LEGUME RESEARCH NETWORK PROJECT NEWSLETTER

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ABOUT THIS ISSUE

This ninth issue of the LRNP covers a wide range of topics involving green manure legume (GML) work. One of the articles is on resource competition and addresses the effect of planting density and time of planting legumes on legume and maize performance in a maize-mucuna intercrop system. Most previous articles on GML have largely dealt on their use for improving soil fertility and crop production. In this issue, three articles are given which highlight other important uses of GML. The articles are on the importance of inoculating common bean for increased grain yields in a bean - maize intercrop system, GML in improving soil physical properties and in managing root - rot nematodes. Matanya continues to be one of the most active site of the network. Apart from an article on the response of food grain legumes to phosphorus application, the site has also reported of an increased demand for GML seeds by the local community. This article tabulates the amount of seeds which have been distributed to the farmers and other institutions for the purpose of up-scaling GML technologies in Matanya area. The LRNP is grateful to the financial and technical support it has continued to receive from the Rockefeller Foundation since the network's inception. The network also sincerely acknowledges the support it has continued to receive from Director, KARI.

Contents

EDITOR'S NOTE

The LRNP newsletter is published to provide a forum for highlighting Network activities and sharing research findings with network members and other projects, individual researchers and farmers who are involved in similar work in Kenya. This is a biannual newsletter and is published in June and December of each year. Your contributions and constructive comments are welcome and should be addressed to the Editors of LRNP Newsletter, CKK Gachene or LRNP Coordinator, JG Mureithi.

Effects of Mucuna Planting Density and Time on Water and Light Use in a Maize - Legume Intercrop System

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Introduction

High yielding legume cover crops (LCC) have the potential to improve soil nutrient status in the low input maize cultivation systems of Kenya. This is through incorporation of LCC biomass into the soil as green manure and through biological nitrogen fixation. LCC integration into maize based production system may be through relay planting, inter-planting or rotation systems. Relay maize-LCC production is attractive to farmers in areas where the land is under continuous use for household food supply. For effective relay LCC production, competition for resources (water, light and nutrients) in maize-LCC inter-crop system should be minimal. The challenge of including LCC in the system is to produce substantial LCC biomass to meet nutrient requirements for a subsequent maize crop without reducing the maize yield in the season the LCC is grown. This might be achieved through judicious planting time and density of the legume in the intercropping system. The objective of this study was to determine the effect of planting density and time of planting legumes on growth, yield, light and water use in a maize-mucuna intercrop.

Methodology

The study was carried out at Kabete Field Station farm, University of Nairobi, between November 2001 and September 2002. Maize was inter-cropped with velvet bean (*Mucuna prurien*) at two planting densities and three planting dates. Planting densities were single legume row between maize (D1) and two rows between maize (D2) while planting dates were 0, 2 or 4 weeks after planting maize; T1, T2 and T3, respectively. Mucuna population was 44,000 in D1 (37.5 cm x 30 cm; 1 plant/hill) and 88,000 plants/ha in D2- (25 cm x 30 cm; 1 plant/hill). The planting density and planting time were factorial combination and laid out as randomised complete block design replicated three times for each legume (2 x 3 x 3). Non-factorial treatments included sole legume (at the two planting densities) and maize crop, which was sown at the beginning of the experiment.

Phosphorus was applied to both legume and maize at 20 kg P/ha (as triple phosphate; 46% P_2O_5) but no N was added to the system. The plot size was 8 x 5 m. Neutron access tubes for soil moisture determination were installed to 1.3 m depth; one tube/plot in the sole crop and 2 tubes in the intercrop plot. Soil water content was measured at 30, 60, 90 and 120 cm at a two-week interval. Soil moisture content at 0-25 cm was determined gravimetrically at the same time when neutron readings were taken. Canopy photosynthetically active radiation (PAR) interception using ceptometer was measured between 11.30 am and 1.30 pm local time. At least five PAR measurements were taken per plot at above the mucuna and below the maize canopy. Maize and legume above ground biomass at maize harvest maturity was determined. Root biomass was determined using the soil core method. The experiment was conducted for three seasons; November 2001 to April 2002 (season 1), May to October 2002 (season 2) and July to November 2003 (season 3)

Results and Discussion

Maize yield

Mucuna planting density and planting time did not have a significant effect on maize grain and stover yields. The highest grain yield was in season 1 which had the highest rainfall (Table 1). Seasonal variation of maize yield in the maize-mucuna intercrop was attributable to differences in rainfall. The total seasonal rainfall was highest in season 1 and lowest in season 2 (Figure 1, Table 1). Rainfall in season 2 was low and therefore supplemented with irrigation (60 mm), however late season rainfall (when maize flowered) accounted for improved growth. The average harvest index (HI) of maize was highest in season 1. The decline in HI was presumably because of increased water stress, due to low rainfall, resulting in assimilate retention in the stem in dry seasons.

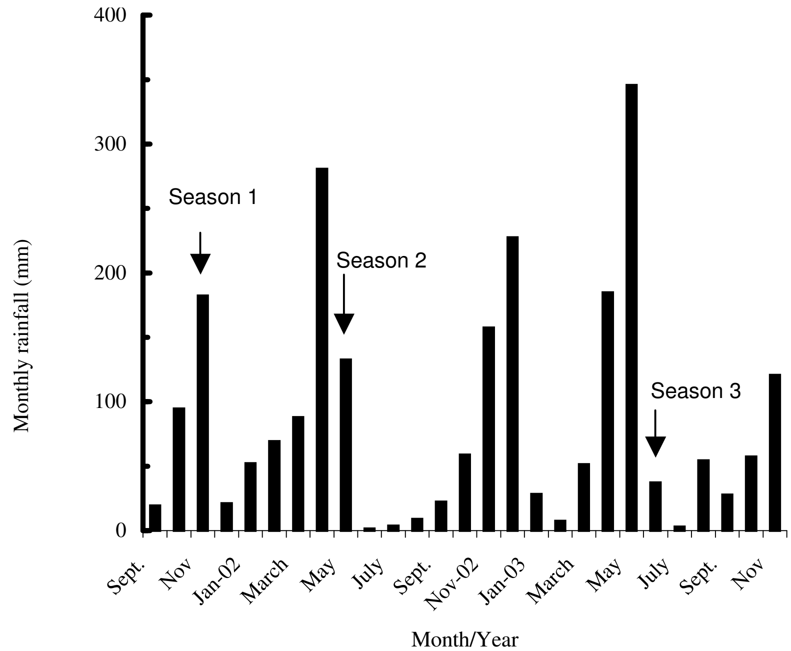

Figure 1. Monthly rainfall (mm) at Kabete Field station during the experimental period. Arrows indicate the beginning of seasons.

Table 1. Effect of mucuna intercropping on maize grain and stover yield

Season	Precipitation (mm)	Maize grain yield (kg/ha)		Stover yield (kg/ha)		Harvest index	
		Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
Season 1	693	3989	2901	5918	5889	0.37	0.36
Season 2	146	415	420	1774	1764	0.18	0.20
Season 3	330	2383	2303	8805	8233	0.19	0.20

Mucuna planting density did not influence stover biomass significantly in the three seasons, however stover yield increased significantly with delayed planting time in season 2 and 3 (Table 2). The stover increase between 0 and 4 weeks after planting maize varied from 11% to 33% in the three seasons and was higher in the driest season. Stover biomass accumulation occurs early in the season because it comprises vegetative growth, hence early season environmental stresses tend to reduce it more, as opposed to grain growth, which occurs later in the season.

Mucuna biomass

Intercropping significantly and drastically depressed mucuna biomass yields compared to sole mucuna yields in the three seasons. The reduction was by 360, 84 and 380 % in seasons 1, 2 and 3, respectively. Although mucuna planting density did not have a significant effect on mucuna biomass except in season 1 when rainfall was high, the higher planting density reduced biomass yield by over 70%. It is probable water stress under high planting density reduced biomass accumulation due to both inter-specific and intra-specific competition.

Table 2. Maize stover response to mucuna under-sowing time (weeks after planting maize) in maize

Time of planting mucuna (weeks after planting maize)	Maize stover (kg/ha)		
	Season 1	Season 2	Season 3
0	5677	1474	7024
2	5556	1762	7966
4	6434	2055	9707
Mean	5889	1764	8233
F test	Ns	0.05	0.031
LSD (0.05%)		463	2000
CV (%)		20.4	19.4

Table 3. Effect of mucuna planting density on biomass

System/Density	Mucuna biomass (kg/ha)		
	Season 1	Season 2	Season 3
Intercrop			
D1	677	395	656
D2	1614	690	1004
Mean	1145.5	542.5	830
F test	0.004	0.09	0.06
CV%	41.4	61.3	42
LSD (0.05%)	528.3	349.5	566
Sole Crop			
Mean	4072	998	3194

Delayed planting reduced mucuna biomass significantly (Figure 2). In season 1 and 3, time of planting accounted for 98% of the variation in biomass compared to 72% in the drier season 2. In sole cropped mucuna in season 3, delayed planting time resulted in increased biomass, though not significantly. The slight increase in late-planted mucuna biomass under sole cropping may be attributable to lack of competition and the advantage of late season rainfall.

Canopy photosynthetically active radiation interception

Planting density and time of under-sowing did not have significant effect on maize/mucuna photosynthetically active radiation (PAR) interception early in the season but effects emerged late in the season (Figure 3). Planting time effects were apparent at the end of the season (120 days after planting). Sole mucuna intercepted the highest amount of incident PAR while intercropped and late-planted mucuna (D1T3) intercepted the least. Sole maize intercepted between 54% and 60% of the incident PAR in all the seasons. Mucuna under-sown in maize captured less than 40% of the incident light while the maize crop was in the field. This indicates that the growth of mucuna under-sown in maize may have been greatly limited by light most of the season. Mucuna planting density did not have a significant effect on canopy radiation interception possibly due to the ability of mucuna to branch prolifically. Extensive branching and the spreading habit could have increased PAR interception at the low planting density. Mucuna planting time effect was more pronounced in season 1 than the other seasons. The inter-seasonal variation in intercepted PAR was attributable to leaf growth variation due to rainfall differences. In the second season canopy expansion, possibly both emergence and expansion may have been restricted by water stress (Mburu *et al.*, 1999)..

Soil water content

Mucuna planting density did not have a significant effect on the soil profile water content in the two seasons and there was no significant interaction between planting density and time. Planting time influenced the water content deep in the soil profile late in the season for both seasons (Table 3). This corresponded to the periods characterized by late season water shortage and plant roots were likely to have grown deep into the soil profile in search of water.

Soil water content was lowest in the top 50 cm but increased down the profile (Figure 4). Depletion of soil water in the deep profile would be indicative of root water extraction assuming that drainage loss was negligible most of the time. The available soil water in the soil is 0.25 to 0.4 of the volumetric water content (Mburu, 1996). Soil water content was lowest in T1 at 110 and 130 cm depth compared to the other treatments presumably due to a well developed

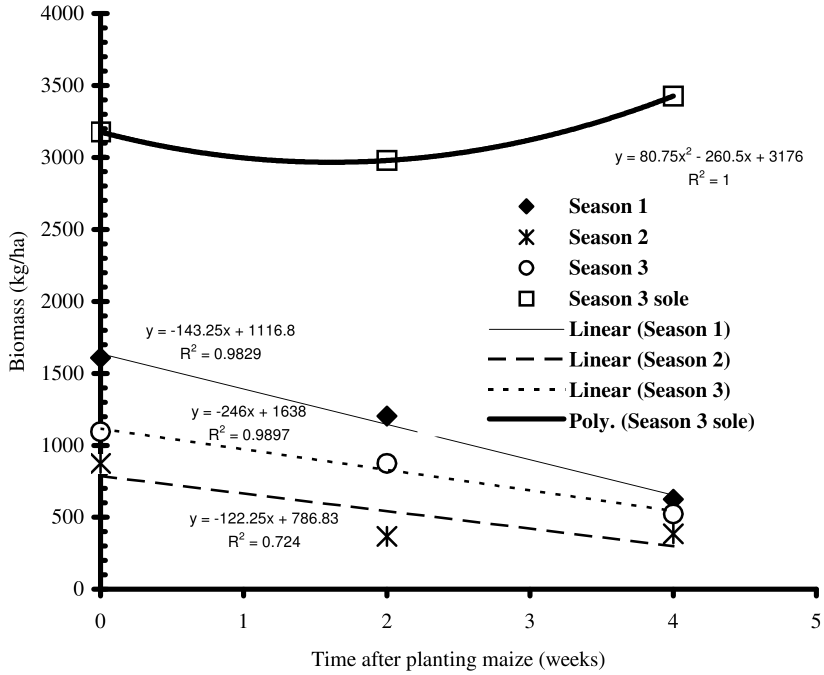

Figure 2. Effect of time of undersowing mucuna in maize on mucuna biomass

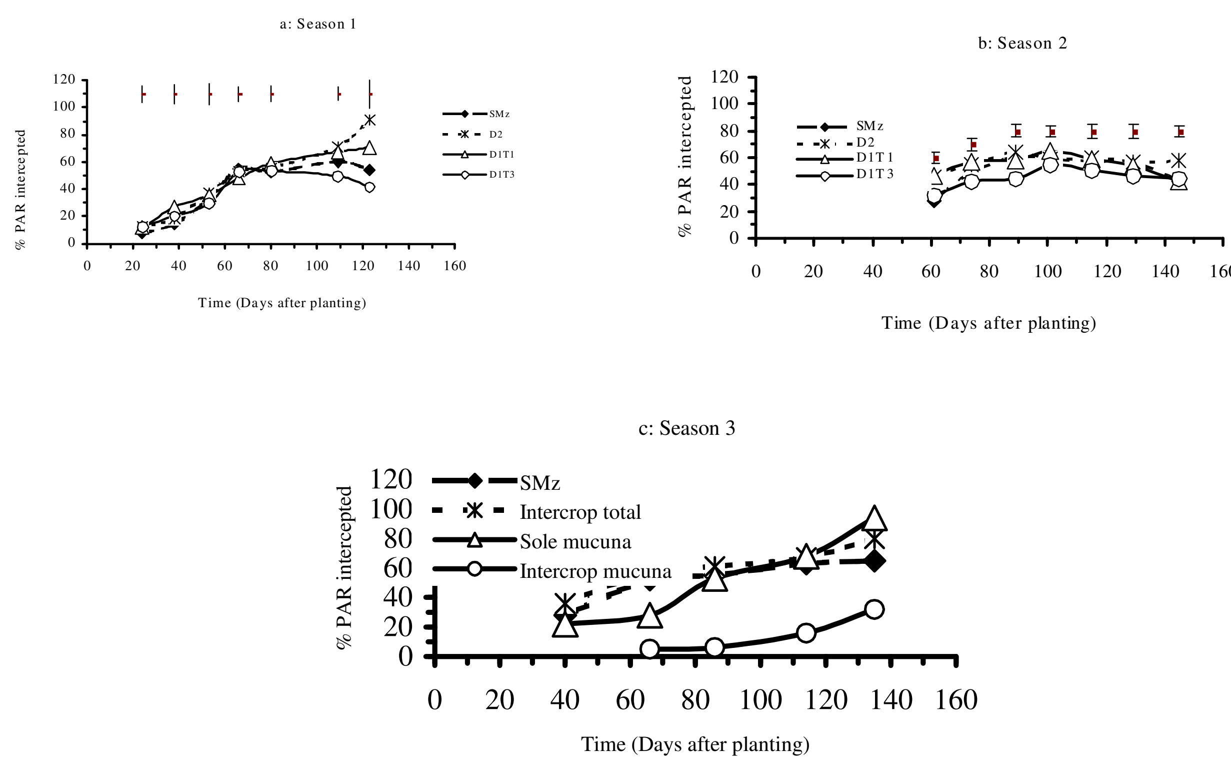

Figure 3. Canopy photosynthetically active radiation interception in seasons 1 and 2. D1 = 4.4 plants/m2; D2 = 8.8 plants/m2; SMz = sole maize; T1 and T3 = mucuna under-sown at the same time and four weeks after maize, respectively. Least significant difference (LSD) bars shown.

Table 3. Summary of analysis of variance (F test) for mucuna planting time effects on seasonal soil volumetric water content at different depths

Season	Depth (cm)	Time (days after planting maize)			
		52	66	80	95
1	110	0.017	0.018	0.059	0.086
	130	0.008	0.082	0.041	0.006
		Time (days after planting maize)			
2		88	116	130	144
	110	0.059	0.075	0.071	0.029
	130	0.058	Ns	0.04	0.093
3		Time (days after planting maize)			
		120			
	30	0.007[1]			
	90	0.024[2]			

Ns – not significant
[1]Differences occurred in the maize-mucuna intercrop
[2]Differences occurred in sole cropped mucuna

root system of early-planted mucuna. It is notable that the soil water content under sole maize was lowest at about 50 cm depth but was higher in the lower profile, possibly due to maize root concentration in the top 50 cm (Wanderi *et al.*, 2002). Soil water content was slightly higher in the sole mucuna treatment (D2) in season 1. Although this difference was not significant, it may be indicative of microclimate change by mucuna canopy. This may have been as a result of accumulated litter and also live biomass insulating the soil surface thus reducing direct evaporation from the soil. This effect was not apparent in season 2, possibly because mucuna canopy growth was restricted by limited water supply.

Root biomass

Over 90 % of maize and Mucuna roots were concentrated in the 60cm soil layer. Intercropping reduced maize and mucuna root biomass by approximately 50% in the entire soil profile (Table 4). However maize had the highest root biomass both in the sole and intercrop. The total root mass of the intercrop components was comparable to that of sole maize. In the intercrop, maize root biomass comprised 70% of the total intercrop root mass in the entire profile. This indicates that maize possibly had a relative advantage over mucuna in water and nutrient uptake in the entire profile. The higher maize root mass in the 0-20 cm may explain the lower soil water content in the topsoil layer (Figure 4).

Conclusions

Maize possibly had a comparative advantage over mucuna in light and water capture because it grew taller and had a much larger root system than mucuna. Therefore maize inter-planted with mucuna at the same time would produce substantial grain yield and mucuna biomass for incorporation into the soil for the subsequent maize crop. Mucuna may be planted at high planting density in a wet season but in a dry season low density is adequate. It is likely that reduced growth for the late-planted mucuna can be attributed to shading from the maize and late season water stress. Mucuna grown in sole crop can be planted at lower planting density because branching is more pronounced than in the intercrop.

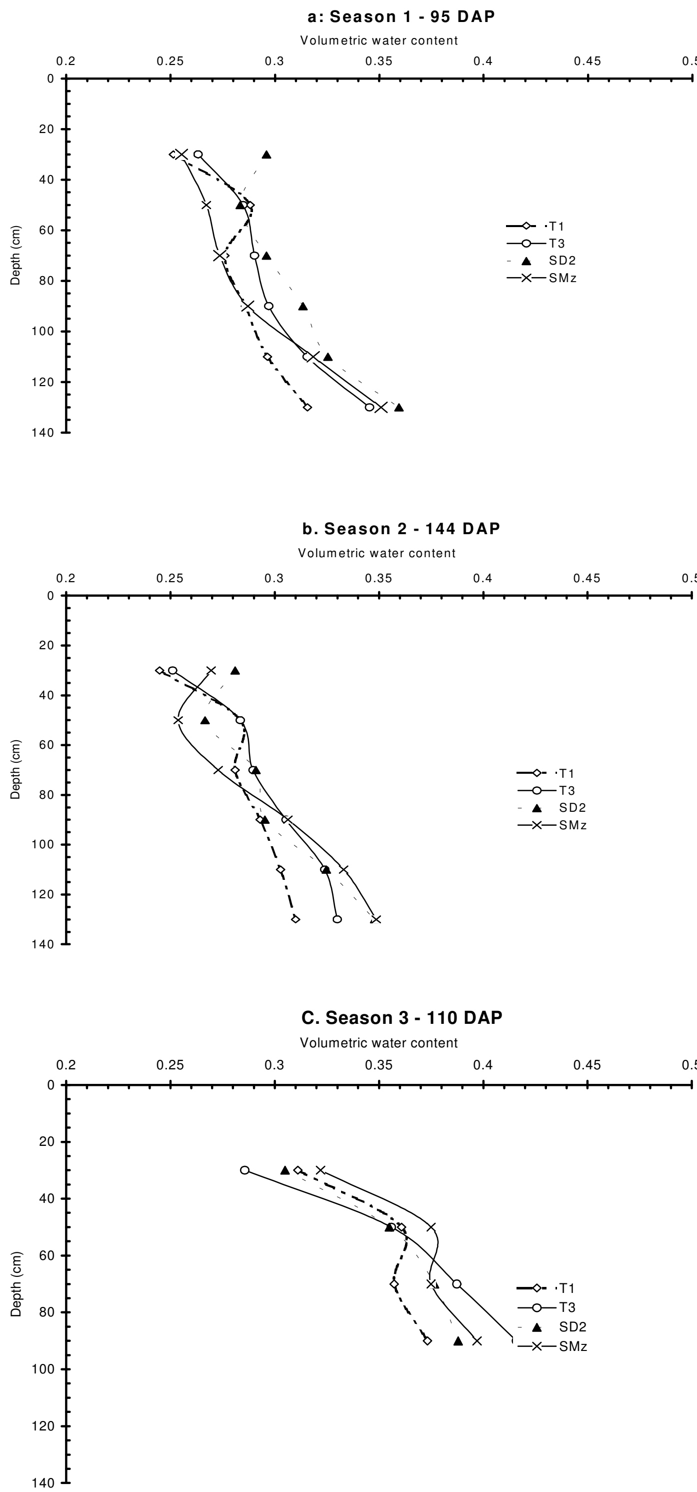

Figure 4. Soil water content in intercropped and sole cropped maize and mucuna in season 1. SMz = sole maize, SD2 = sole mucuna at density 2 (8.8 plants m-2). T1 and T3 = mucuna under sown in maize at 0 and 4 weeks after maize respectively.

Table 4. Effect of cropping system on maize and mucuna root mass distribution in soil profile

	---------------- Root biomass (mg) ------------			
Depth (cm)	Sole maize	Inter-cropped maize	Sole mucuna	Inter-cropped mucuna
0-20	253	152	175	65
20-40	97	70	70	28.3
40-60	56.7	35	31.7	15
60-90	40	11.7	11.7	10

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Response of Food Grain Legumes to Phosphorus Application at Matanya, Central Rift Kenya

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Introduction

The trial was carried out at Matanya bulking site of Laikipia District. The area is at an altitude of 1842 m asl and is located between latitude 00^0 03” 12’ South and longitude 36^0 57” 06’ East. The soil of the area is vertic Luvisol, which has a pH of 5.7.

The objective of the trial was to study the effect of phosphorus fertilizer on dry matter (DM) accumulation of six grain legumes, namely *Phaseolus vulgaris* (the commom bean), *Phaseolus lunatus* (lima bean), *Lablab purpureus* cv Rongai and the black seeded type, and *Phaseolus coccineus* (butter bean) both coloured and white seeded type. Butter bean was included because of its good performance as a grain legume in similar environments in Nyandarua districts (Onesmus Kamau, personal communication). Two phosphorus levels were used, 0 and 100 kg P ha^{-1}. DM accumulation was determined at 4 and 8 weeks after planting. The study was conducted for three seasons; long and short rains 2002, and long rains 2003.

Matanya site – Mt Kenya in the background

Butter bean – scarlet type

Result highlights

Surprisingly, the soil had high levels of initial P (81 mg kg^{-1}). As a result the legumes did not respond to application of P (Table 1). Generally, the mean DM production across the six legumes at 8 weeks was 4.5 times more than at 4 weeks. Although ground cover data was not collected in this study, data collected during legume screening indicated that at 8 weeks the mean ground cover was 50% which was 3.3 times that at 4 weeks (Mureithi and Gitahi, 2004). The DM accumulation at the two periods tended to mirror the development of ground cover.

As expected, the legumes' DM yield differed significantly among species in most seasons (Table 2). The butter beans performed better than the other grain legumes and in long rains 2002 gave the highest mean DM accumulation of 3300 kg ha^{-1} when harvested after two months. Common beans gave comparable DM yields to *Lablab purpureus* cv Rongai although during the LR 2003 the bean DM yield was double that of Rongai when harvested after two months. Lima bean generally performed poorer compared to the other legumes.

Table 1: Effect of P on mean DM accumulation at 4 and 8 weeks after planting

P level (kg ha^{-1})	Dry matter accumulation (kg ha^{-1})	
	4 weeks	8 weeks
0	330	1470
100	340	1550
Mean	335	1510

Conclusion

This study has shown that the legumes did not respond to application of P but this was mainly due to the high level of P in the soil. Butter beans performed better than the other legumes and more work should be done to popularize them as cover crops and food grain legumes in the region.

Reference

Mureithi J.G. and Gitahi F. 2003. Legume Screening Database (LSD) Manual, KARI - NARL, Nairobi, 23 pp.

Table 2: Effect of grain legume species on DM accumulation for three seasons at Matanya

Grain legume species	Dry matter accumulation (kg ha^{-1})					
	4 weeks			8 weeks		
	LR2002	SR2002	LR2003	LR2002	SR2002	LR2003
Phaseolus coccineus -Butter bean white	620	170	480	3680	1560	1310
Phaseolus coccineus -Butter bean coloured	460	270	630	2910	1410	1530
Lablab purpureus cv Rongai	310	110	300	2400	780	640
Lablab purpureus Black type	540	150	260	1630	900	650
Phaseolus lunatus (Lima bean)	450	220	260	1500	610	1030
Phaseolus vulgaris (Common bean)	380	120	360	2680	780	1240
F test	Ns	Ns	***	*	***	*

Soil Aggregate Stability as Influenced by Different Residue Management Practices

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Introduction

Different soil management practices such as incorporation of plant residue into the soil and farm yard manure application influence soil physical properties such as crust formation, water infiltration rates, and degree of aggregation. The latter is of particular interest because it relates to soil aggregate stability. Soil aggregate stability largely determines the susceptibility of soil to water erosion, crust formation and compaction. In evaluating the aggregation of soils, one is interested in the size distribution, quantity and stability of the aggregates under dry or wet conditions. These parameters of aggregation are important in determining both the pore spaces associated with the aggregates and the susceptibility of soil to water and wind erosion. The effect of soil management practices on aggregate stability therefore requires special attention. Several studies on the role of green manure cover crops (GMCC) in improving soil fertility and crop production have been reported but the effect of the incorporated residue on soil physical properties especially soil aggregate stability is hardly addressed. The objective of this study was to determine the effect of different residue management practices on the degree of soil aggregation.

Materials and Methods

Soil samples (0-10cm) were collected from a long-term experiment involving the use of GMCC for soil fertility improvement and increased crop yield (Gachene *et al*., 2002). The GMCC experimental site is located at the University of Nairobi, Kabete campus field station. The soils are nitisol which are dark red to dark reddish brown, deep friable clay. Several GMCC experiments have been carried out at the site. These are; soil moisture extraction by different GMCC species, seed bulking, intercropping GMCC with maize and residue management of GMCC biomass. Soil aggregate stability was determined for soils where GMCC biomass was either incorporated into the soil, left as surface mulch or removed from the plots.

The residue management experiment was initiated in 1997 short rains (October-December) to determine appropriate methods of residue management for maintaining and improving soil fertility through the use of GMCC, namely *Mucuna pruriens, Vicia benghalensis* and *Crotalaria ochroleuca*. In addition, there were two checks i.e. pure stand of maize with or without inorganic P fertilizer. For comparison purposes, another sample was taken from an adjacent area which had been under grassland for the last 15 years. The layout of the experiment was RCBD with 15 treatments each replicated 3 times.

Determination of wet-aggregate stability

Wet-aggregate stability was carried out according to the method outlined by Angers and Mehuys (1993) but with few modifications. Aggregate stability is determined by measuring the proportion of aggregates of a given size (usually 1 to 2.0 mm) which do not break down into units smaller than a pre-selected size (usually 250 µm) under the influence of disruptive forces.

Briefly the method involves weighing 100 gm of 1-to-2 mm air dried aggregates (w1) which are then spread on 250µm sieve. The sieve is placed on a wet sieving apparatus. After spraying the soil with a fine jet of water for 10 min, aggregates remaining in the 250µm sieve are oven dried at 105^{O}C and weighed (w2). To correct for the presence of primary particles in the stable aggregate fraction, the aggregates (w2) are put in a flask and 0.5% Na-haxametaphosphate is added and the mixture shaken for 45 min. The dispersed aggregates are washed on a 250µm sieve. The primary particles remaining on the sieve are collected into a flask. The primary particles are dried at 105^{O}C and weighed (w3). A subsample of 1-to 2-mm aggregates is weighed and its gravimetric water content (wc) is measured. Percent wet-aggregate stability (WAS) is calculated as follows:

$$\%WAS=100\ (w2-w3)/((w1/(1+wc))-w3).$$

Results
The wet-aggregate stability of soils for the different residue management practices are shown in Table 1.

Table 1. Percent wet-aggregate stability of soils under different residue management practices

Residue management*	% WAS
Incorporation	50.5
Mulch	45.7
Removal	41.3
With fertilizer	41.3
Without fertilizer	40.3
Grassland	65.9
LSD 0.05	7.38

* irrespective of the green manure legume species used

The results show that aggregate stability is affected by GMCC residue management practices. Soils where biomass was incorporated and left as surface mulch had significantly higher stable aggregates than in the removal and the two check plots. Probably this is a reflection of high soil organic matter (SOM) in the soil. Studies conducted on the beneficial effect of SOM on aggregate stability have shown that aggregate stability increases with increased rates of SOM (Gicheru et al, 2004). One of the important advantages of using GMCC and which is often overlooked, is the improvement of soil structure through incorporation of residue into the soil. This is an important component as far as water holding capacity, aeration, rootability and workability of a soil are concerned. The high percent of WAS for grassland soils, which is significantly higher than all the other treatments, indicates that opening land for cultivation has a negative effect on soil structure. However, with proper management practices such as incorporation of GMCC residue into the soil, it is possible to improve soil structure. No significant differences were detected between treatments with or without fertilizer. Thus, use of inorganic fertilizer did not have any influence on soil aggregation, indicating that inorganic fertilizers are more for correcting chemical rather than physical soil properties. In this study, the below ground biomass (roots) in the removal plot had no significant influence on WAS. Further work is needed on size distribution of water stable aggregates and particulate organic matter occluded within the different aggregate sizes under these GMCC residue management. This will shed more light on the importance of GMCC on soil structure and in sustaining SOM of central Kenya highland soils.

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Inoculation of Beans with Rhizobia Can Improve Productivity of Maize-Bean Intercrops

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Introduction
Nitrogen (N) is perhaps the most important nutrient in production of maize (*Zea mays* L.), which is the main staple food crop in Kenya. However, soil nitrogen has been depleted in most maize-growing smallholder farms because of continuous cropping without adequate replenishment of the nutrients taken up by crop. There are several options which are available to manage nitrogen in farmers' fields, the main one being use of commercial nitrogen fertilizers. Unfortunately, commercial nitrogen fertilizers

are expensive and out of reach of most small scale farmers in Kenya. As long as maize remains the staple food in Kenya, cheaper sources of N need to be sought if yields are to be sustained and food security attained. One such strategy is to integrate nitrogen-fixing legumes into maize production systems. Fortunately, intercropping maize and beans is a widespread practice in Kenya. For maximum nitrogen-fixation benefits to be realized, beans may need to be inoculated with superior strains of rhizobia and intercropped with maize in appropriate plant arrangement. Currently, most farmers do not inoculate beans before planting and intercrop maize and beans in the same hole, in alternate holes in the same row, or in alternate rows. A study was conducted to investigate if *Rhizobium* inoculation of beans would enhance the yield of both maize and beans intercropped in the three patterns.

Materials and methods

Field plots were set up at Kabete Field Station of the University of Nairobi for two seasons. The following planting patterns were tested: maize grown alone, beans grown alone, maize and beans intercropped in alternate rows, maize and beans intercropped in alternate holes within same row and maize and beans intercropped in the same hole. Hybrid 512 maize variety and GLP-2 bean variety were used in both seasons. The bean seeds were either uninoculated or inoculated with *Rhizobium*. Maize was planted in rows that were 75 cm apart and spacing between maize plants was 25 cm as recommended for sole hybrid 512 at Kabete. The same spacing and hence same population was used for beans. Recommended crop management practices were carried out during the crop-growing period.

Bean plants were uprooted at 11 weeks after emergence, then were carefully washed and nodules counted. Maize and beans were harvested at maturity. The data collected was statistically analyzed.

Results and discussion

The results of the experiments showed that beans that were grown in close proximity with maize formed more nodules than beans grown alone (Table 1). In addition, inoculated beans were more nodulated than the non-inoculated beans. Inoculation of beans increased yield of maize when grown in the same hole or in alternate holes (Table 2). Maize intercropped with beans in the same hole yielded more than maize grown in the other arrangements. Beans intercropped with maize in the same hole and in alternernate holes out-yielded beans grown alone, while beans intercropped with maize in alternate rows had the lowest yield (Table 3).

Table 1. Effect of planting pattern and rhizobia inoculation on number of nodules per bean plant

	Planting patterns (PP)				
Inoculation	Sole beans	Alternate row	Same row	Same hill	Inoculation means
(a) First season					
Uninoculated	58.0	56.0	66.0	67.3	61.8b
Inoculated	60.0	60.7	68.0	70.0	64.7a
PP means	59	58.4c	67.0b	68.7a	
(b) Second season					
Uninoculated	58.8	58.0	67.4	69.3	63.4b
Inoculated	61.9	61.3	69.1	71.4	6.9a
PP means	60.4b	59.7b	68.3a	70.4a	

Means followed by the same letter (s) are not significantly different at 5% probability level, according to Duncan's multiple range test.

Table 2. Effect of planting pattern and rhizobia inoculation on maize grain yield (t/ha)

	Planting patterns (PP)				
Inoculation	Sole maize	Alternate row	Same row	Same hill	Inoculation means*
		(a) First season			
Uninoculated	3.7^{c}_{x}	3.7^{c}_{x}	5.0^{b}_{x}	5.7^{a}_{x}	4.8_{x}
Inoculated	3.9^{c}_{x}	3.9^{c}_{x}	5.8^{b}_{y}	6.3^{a}_{y}	5.3_{y}
PP means	3.8^{c}	3.7^{c}	5.4^{b}	6.0^{a}	
		(b) Second season			
Uninoculated	4.7^{c}_{x}	4.4^{c}_{x}	6.0^{a}_{x}	6.1^{a}_{x}	5.5_{x}
Inoculated	4.7^{c}_{x}	4.7^{c}_{y}	6.8^{b}_{y}	7.2^{a}_{y}	6.2_{y}
PP means	3.7^{c}	3.7^{c}	6.4^{b}	6.7^{a}	

Within each row, means followed by the same superscript (a, b, c), and within each column, means followed by the same subscript (x, y), are not significantly different at 5% probability level according to Duncan's multiple range test.

Table 3. Effect of planting pattern and rhizobia inoculation on bean yields (kg/ha)

	Planting patterns (PP)				
Inoculation	Sole beans	Alternate row	Same row	Same hill	Inoculation means
		(a) First season			
Uninoculated	574	572	593	614	588b
Inoculated	590	601	610	622	606a
PP means	582c	587c	602b	618a	
		(b) Second season			
Uninoculated	630	629	669	671	650b
Inoculated	647	636	681	683	662a
PP means	639bb	632c	675a	677a	

Means followed by the same letter (s) are not significantly different at 5% probability level, according to Duncan's multiple range test.

The results of these experiments suggest that intercropping maize and beans (inoculated with good quality rhizobium inoculant) in close proximity improves productivity of both intercrops. It may be advisable for smallholder-farmers to intercrop maize and beans, inoculated with an appropriate *Rhizobium* strain, in the same hole in order to maximize N contribution of beans to maize. This recommendation is particularly pertinent since the purchase cost of *Rhizobium* inoculum is much lower than that of inorganic nitrogen fertilizer.

Utilization of Legumes in the Management of Root-knot (*meloidogyne spp.*) Nematodes

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Introduction

Crops are attacked by several plant parasitic nematodes but root-knot are the most important causing considerable losses due to their wide distribution and host range. A part from being pathogenic, plant parasitic nematodes also act as wounding agent and host modifiers resulting in reduced resistance to other plant pathogens especially those found in soil. Several strategies have been developed for the management of root knot nematodes but their adoption has faced some limitations. Following the banning or restricted use of chemical nematicides because of side affects on human health and the environment, considerable efforts have been directed towards development and implementation of alternative control strategies of root-knot nematodes. Despite their wide host range, *Meloidogyne* spp. can be controlled by suitable legumes when rotated or interplanted with susceptible crops. Several studies have shown that legumes are used to improve soil fertility, conserve moisture and control soil erosion.

Crop rotation systems are particularly useful in maintaining soil fertility and reducing or preventing build up of pests and diseases especially in the soil. The principle that guides use of crop rotation in nematode management is to reduce populations of the damaging nematode species to levels that allow subsequent crops to complete early growth before being heavily attacked (Bridge, 1996). This can be achieved by alternating poor hosts, non-hosts or resistant crops with susceptible or tolerant crops (Swamy *et al*., 1995).

Although sequential cropping is recognized as one of the strategy in root-knot nematode control its adoption especially in the smallholder farms is restricted due to scarcity of arable land coupled with market-driven production of particular crops and/ or varieties (Bridge, 1996). The challenge to research is therefore, to identify nematode suppressive crops that satisfy the economic considerations in crop production. This study was conducted with the aim of identifying potential rotation legumes with food, forage or commercial value to be incorporated into cropping cycles for root-knot nematode management.

Materials and methods

Greenhouse experiment

Six plant species (Table 1) were selected and evaluated to determine their reaction to root-knot nematodes under greenhouse conditions. Tomato C.V. Moneymaker and *Tagetes minuta* were included as negative and positive controls, respectively. Pots measuring 21 cm in diameter were filled with 5 kg heat sterilized loam and sand and, seeds of each test plant sown. Ten days after seedling emergence, 6000 eggs and/ or juveniles, suspended in 10ml of water, were pipetted around the base of each seedlings. Treatments were arranged in a completely randomized design with ten replications. Plants were watered when necessary and fertilized biweekly by adding 5g of calcium ammonium nitrates (CAN). The experiment was terminated eight weeks after inoculation.

Plants were then uprooted, roots washed free of adhering soil and galling quantified using the scale of 0-10 as described by Bridge and Page (1980). Egg masses were stained using phloxine B (Holbrook *et al.*, 1983) and quantified using a scale of 1-9 (Sharma *et al.*, 1994). Second-stage juveniles were extracted from 200cm^3 soil using modified Baermann funnel technique and enumerated (Hopper, 1990). The experiment was repeated twice.

Field experiment

The plants selected for this test were *Tagetes patula*, *Crotalaria juncea*, and *Desmodium* sp., with tomato C.V. Moneymaker as a control. The plants were grown in nematode infested micro-plots measuring 1 x 1.8m and fertilization done by adding 5g of diamonium phosphate to each planting hole. Weeds were controlled regularly and plants irrigated when necessary. The experimental design was randomized complete block with three replications. The experiment was terminated after 90 days and data recorded as above. The experiment was repeated twice.

Results

Greenhouse

There were significant (P£0.05) differences in galling, egg masses and juvenile counts among the plants tested (Table 1). Galling and egg mass indices ranged from 8.5 – 9.0 in tomato, lablab, and bambara nuts. These plants were rated as susceptible. Velvetbean was rated as moderately resistant with *Tagetes patula*, desmodium, crotalaria, and tithonia being resistant with galling and egg mass indices ranging from 1-3. No egg masses were observed on roots of desmodium. Tomato C.V. Moneymaker had the highest number of egg masses but was not significantly (P=0.05) different from lablab and bambara nuts (Table 1).

Field experiment

Results of the micro plot experiment were similar to those observed in the greenhouse. Significant (P£0.05) differences in galling and egg mass indices were observed among the plants tested. All the tested plants had galling indices that ranged between 1.2 and 2.4 thus being rated as resistant compared to tomato (control) that was susceptible with a galling index of 6.8. The egg masses followed a trend similar to that of the galling index and ranged from 1.4 to 2.9 among the tested plants while tomato C.V. Moneymaker had the highest of 7.3. There were significant (P £0.05) differences in juvenile (J_2) populations between treatments and the control. *Meloidogyne* juvenile count was highest in plots where tomato was grown and lowest in plots grown with *crotalaria* spp.

Discussion

This study demonstrated that marigold *(Tagetes patula* and *T. minuta)*, sunnhemp *(Crotalaria juncea)*, desmodium, were suppressive to root-knot nematodes under greenhouse and field conditions. Desmodium legume is a high quality forage crop that can be incorporated into cropping systems for soil fertility improvement and soil erosion control, with the added advantage of root-knot nematode suppression.

There was moderate nematode damage on roots of velvet bean. This indicates that this crop supports root-knot nematode reproduction to a certain extent and should therefore be introduced into cropping systems with caution by those farmers who constantly interplant these crops with the susceptible ones. Farmers should be encouraged to rotate them with resistant ones to reduce the nematode inoculum level in the soils.

Table 1. Galling and egg mass indices and numbers of *Meloidogyne* juveniles (J_2) on different plants species grown in soil infested with root-knot (*Meloidogyne* spp.) nematodes

Plant	GI		EMI		J_2/200cm³		Reaction
	I	II	I	II	1	II	
Tagetes *(Tagetes patula)* (control)	1.0	1.0	1.0	1.0	229	48	R
Tagetes (Tagetes minuta)	1.0	1.8	1.0	1.8	235	13	"
Desmodium *(Desmodium uncinatum)*	1.0	1.0	1.0	1.0	299	85	"
Crotalaria *(Crotalaria juncea)*	1.5	1.6	3.4	3.6	239	77	"
Tithonia *(Tithonia diversifolia)*	2.9	3.6	3.0	3.3	405	75	"
Velvet bean (*Mucuna pruriens*)	3.8	3.1	3.6	3.6	370	46	MR
Dolichos (*lablab purpureus)*	8.5	9.0	8.4	9.0	738	120	S
Bambara nuts *(Vigna subterranea)*	9.0	9.0	9.0	9.0	381	141	"
Tomato (*Lycopersicon esculentum*) (Control)	9.0	9.0	9.0	9.0	1457	373	"

R= Resistant　MR= Moderately resistant　S= Susceptible

GI= Galling index　EMI= Egg mass index　J_2= Juvenile counts

Use of *Crotalaria juncea* resulted in reduced nematode populations and minimal damage. *Crotalaria* spp is a suitable green manure and vegetable crop that should be grown in fields that are heavily infested with nematode populations. Therefore, farmers should be encouraged to use crotalaria as a rotational crop as it both reduces root-knot nematode population density and increase the yield of a companion or succeeding crop. These findings are very important since very little work has been done in this country concerning the reaction of root knot nematodes on these plants. Observations made from this study were based on greenhouse, micro plot and on-station field experiments. On-farm studies are required to verify these findings and establish the acceptability of selected crops as rotational or intercrops for root-knot nematode management.

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Evaluation of Purple Vetch (*Vicia Benghalensis*) as a Green Manure Legume for Irish Potato Production in Matanya, Central Rift, Kenya.

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Introduction

Purple vetch (*Vicia benghalensis*) was evaluated as a green manure for production of Irish potatoes in Matanya, Central Rift, Kenya, four seasons; LRS and SRS 2001, and LRS and SRS 2002. The legume was among six that were identified by the Legume Research Network project in 1995 as promising for incorporation into the smallholder farming systems. The others included, *Mucuna pruriens, Neonotonia wightii, Crotalaria ochroleuca, Lablab purpureus* and *Phaseolus lunatus.* Purple vetch was selected for this study because of its upright growing nature and hence would not compete vigorously for light with Irish potato. The following three treatments were evaluated;

1. Intercropping Irish potato with maize and applying farm yard manure at the rate of 5.5 t/ha.
2. Growing purple vetch as a green manure for Irish potato in a relay cropping system.
3. Fertilizing Irish potato with DAP fertilizer at the recommended rate of 80 kg N and 90 kg P/ha.

The treatments were laid down in a completely randomized block design and replicated three times. The plot size was 3 x 3 m. Potatoes were planted on ridges spaced 75 cm apart and intra-spacing was 30 cm. Maize var. H511 was planted at a spacing of 75 x 30 cm. In intercropping treatment, potatoes were planted between maize rows at an intra-spacing of 30 cm. Purple vetch was drilled at the rate of 35 kg/ha between the ridges where potatoes were planted. After harvesting the potato crop, the legume was left to grow until land preparation for the following season when it was harvested and biomass incorporated into the soil as green manure.

Results

The nutrient source treatments affected the tuber yields substantially during the four cropping seasons (Table 1). These effects were generally more pronounced on the annual total yields for 2001 and 2002, which were statistically different at P<0.01. While the high tuber yields from the recommended fertilizer treatment were hardly surprising, the yields obtained from the vetch treatment were equally good. In 2001 the vetch treatment gave almost similar yields to the fertilizer treatment and although the annual total yields in 2002 were depressed by 30% compared to the fertilizer treatment, the difference in yield was not statistically significant. Intercropping potatoes with maize always depressed tuber yields. In all the four seasons the yields were always about half that of the fertilizer treatment.

However, since potato / maize intercropping treatment also produced maize grain yield, it is only fair to consider the grain yield while comparing its benefits with other treatments. The mean seasonal maize grain yield was 6 and 3.5 t/ ha for 2001 and 2002, respectively.

Economic analysis was conducted to determine the profitability of the three treatments (Table 2). Although potato yield was lowest in the intercropping treatment, its gross revenue and gross margin were the highest compared to the other treatments because they were boosted by the maize grain yield which fetched higher price compared to the potato tubers. The gross margin of the vetch treatment was the lowest but it was only 10 and 13% lower than that of the fertilizer and intercropping treatments, respectively. The variable costs were lowest in the vetch treatment because there were savings on labour for weeding (the legume smothered weeds) and because there was hardly any money spent to transport inputs. The other two treatments required money to transport inorganic fertilizer from market and manure from livestock farmers.

Conclusion

The fertilizer and intercropping treatments gave better gross margins than the green manuring treatment although the differences were not substantial. The two treatments have not been adopted by majority of farmers because they lack ready cash to purchase the inputs and transport them to their farms during the beginning of the season when they are normally strapped. Green manuring with purple vetch is a more preferable option because farmers do not need a lot cash to purchase the inputs and the legume seeds are available locally at a nominal fee.

Table 1: Effect of different nutrient sources on tuber yield of Irish potato in Matanya, Central Rift, Kenya

Nutrient source treatments	Tuber yield (t/ha)					
	2001			2002		
	LRS	SRS	Total	LRS	SRS	Total
DAP fertilizer at the rate of 80 Kg N + 90 Kg P/ha	17.3	10.0	27.3	8.2	19.0	27.2
Vetch as green manure legume (110 Kg N/ha)	15.6	10.7	26.3	7.0	13.6	20.6
Intercropping Irish potato with maize and applying FYM at the rate of 5.5 t / ha (70 Kg N/ha)	9.4	5.1	14.5	3.3	11.5	14.8
F test[a]	Ns	Ns	**	Ns	**	**
LSD (P<0.05)	7.63	5.38	7.45	5.14	4.19	8.50
CV (%)	27.1	31.4	16.4	41.8	13.3	20.4

Ns – Not statistically significant; ** - Statistically significant at P<0.01.

Table 2: Gross margin analysis for the use of different nutrient sources for Irish potato production in Matanya, Central Rift, Kenya

Nutrient sources treatment	Mean total annual yields* (t/ha)		Gross revenue** (Ksh)	Total variable costs (Ksh)	Gross margin (Ksh)
	Potato	Maize			
DAP fertilizer at the rate of 80 Kg N + 90 Kg P/ha	27.2	-	182,240	56,320	125,920
Vetch as green manure legume (110 Kg N/ha)	23.4	-	156,780	42,200	114,580
Intercropping Irish potato with maize and applying FYM at the rate of 5.5 t/ha (70 Kg N/ha	13.0	9.8	194,900	64,870	130,030

* - Mean annual potato and maize yields for 2001 and 2002

** - Price per ton of potato and maize is Ksh 6,700 and Ksh 11,000, respectively.

Popularity of Green Manure Legume Technologies Results in Demand for More Seeds in Matanya Area

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Since the inception of Matanya LRNP site in 1995, several activities have been carried out inorder to enhance GML technologies. These include GML seed bulking and on-farm trials involving use of GML for soil fertility improvement and their utilisation as human food.

Local farmers have learnt about the GML technologies through farmers who have, for the last four years, been actively involved in carrying out LRNP trials. This is in addition to lessons learnt during legume utilization days. As a result, farmers have requested to be provided with legume seeds to plant in their farms. Faced with this challenge, Matanya site has been bulking the seeds to try to meet local demand. Thus, during year 2003, several seeds were distributed to farmers and institutions as shown Tables 1 and 2.

Way Forward

Seed production will continue at Matanya bulking due to increased demand. Follow-up visits to the farmers and institutions given the seeds will be conducted to monitor how the given seeds are being utilised.

Publications

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Table 1. Seed distribution to farmers during 2003

Legume species	No. of farmers	Amount per farmer (Kg)	Total amount of seeds (Kg)
Lablab purpureus (Black)	10	1	10
Lablab purpureus (Rongai)	12	0.5	6
Vicia dyscarpa	5	0.3	1.5
Vicia villosa	5	0.3	1.5
Vicia benghalensis	5	0.3	1.5
Phaseolus Coccineous (white)	12	1	12
Phaseolus Coccineous (coloured)	18	1	18
Crotalaria ochroleuca	7	0.3	2.1
Phaseolus lunatus	38	1	38
Glycine max (Duicker)	5	0.5	2.5
Glycine max (Nyala)	8	0.5	4
Total	**125**		**97.1**

Table 2. Seeds distributed to Institutions and farmers outside Matanya Division during 2003

Institution	Legume species	Amount (Kgs)
Ministry of Agriculture (ASK) Show Stand	*Glycine max* (Duicker)	1
	Glycine max (Nyala)	1
	Phaseolus coccineous (white)	1
	Phaseolus coccineous (coloured)	1
	Phaseolus lunatus	1
Lamuria Division Farmers	*Glycine max* (Duicker)	2
	Glycine max (Nyala)	2
	Phaseolus lunatus	2
	Lablab purperus (Rongai)	2
	Lablab purperus (Black)	2
	Phaseolus coccineous	1
		16

Wanjekeche E, Wekesa V and Mureithi JG. 2003. Effect of alkali, acid and germination on nutritional composition and anti-nutritional factors of Mucuna (*Mucuna pruriens*) *Tropical and Subtropical Agroecosystems, 1 (2003): 183-192.*

Conferences/Meetings/Workshops

13th International Soil Conservation Organization Conference, July 4 -9, 2004.
Theme: Conserving soil and water for society: sharing solutions, Brisbane. Contact Conference Secretariat, isco2004@icms.com.au.

4th International Crop Science Congress, 26th Sept - 1st Oct 2004, Brisbane, Austarlia.Theme. New directions for a diverse planet. Contact Congress managers, 4icsc04@im.com.au

International conference on Ecoagriculture, 27th Sept - 1st Oct 2004 Contact Sara J. Scherr, sscherr@futureharvest.org, Nairobi, Kenya

1st World Congress of agroforestry: Working together for sustainable land use system, June 27th - July 2nd 2004, Orlando, Florida, USA. Contact PK Nair or M. Padgett; pknair@uhl.edu, mrpadget@mail.ifas.ufl.edu

The Status of Legume Seed Availability and Distribution by June 2003

Species	Amount from sites (Kg)	Amount issued out (kg)	Amount in store (kg)
Canavalia ensiformis	587	339.1	247.9
Crotalaria juncea	20.5	11.8	8.7
Crotalaria ochroleuca	277.5	254.7	22.8
Desmodium unicinatum Silver	19.7	10.9	8.8
Lablab purpureus (Brown	424	379.8	44.2
(Black)			
	51.2	25.5	25.7
Phaseoulus lunatus	77	34.25	42.75
Macroptilium atropurpurem	88.1	86.1	2
Mucuna pruriens (White)	1591.4	1066.8	524.6
(Black)			
	456.5	334	122.5
Stylosanthanes	9.3	5.6	3.7
Neontonia wightii	73.3	73.3	-
Vigna unguiculata: (Cowpea K80)	19	19	-
(Cowpea M66)			
	32	17.7	14.3
Vicia villosa	11.7	11.7	-
Phaseolus coccineus (Black)	38.2	22.3	15.9
(White)			
	29.3	20.4	8.9
Vicia benghalensis	27	13.7	13.3
Vicia dasycarpa	5.7	4.8	0.9
Vicia sativa	7	6	1

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