L.R. Hassner, and S.R. Juo. 1998. Integrated nutrient management for sustained crop production in sub-Saharan Africa: A review. Soil Management CRSP, TropSoils/TAMU Technical Bulletin No. 98-03. Texas A and M University, TX, USA.

Jaetzold, R., and H. Schmidt. 1983. Farm management handbook. Part B: Rift Valley and Central Provinces. Ministry of Agriculture, Republic of Kenya, Nairobi, Kenya.

Lisiewska, Z., W. Kmiecik and A. Korus. 2008. The amino acid composition of kale (*Brassica oleracea* L. var. *acephala*), fresh and after culinary and technological processing. Food Chemistry 108(2):642-648.

Mafongoya, P.L., and P.K.R. Nair. 1997. Multipurpose tree prunings as a source of nitrogen to maize under semi-arid conditions in Zimbabwe. 1. Nitrogen recovery in relation to pruning quality and method of application. Agroforestry Systems 35:31-46.

Muriuki, A.W., H.F. Schnier, H. Recke and S.N. Kanyajua. 2002. The effect of farmyard manure and fertilizers on cabbage yields in Kenya. East Africa Agricultural and Forestry Journal 68(1):41-49.

Nabasa, J., G. Rutwara, F. Walker, and C. Were. 1995. Participatory Rural Appraisal: Practical Experiences. Natural Resource Institute, Overseas Development Administration.

Nyambati, E.M. 2002. Management and nutritive evaluation of *Mucuna pruriens* and *Lablab purpureus*-maize intercrops in the sub-humid highlands of northwestern Kenya. Ph.D. Dissertation, University of Florida, USA.

Nyambati, E.M., and L.E. Sollenberger. 2003. Nutritive value of top-canopy herbage of *Mucuna* and *Lablab* relay cropped in maize in the sub-humid highlands of northwestern Kenya. Tropical and Sub-tropical Agroecosystems 1:81-86.

Nyambati, E.M., L.E. Sollenberger, C.K. Hiebsch and S.C. Rono. 2006. On-farm productivity of relay-cropped mucuna and lablab in smallholder crop-livestock systems in northwestern Kenya. Journal of Sustainable Agriculture 28(1):97-116.

Powell, J.M., and T.O. Williams. 1993. Livestock, nutrient cycling and sustainable agriculture in West African Sahelian Gatekeeper series No. 37. International Institute of Environmental Development, London, UK.

Sanchez, P.A., K.D. Shepherd, M.J. Soule, F.M. Place, A.U. Mokwunye, R.J. Bureshi, F.R. Kwesiga, A.M.N., Izac, C.G. Ndiritu, and P.L. Woomer. 1997. Soil fertility replenishment in Africa, p. 1-46. *In:* Buresh, R.J, Sanchez, P.A and Calhoun, F (eds.). Replenishing Soil Fertility in Africa. SSSA Special Publication No. 51. SSSA, Madison, Wisconsin, USA.

SAS (Statistical Analysis Systems Institute). 2001. SAS system for windows. Release 8.12, SAS Institute, Cary, North Carolina, USA.

Tian, G., G.O. Kolawole, B.T. Kang, and G. Kirchhof. 2000. Nitrogen fertilizer replacement indexes of legume cover crops in the derived savanna of West Africa. Plant and Soil 224:287-296.

Versteeg, M. N., F. Amadji, A. Eteka, A. Gogan, and V. Koudokpon. 1998. Farmers' adoptability of *Mucuna* fallowing and agroforestry technologies in the coastal savanna of Benin. Agricultural Systems 56(3):269-287.

Wambani H., E.M. Nyambati and M. Kamidi. 2006. Participatory development and scaling up of organic and inorganic fertilizers for kale (*Brassica oleraceae* var. *acephalla*) production in northwestern Kenya. Proceedings of the 10th KARI Biennial Scientific Conference, 13th to 17th November 2006, Nairobi, Kenya.

Wortmann, C.S., B.D. McIntyre, and C.K. Kaizzi. 2000. Annual soil improving legumes: Agronomic effectiveness, nutrient uptake, nitrogen fixation and water use. Field Crops Research 68:75-83.

Woomer, P.L. and M. Imbumi. 2003. Traditional green vegetables in Kenya, p. 116-125. *In*: Savala, C.E.N., M.N. Omare and P.L. Woomer (eds.). Organic Resource Management in Kenya: Perspectives and Guidelines. FORMAT (Forum for Organic Resource Management and Agricultural Technologies), Nairobi, Kenya.