



KARI Technical Note Series. No. 12, December 2003

LEGUME COVER CROPS RESEARCH IN KENYA: EXPERIENCES OF THE LEGUME RESEARCH NETWORK PROJECT

HIGHLIGHTS OF PHASES 1 RESEARCH ACTIVITIES (1994-2000)



Joseph G Mureithi, Charles K K Gachene and Jane W Wamuongo

*The **KARI Technical Note Series** was launched to provide an outlet for the enormous amounts of technical work generated by KARI, some of it dating many years back, that has not been published in any of the existing outlets—the East African Agricultural and Forestry Journal, the KARI Annual Report, the Highlighter, the KARI updates. The articles may be on completed or on-going work. The outlet carries advisory technical information intended to benefit various stakeholders in research findings generated by the institute. Contribution to the series will be limited to KARI staff and collaborators, at least initially, and should be submitted to the Publications Unit, KARI, PO Box 57811, Nairobi.*



KARI Technical Note Series. No. 12, December 2003

**LEGUME COVER CROPS RESEARCH IN KENYA:
EXPERIENCES OF THE LEGUME RESEARCH
NETWORK PROJECT**

**HIGHLIGHTS OF PHASES 1 RESEARCH ACTIVITIES
(1994-2000)**

KARI TECHNICAL NOTE NO. 12

**LEGUME RESEARCH NETWORK PROJECT
A SYNTHESIS REPORT OF PHASE I (1994-2000)**

Authors

Joseph G Mureithi
Charles K K Gachene
Jane L W Wamuongo

Science Editor

Rachel Rege

Layout and design

Irene W Kimani

Photographs

Joseph G Mureithi

Cover Photographs

Maize intercropped with *Crotalaria ochroleuca*
in Kimutwa, Machakos District, Kenya

Published 2004

KARI Publications Unit
PO Box 57811, Nairobi, KENYA
Tel: (02) 583301-20, ext. 2212, 2228, 2338, 2340 or 2341
Fax: (02) 583344
E-mail: resource.centre@kari.org

TABLE OF CONTENTS	
SUMMARY	1
INTRODUCTION	2
FORMATION OF LEGUME RESEARCH NETWORK	
PROJECT (LRNP)	4
HIGHLIGHTS OF RESEARCH UNDERTAKEN IN PHASE 1	5
Screening herbaceous legumes for soil fertility improvement	5
Response of best-bet legume species to rhizobia inoculation	7
Response of legume species to phosphorus application	9
Management of legume residue in maize based cropping systems	9
Green manure legumes as component of integrated nutrient management	11
Effect of green manure legumes on control of striga in south Nyanza	12
Participatory cowpea varietal screening trial	13
Introduction of improved pigeon pea (<i>Cajanus cajan</i>) in the marginal areas of Lake Victoria region of southwest Kenya	14
Evaluation of selected forage legumes as supplementary feeds for Dual-Purpose Goats in semi-arid region of Eastern Kenya	14
Evaluation of selected legumes as supplementary feed resource Livestock	14
LEGUME SEED BULKING	17
EMERGING GREEN MANURE LEGUME TECHNOLOGIES	17
Intercropping green manure legumes with maize	17
Late intercropped legumes in maize	18
Rational short-term fallow with green manure legumes	18
ADDITIONAL FARMER-IDENTIFIED NICHES FOR GREEN MANURE LEGUMES	18
SPREAD OF THE GM TECHNOLOGY	20
DISSEMINATION OF NETWORK RESULTS	20
LRNP newsletter	20
WAY FORWARD: RESEARCHABLE AREAS	21
Nitrogen fixing potential of best-bet legumes	21
Legume residue mineralization and methods of incorporation	21
Management of green manure cover crops in plantation crops	21
Use of legume forage and seed for human and livestock feed	21
Intercropping with food crops	22
Socio-economic studies	22
Screening of legumes tolerant to abiotic stresses	22
Seed bulking	22
ACKNOWLEDGEMENT	23
REFERENCES	24

SUMMARY

The Legume Research Network Project (LRNP) was started in 1994 (by then known as the Legume Screening Network) to evaluate suitable legume species for different agro-ecological environments and to subsequently incorporate the “best bets” into the existing farming systems. Initial Network activities included the screening of about 40 legume species, among them, green manuring species, food legumes and forage species. The screening trials were conducted in 11 sites across the country especially where soil infertility had been identified as a major constraint to crop production. The Network extended its activities to include research on legume residue management, integrated nutrient management, livestock feeding and cowpea screening trials. Each site had the task of bulking seeds of promising legume species. The Network members are from KARI, University of Nairobi (UoN), Environmental Action Team (EAT, an NGO based in Kitale) and Community Mobilisation Against Desertification (C-MAD, an NGO based in Rongo near Kisii). The main collaborators are the Ministry of Agriculture, and Rural Development staff, and the farmers from different regions of Kenya.

The following are the major highlights of phase 1 activities:

- ◆ **Promising green manure (GM) legume species:** The most outstanding green manure legume species across Network sites based mainly on biomass accumulation are *Mucuna pruriens*, *Lablab purpureus*, *Crotalaria ochroleuca*, and *Canavalia ensiformis*.
- ◆ **Inoculation of best-bet legume species:** The rhizobia inoculation study concluded that inoculation of best-bet legumes in the study sites was not necessary but further systematic studies to characterise the native rhizobia and to determine their levels in the soil should be undertaken.
- ◆ **Response of legume species to phosphorus:** Three Network sites participated in this trial, namely Kakamega, Kisii and Gatanga. In Kakamega and Kisii, legumes did not respond to application of P. In Gatanga they responded to application of P at the rate of 20 kg ha⁻¹ but did not respond substantially to application beyond this rate.
- ◆ **Potential benefits of GM legume technologies for improved maize yields:** Incorporating mucuna biomass (4 - 11 t DM ha⁻¹) into the soil for maize production increased maize yields by 120%. The additional labor required for digging mucuna into the soil was compensated by increased maize yields. Returns to labour were higher in mucuna (US\$ 11.50) than in maize only plots (US\$ 8.00). Besides, farmers in Gatanga and Kisii Network sites

reported that additional labour required for incorporation of legume biomass was minimal because incorporation and land preparation for the companion crop were done simultaneously.

- ◆ **Potential for soil moisture conservation:** In a semi-arid site Machakos, mucuna on the surface as mulch gave better yields than incorporating it in the soil probably because of the moisture conservation effect. A farmer in Embu reported that soil moisture was retained for a longer time in plots where mucuna was grown than in plots without mucuna.
- ◆ **Potential for soil improvement:** Integrated Nutrient Management (INM) at three sites, Kakamega, Embu and Mtwapa, mucuna and crotalaria were evaluated in field studies that involved the combinations of green manure, FYM and inorganic fertilisers. Higher maize yields were obtained by combining green manure legume with FYM and inorganic N.
- ◆ **Potential for feeding livestock:** Livestock feeding studies at, Mtwapa and Katumani showed that performance of cattle and goats improved when fed on legume forage. In Mtwapa, dairy cows fed on mucuna and lablab forage had a daily DM intake of about 9.2 kg cow⁻¹, which was similar to cows fed on *Gliricidia sepium* forage, a proven fodder tree for the coastal Kenya. Milk yield (6.5 kg day⁻¹) was only 8% less than that produced by cows fed on gliricidia forage. In Katumani, goats supplemented with *Neonotonia wightii* gained on average 16.37 g while those on basal diet alone lost 23.81g daily.

INTRODUCTION

As in most of the sub-Saharan African countries, a major constraint to smallholder farming in Kenya is declining soil fertility (Smaling *et al.*, 1997). smallholder farms, of about 2 ha on average are usually cultivated continuously without adequate replenishment of plant nutrients. Smaling and Braun (1996) reported nutrient mining in smallholder farms in Kisii District one of the most densely populated districts (plate 1) in southwest Kenya to be in the order of 112 kg N, 3 kg P and 70 kg K ha⁻¹ yr⁻¹. Soil erosion on most smallholder farms is severe due to hilly terrain, poor cultivation practices and poorly maintained soil erosion control measures. A two-year study conducted in central Kenya in 1991 and 1992 revealed that soil loss ranged from 0.8 to 247.3 t ha⁻¹ and runoff ranged from 1 to 89 mm (Gachene *et al.*, 1997). The high cost of inorganic fertilizers coupled with low returns and unreliable markets for agricultural produce have limited the use of fertilizers by the majority of smallholders in Kenya (Hassan *et al.*, 1998). The most common method of maintaining soil fertility is the

application of farm yard manure but its quality is usually low because of poor handling and poor quality feeds for livestock (Lekasi *et al.*, 1998). Traditionally, farmers left land fallow for several seasons as a means of maintaining soil fertility but this method is no longer feasible because of diminishing size of land holdings.

Legumes can play a major role in improving farm productivity in smallholder agriculture as short-term fallow species (Hudgens, 1996). Green manure (GM) legumes can increase plant nutrient supply in the soil (especially nitrogen) and can improve soil physical properties, thereby improving crop yields (Yost and Evans, 1988; Peoples and Craswell, 1992; Muller-Samann and Kotschi, 1994). Legumes can also provide good ground cover, minimizing soil erosion through raindrop impact and runoff (Lal *et al.*, 1991). Intercropping purple vetch (*Vicia benghalensis*) with maize in central Kenya reduced cumulative soil loss over an eight-month period by three fold compared to bare plots which had 7.1 t ha⁻¹ cumulative soil loss (Gachene and Haru, 1997). In addition, grain legumes are important as a human food source as they are rich in protein, while herbaceous and tree legumes are important livestock feeds (Peoples and Craswell, 1992; Weber, 1996). In 1994 efforts were undertaken to introduce green manure cover crops in Kenya to arrest soil degradation (Dyck, 1997).



Plate 1. Kisii is one of the most densely populated districts in Kenya

FORMATION OF LEGUME RESEARCH NETWORK PROJECT (LRNP)

A Legume Screening Network was formed in 1994 to primarily evaluate and identify suitable “best bet” legume species for the different regions in Kenya (Dyck, 1997). The Network expanded its activities to include coordinated studies on legume residue management, evaluation of legume green manure as a component of integrated soil management, and livestock feeding studies based on selected legumes. As a result of this expansion, the Network changed its name in 1998 to the Legume Research Network Project (LRNP) to reflect the range of activities in which it is involved. The LRNP covers eleven sites spread across Kenya from the coastal region to western Kenya (Figure 1 and Table 1). The sites represent major agro-ecological zones of Kenya. Table 1 gives the characteristics of the sites. The Network is mainly funded by the Rockefeller Foundation (RF) and Kenya Agricultural Research Institute (KARI) and is housed by KARI at the National Agricultural Research Laboratories (NARL).

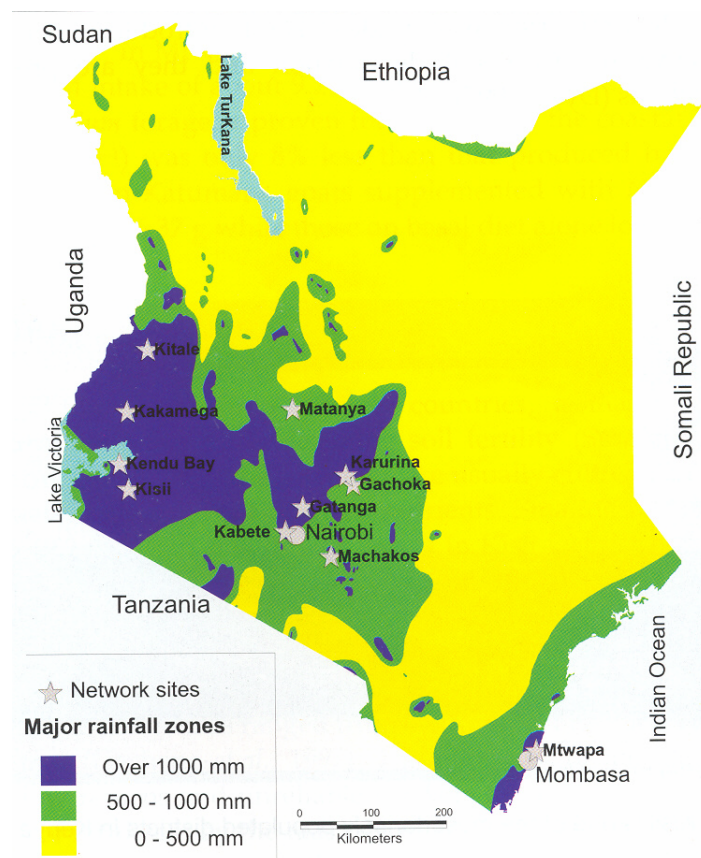


Fig. 1 Legume Research Network Project Sites

Table 1. Characteristics of LRNP sites

Site name	Elevation (masl)	Annual rainfall (mm)	Soil type
Kendu Bay	1190	1130	Vertisol/Ferralsol
Kisii	1750	2000	Nitisol
Kakamega	1560	1800-2000	Nitisol
Kitale	1890	1000-1200	Ferralsol
Matanya	1842	600	Vertic Luvisols
Karurina	1280	1100	Nitisol
Gachoka	1070	950	Ferralsol
Gatanga	1500	1100	Nitisol
Kabete	1700	1000	Nitisol
Machakos FTC	1600	750	Luvisol
Mtwapa	15	1200	Acrisol/luvisol

HIGHLIGHTS OF RESEARCH ACTIVITIES UNDERTAKEN IN PHASE I

Screening herbaceous legumes for soil fertility improvement

Approximately 40 legume species were screened in the 11 Network sites for a period of 2 years (Table 2). Some legume species were obtained locally such as common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), and lablab (*Lablab purpureus* cv Rongai) while others were obtained from USA and Australia. Some temperate species were included for screening in the cooler sites. Buckwheat (*Fagopyrum esculentum*), a temperate species and a non-legume, was tested at each site because of its wide usage for weed control and as a cover crop in temperate countries. The criteria for selection included biomass production, nodulation and nitrogen fixation, ground cover, pest and disease resistance.

The legume screening trial was conducted under optimal conditions, which included inoculation and application of P at the rate of 20 kg P ha⁻¹. Based on their phenology and cumulative dry matter production, the legumes were classified into two groups: short duration and long duration green manure legumes (Dyck, 1997). The short duration green manure legumes were those species that produced substantial green manure biomass within two to three months after planting. These legumes had fast establishment and early growth. Buckwheat, a non-legume that grew rapidly, produced flowers within four weeks and senesced after two months, was classified in this category. Among the legumes that produced the highest amount of biomass after three months of growth were *Vicia dasycarpa* (lana vetch) and *Crotalaria juncea*. *Crotalaria* species performed well in most sites. In the Kisii site for instance, *C. juncea* and *C. ochroleuca* produced 10.3 and 7.9 t ha⁻¹ of dry matter respectively after a 3 month growth period (Maobe *et al.*, 1998). In the Karurina site *Vigna unguiculata*, P.

Table 2. Legume species screened in Network sites from 1995 to 1997

Species name	Common name	Species name	Common name
<i>Arachis hypogaea</i>	Groundnut	<i>Melilotus alba</i>	White sweet clover
<i>Arachis pintoii</i>	Wild peanut	<i>Mucuna pruriens</i>	Velvet bean
<i>Cajanus cajan</i>	Pigeon pea	<i>Neonotonia wightii</i>	Glycine
<i>Calopogonium mucunoides</i>	Calopo	<i>Pisum sativum</i> (3 var)	Pea, field pea
<i>Canavalia ensiformis</i>	Jackbean	<i>Phaseolus lunatus</i>	Lima bean
<i>Cicer arietinum</i>	Chickpea	<i>Phaseolus vulgaris</i>	Common bean
<i>Clitoria ternatea</i>	Clitoria	<i>Pueraria phaseoloides</i>	Tropical kudzu
<i>Crotalaria juncea</i>	Tanzanian sunnhemp	<i>Stylosanthes guianensis</i>	Stylo
<i>Crotalaria ochroleuca</i>	Sunnhemp	<i>Trifolium alexandrinum</i>	Berseem clover
<i>Desmodium intortum</i>	Greenleaf desmodium	<i>Trifolium hirtum</i>	Rose clover
<i>Desmodium uncinatum</i>	Silverleaf desmodium	<i>Trifolium incarnatum</i>	Crimson clover
<i>Fagopyrum esculentum</i> *	Buckwheat	<i>Trifolium subterraneum</i>	Subclover
<i>Glycine max</i>	Soybean	<i>Trifolium vesiculosum</i>	Arrowleaf clover
<i>Lablab purpureus</i> cv Rongai	Lablab	<i>Vicia benghalensis</i>	Purple vetch
<i>Lupinus albus</i>	Sweet white lupine	<i>Vicia faba</i>	Faba bean
<i>Lupinus angustifolius</i>	Blue lupine	<i>Vicia dasycarpa</i>	Lana woolly pod vetch
<i>Lupinus luteus</i>	Yellow lupine	<i>Vigna sativa</i>	Common vetch
<i>Macroptilium atropurpureum</i>	Siratiro	<i>Vigna villosa</i>	Hairy vetch
<i>Macrotyloma axillaris</i>	Axillare	<i>Vigna radiata</i>	Green gram
<i>Macrotyloma uniflorum</i>	Horse gram	<i>Vigna unguiculata</i>	Cowpea
<i>Medicago sativa</i>	Lucerne, alfalfa	<i>Voandzeia subterranean</i>	Bambarra groundnut
<i>Medicago truncatula</i>	Barrel medic		

*Non-legume included in the screening trial because of its good cover and high biomass production

lunatus, *F. esculentum* and *V. benghalensis* were placed in the short duration category. These legumes are suitable for short-term fallow systems. The long duration green manure legume species were those that took 6 to 12 months or longer to yield substantial amount of biomass. Most species in this category were slow to establish but picked up by the sixth month. They included species like *Desmodium uncinatum*, *Calopogonium mucunoides* and *Neonotonia wightii*. These legumes are suitable for medium to long-term fallow systems.

The most outstanding legumes across the sites were identified based mainly on biomass accumulation and they included *Mucuna pruriens*, *Lablab purpureus*, *Crotalaria ochroleuca*, and *Canavalia ensiformis* (Table 3). The farmers perception of suitable GM legumes was assessed in all Network

Table 3. Some of the “best bet” green manure legume species for different regions of Kenya

Region	“Best bet” green manure legumes
Semi-arid eastern Kenya (Machakos)	<i>Mucuna pruriens</i> , <i>Canavalia ensiformis</i> , <i>Phaseolus lunatus</i> , <i>Vigna unguiculata</i> and <i>Neonotonia wightii</i>
Central highland (Kabete and Gatanga)	<i>Mucuna pruriens</i> , <i>Lablab purpureus</i> , <i>Phaseolus lunatus</i> , <i>Desmodium uncinatum</i> , <i>Crotalaria ochroleuca</i>
North Rift Valley (Kitale)	<i>Mucuna pruriens</i> , <i>Lablab purpureus</i> , <i>Canavalia ensiformis</i> , <i>Crotalaria ochroleuca</i> , <i>Desmodium uncinatum</i>
South west Kenya-Nyanza highlands (Kisii)	<i>Mucuna pruriens</i> , <i>Lablab purpureus</i> , <i>Canavalia ensiformis</i> , <i>Crotalaria ochroleuca</i>
Western Kenya (Kakamega)	<i>Mucuna pruriens</i> , <i>Lablab purpureus</i> , <i>Canavalia ensiformis</i> , <i>Crotalaria ochroleuca</i> , <i>Glycine max</i>
Eastern highland (Embu – Karurina)	<i>Mucuna pruriens</i> , <i>Crotalaria ochroleuca</i> , <i>Lablab purpureus</i> , <i>Desmodium uncinatum</i> , <i>Neonotonia wightii</i>
Lower Embu (Gachoka)	<i>Mucuna pruriens</i> , <i>Lablab purpureus</i> , <i>Crotalaria ochroleuca</i> , <i>Vigna unguiculata</i>
Mt Kenya lee word side (Matanya)	<i>Mucuna pruriens</i> , <i>Lablab purpureus</i> , <i>Phaseolus lunatus</i> , <i>Neonotonia wightii</i>
Lake Victoria Basin (Kendu Bay)	<i>Mucuna pruriens</i> , <i>Lablab purpureus</i> , <i>Canavalia ensiformis</i> , <i>Crotalaria ochroleuca</i> , <i>Glycine max</i>
Coastal lowlands (Mtwapa)	<i>Mucuna pruriens</i> , <i>Canavalia ensiformis</i> , <i>Lablab purpureus</i> , <i>Clitoria ternatea</i> , <i>Macroptilium atropurpureum</i>

sites as this was key to their adoption. In Gatanga an area with serious soil erosion problems (Plate 2 and plate 3), a study was conducted using informal visits and semi-structured interviews to identify the characteristics that farmers considered suitable for GM legumes species (Mureithi *et al.*, 2000). They included high biomass production, ability to cover the ground quickly, twining ability, alternative uses and ease of incorporation into the soil.

Response of best-bet legume species to rhizobia inoculation

Since the majority of farmers in Kenya do not inoculate legume seeds at planting (Woomer *et al.*, 1997), a study was initiated to assess the importance of inoculating legume seed with rhizobia (Mureithi *et al.*, 1998). Eighteen legumes were selected and they included those with a wide agro-ecological adaptation such as velvet bean, jackbean, lablab and sunnhemp. The study was conducted in 10 Network sites namely Mtwapa, Machakos Farmers Training Centre (FTC), Gatanga, Kabete, Gachoka, Matanya, Kitale, Kakamega, Kisii and Kendu Bay at the beginning of the 1997 long rains. Each legume was inoculated with appropriate rhizobia and fertilised with P. Strict procedures were followed during inoculation, at planting and at sampling of nodules to avoid contamination of seeds and individual plots. Total number and effective nodules per plant were assessed at 2 (early) and 4 (late) months after planting



Plate 2. Soil erosion is a serious problem in Gatanga division



Plate 3. LRNP monitoring team in Machakos

(MAP). The most significant result of this study was that in all the 10 sites most legumes did not respond to inoculation. A side study to characterise the indigenous rhizobia in the study sites revealed surprisingly very low levels of native rhizobia, which was not supported by the performance of the legumes. This study concluded that inoculation of best-bet legumes in the study sites was not necessary and that further systematic studies to characterise the native rhizobia and to determine their levels in the soil should be undertaken.

Response of legume species to phosphorus application

The objective of this study was to assess the response to P of legume species with potential for use as GM. Trials were established at Kakamega and KARI-NARL (Kabete) during 1998 long rains season. Six legumes were selected for the Kakamega site, namely sunnhemp, calopo (*Calopogonium mucunoides*), lablab, jackbean, velvet bean and soybean (*Glycine max*) cv. SCS-1. Three legumes; velvet bean, sunnhemp and purple vetch were selected for Kabete. In Kakamega, biomass production and nodulation performance with (30 kg P ha⁻¹) and without application of P was assessed at 3 MAP. Sunnhemp, lablab and soybean had higher biomass accumulation although not significantly different with application of P than without P. Calopo, jackbean and velvet bean did not show any response to P with respect to biomass production. Higher non significant nodulation was recorded with application of P than without P. At Kabete response of the legumes to three levels of P: 0, 20 and 40 kg ha⁻¹ was assessed at 5 MAP. Application of 20 kg P ha⁻¹ increased biomass yield of velvet bean from 1.9 to 3.3 t ha⁻¹, sunnhemp from 0.2 to 0.7 t ha⁻¹ and that of purple vetch from 0.5 to 1.4 t ha⁻¹. The legumes did not respond substantially to application of P beyond 20 kg ha⁻¹ (Ojiem *et al.*, 2000)

Management of legume residue in maize based cropping systems

The main goal of the study was to develop management practices for incorporating green manure legumes in smallholder cropping systems. Three methods of residue application were assessed; incorporating the legume biomass into the soil, slashing and leaving the residue on the surface as mulch and removing the slashed legume biomass. The last treatment was to assist in assessing the contribution of nutrients by the below ground legume biomass. One of the important parameters monitored was the labour requirement for each of the methods as this is a critical factor in smallholder farming (Mureithi and Ojiem, 2000 LRNP, 2000). Other parameters monitored related to soil properties, and crop and legume performance. The study was conducted at five Network sites both on-station and on-farm in close collaboration with farmers where maize production is an important component of the farming systems. The sites were Machakos, Kabete, Gatanga, Kitale and Kisii (Figure 1 and Table 1). Prior to planting of maize, the legume residue from the previous season was

incorporated into the soil or removed completely or left as surface mulch. In addition, a pure stand of maize, with and without fertiliser served as controls. The legumes used at the different study sites are shown in Table 4.

Table 4. Legumes used for residue management trials in five LRNP sites

Study site	Legumes used
Machakos	Lima bean, sunnhemp and velvet bean
Kabete	Sunnhemp, purple vetch and velvet bean
Kitale	Velvet bean
Gatanga	Sunnhemp and velvet bean
Kisii	Sunnhemp and velvet bean

In Machakos, the biomass yield of lima bean, sunnhemp and velvet bean averaged 1, 3 and 4 t DM ha⁻¹, respectively. Increased maize yield was recorded during the 1998 long rains season in plots with the legumes. The plots that were mulched with velvet bean had the highest amount of grain yield (4 t ha⁻¹). This was attributed to a moisture conservation effect rather than increased soil fertility. At Kabete, average biomass production was 2 and 11 t DM ha⁻¹ for purple vetch and velvet bean, respectively. Maize grain yield was highest where the residue was incorporated in the soil and lowest where the residue was removed. Incorporating sunnhemp in the soil increased grain yield by more than 100% (3.62 t ha⁻¹) compared with the control (1.76 t ha⁻¹). This experiment was repeated during the 1998 short rains season but failed due to poor rainfall at both sites.

The work of Environmental Action Team (EAT) in Kitale involved the use of velvet bean and maize stover as crop residue. The average legume biomass yield prior to planting maize was 6.4 t DM ha⁻¹. Maize yield where legume biomass was included as part of the residue was 5.7 t ha⁻¹, which was significantly higher by 40% than where legume biomass was excluded. There was no significant difference between the yield of maize from plots where legume biomass was left on the surface as mulch compared to where it was incorporated into the soil.

The study at Gatanga involved 19 farmers. The mean legume biomass yield was 0.6 for sunnhemp and 2.5 t DM ha⁻¹ for velvet bean. Initial results for the 1998 long rains indicated that maize grain yields in plots where sunnhemp and velvet bean biomass were incorporated in the soil was 2.5 and 2.0 t ha⁻¹, respectively 66 and 120% higher than where biomass was left as mulch. Maize yields from plots where legume biomass was removed were low (about 1 t ha⁻¹) and were not any better than those for control plots with no inputs. Analysis of returns to labour for the different residue management methods showed that incorporation of legume residue into the soil gave greater returns to labour compared to leaving it on the surface as mulch. Returns to labour from the plots where mucuna biomass was incorporated into the soil was Kshs 4.8, which was 44% higher than in maize plots without fertilizer or legume.

In Kisii site, the study was conducted both on-station at KARI Kisii and on-farm in Nyamira. Twelve farmers were involved in the on-farm site. Preliminary results from the on-station site did not reveal significant differences between the legume residue management treatments. However, incorporating the legume residues into the soil gave, on average, higher maize grain yields of 6.4 t ha⁻¹ than in using the residues as mulch (5.6 t ha⁻¹). Maize grain yield from the control plot without legume and fertilizer was half that of plots where velvet bean biomass was incorporated into the soil. Like the on-station study, the on-farm trials did not show significant differences between treatments.

Green manure legumes as component of integrated nutrient management

The aim of this study was to test the effectiveness of different combinations of legume GM, organic (compost/farm yard manure) and inorganic fertilisers in improving maize yields (Mureithi and Ojiem, 2000). The study was carried out at three KARI centers, at Kakamega, Embu and Mtwapa (Figure 1 and Table 1), both on-station and on-farm. During the first season legumes were planted as intercrop with maize to provide material for incorporation into the soil during the subsequent seasons. The GM tested were sunnhemp, velvet bean and lablab.

In Kakamega, 20 farmers from Lukume, Mahira and Chemche in Kabras Division participated in this study. The legumes were planted in mid-October during the 1997 short rains and incorporated in the soil in February 1998. The other combinations of organic and inorganic fertilizer (N) were applied thereafter and maize was planted. Inclusion of legume in combination with either organic or inorganic fertilizer resulted in higher yield of maize grain than the other combinations. At the on-station site, mean maize grain yield in plots where sunnhemp and velvet bean biomass was incorporated were 0.8 and 1.0 t ha⁻¹, respectively, higher than the mean treatments without legumes. There were

no significant responses to farmyard manure (FYM) and inorganic fertilisers. Results from on-farm studies indicated that treatments combining legume residue with either FYM or inorganic-N had between 0.9 and 1.2 t ha⁻¹ higher grain yield than the farmer practice which gave a yield of 2.2 t ha⁻¹. Farmers ranked the treatments where a legume was included as the best.

In Embu, 20 farmers participated, 10 in Karurina and 10 in Gachoka. At Karurina (wetter site) maize grain yield was higher (6.48 t ha⁻¹) in treatments where legume residues (velvet bean or sunnhemp) was used as a source of N, being 27, 37 and 6% higher than where animal manure, inorganic fertilizers alone, and a combination of legume and inorganic fertilizer were used, respectively. At Gachoka (drier site) yields of maize were similar for different sources of N. Results of the on-station experiment indicated that no single source of N was superior to the others and this was attributed to the relatively high level of initial soil fertility.

At Mtwapa, the organic sources of N did not have any significant effect on grain yield during the 1998 long rains season. On the contrary, application of at least 15 kg N ha⁻¹ increased maize grain yields significantly. Velvet bean and lablab caused a slight depression in maize yields, about 10 and 8% respectively. This experiment was repeated during the 1998 short rains season but the crop failed due to poor rainfall.

Effect of green manure legumes on control of striga in south Nyanza

This study was conducted by Community Mobilization Against Desertification (CMAD) in the lower potential zone of south Nyanza in smallholder farms. Three legumes namely sunnhemp, lablab and velvet bean were used to control striga infestation, improve soil fertility and subsequently increase maize yields. A rotational system was practiced where the legumes were planted in one season and their biomass was incorporated in the soil before planting maize in the following season. Striga infestation was monitored by counting the striga seeds that had germinated. Results from 1996 and 1997 work revealed that plots where the legumes were planted had on average 10 striga counts per m² while the control had 32. These initial results indicated that the legumes had a depressing effect on striga germination. Average maize grain yield was 2.4 t ha⁻¹ in plots where a legume was planted compared to 1.4 t ha⁻¹ in control plots.

Participatory cowpea varietal screening trial

A total of 52 cultivars obtained from IITA were evaluated for adaptation, leaf and grain yield and maturity period (Plate 4). It was found that the local cultivars were more productive in terms of leaf yield which called for screening efforts towards high grain yield rather than leaf yield (Muli and Saha, 2000). Eight out of the 52 cultivars were selected for further evaluation on-station and seven for on-farm testing. The eight cultivars were IT95K-1380, IT93K-273-2-1, IT95K-1156-3, IT93K-2046-2, IT93K-734, IT93K-2045-29, K80, and IT90K-284-2. In both on-station and on-farm trials the grain yield of the different cowpea cultivars did not differ significantly. The mean grain yield for the on-station trial ranged from 1.64 to 2.51 t ha⁻¹. Cultivar IT93-2045-29 gave the highest yield (2.8 t ha⁻¹) followed by IT93-2046-2 (2.4 t ha⁻¹). On-farm mean grain yield ranged from 0.30 t ha⁻¹ for the cultivar IT93K-273-2-1 to 1.30 for cultivar K80. A field day was held primarily for farmers to evaluate the cultivars using their own criteria. The following cultivars were preferred K80; IT95K-1156-3 and IT90K-284-2.



Plate 4. On-farm screening of cowpea varieties in coastal Kenya at Mtwapa

Introduction of improved pigeon pea (*Cajanus cajan*) in the marginal areas of Lake Victoria region of southwest Kenya

Eight varieties of pigeon pea obtained from ICRISAT, (Kenya) were introduced in lower Nyakach and east Karachuonyo in Nyando and Rachuonyo districts, respectively. These were four long maturity varieties: ICEAP 00053, ICPL 9145, ICEAP 00040 and ICEAP 00020; two medium maturity varieties ICEAP 00068 and ICP 6927; and two short maturity varieties: KAT 60/8 and ICPL 87091. Twenty one farms were planted in Karachuonyo and 12 in Nyakach during 1997 and 1998 (Okoko, 2000). Two varieties of different maturity periods were planted in each farm. The trials were farmer-managed while researchers took data on crop vigour, pest and diseases incidence. At the end of the season the farmers did pre and post-harvest evaluation of the crop using their own criteria. Evaluation by the farmers gave both long and medium maturity varieties higher ranking than the short maturity types. The prevalence was based on tolerance to pests and had longer harvesting period in the long and medium maturing varieties. The average yield for each variety was below the expected potential yield. While the expected amount ranged from 500–1500 kg ha⁻¹, the actual yield ranged from 150–300 kg ha⁻¹. This reduction was mainly due to poor crop management by the farmers especially late weeding. Other factors which affected the yields were pests and diseases incidence, livestock damage and flooding in some fields in the Nyakach site.

Evaluation of selected forage legumes as supplementary feeds for Dual-Purpose Goats in semi-arid region of eastern Kenya

This study was conducted in KARI-Katamani and the objective was to assess the live weight changes of Kenya Dual Purpose Goats (KDPG) when supplemented with two forage legumes, siratro (*Macroptilium atropurpureum*) and glycine (*Neontonia wightii*) (Njarui and Wandera, 2000). Sixteen yearling bucks were used for the study. The treatments were; supplementation with siratro forage, glycine forage, leucaena leaf meal control. Leucaena was included in the study for comparison with other legumes since information is available about its nutritive and feeding quality. The feed supplements were given at 30% of the daily dry matter requirement of an individual buckling. The goats were fed on natural pasture grass and chopped Napier grass as the basal diet. The total daily dry matter requirement for individual goat was taken as 3.5% of its body weight. The goats were weighed weekly for 12 weeks. All the goats had a free access to mineral block licks and water *ad-libitum*.

Goats supplemented with siratro had marginal weight gain but this was not significantly different from the control. A daily weight gain of 16.37 g attained from supplementing with glycine was not significantly different from siratro supplement but was better than the control. However, the standard supplement

of leucaena resulted in the highest but non-significant gain. The control group fed on grass alone lost weight throughout the experimental period (on average 23.81 g daily), an indication that the diet did not meet the nutritional requirement of the goats.

Evaluation of selected legumes as a supplementary feed resource for livestock

The trial was carried out at KARI-Mtwapa (Plate 5) (Muinga *et al.*, 2000). Three herbaceous legumes, mucuna, clitoria, and lablab were compared with gliricidia (*Gliricidia sepium*) which is a multi-purpose tree legume recommended for livestock feeding in the region. Sixteen Jersey cows in their second or third month of lactation were divided into four groups balanced for milk yield and parity at the beginning of the experiment. The average daily milk yield per cow per treatment group, one week prior to the start of the experiment was 7.2 kg and the mean live weight was 275 kg (range 235 to 340 kg). During the experimental period, all the cows were fed on Napier grass *ad-libitum* together with 3 kg maize bran in two equal parts daily. Water was provided throughout. A mineral lick was offered to all the cows. The experimental diets were 8 kg of gliricidia, clitoria, mucuna or lablab in two equal parts daily. The study was conducted for twelve weeks. Data on feed in-take, live-weight change and milk production was collected.



Plate 5. Feeding mucuna forage to Jersey dairy cows at the Mtwapa site

The nitrogen concentration in gliricidia, mucuna, lablab and clitoria was 4.3, 3.5, 3.5 and 3.4 % respectively. Total DM intake of Napier grass and legumes are shown in Table 5. All the cows consumed 3 kg maize bran offered and the total intake includes this amount for all the treatments. There were no significant treatment differences in Napier grass intake. Cows offered gliricidia consumed all the legume forage (2.1 kg) while cows on the other treatments consumed significantly less (clitoria 1.7 kg, mucuna 1.4 kg, and lablab 1.2 kg). There was no significant difference in total DM intake between the treatments. However, cows fed on mucuna tended to consume less DM than cows fed on the other treatments. There were no significant live-weight changes during the experimental period. Cows fed on mucuna tended to lose weight from a group average of 280 to 260 kg at the end of the experiment. This may be explained by the lower DM intake recorded for this treatment. Similarly, cows fed on mucuna tended to produce less milk than cows fed on the other legumes. Milk yield decreased from 7.2 kg at the start of experiment to 6.4, 6.4, 6.3 and 5.3 kg at the end of the experiment for cows fed on gliricidia, lablab, clitoria and mucuna respectively. Results from this study indicated that the herbaceous legumes (lablab, clitoria and mucuna) can give a similar lactation performance to that of gliricidia. However, there is need to evaluate the long term effect of feeding the legumes on milk production.

Table 5. Mean daily DM intake of Napier grass and legume and milk yield (kg) for cows

Treatments	Gliricidia	Mucuna	Lablab	Clitoria	LSD
DM intake					
Legume	2.1	1.4	1.2	1.7	0.12
Napier grass	4.1	4.1	5.0	4.2	1.31
Total	8.8	8.1	8.8	8.5	1.31
Milk yield	7.1	6.3	6.8	7.1	1.78

Note: The cows were fed ad-libitum Napier grass and 2.6 kg (DM) maize bran supplement with 8 kg fresh gliricidia, clitoria, lablab or mucuna for 12 weeks.

LEGUME SEED BULKING

In addition to the research activities described above, LRNP members have had the responsibility of multiplying seed for their best-bet legume species. Some of the legume seeds produced from each site was used within the site for further research, while the rest was either distributed to farmers participating in on-farm research and potential collaborators or sent to the LRNP coordination office for safe keeping. Table 6 shows the amount of seeds of some GM legume species issued to collaborators between 30th June 1999 and 31st December 2000.

Table 6. Amounts of seed received from sites and issued to collaborators and farmers

Species	Seed received from sites by 30 th June 1999 (kg)	Seed issued by 31 st December 2000 (kg)
<i>Canavalia ensiformis</i>	393	216
<i>Crotalaria juncea</i>	8	0.5
<i>Crotalaria ochroleuca</i>	84	80
<i>Lablab purpureus</i> : (brown)		
(black)	86	78
	13	7
<i>Phaseolus lunatus</i>	10	6
<i>Macroptilium atropurpureum</i>	39	21
<i>Mucuna pruriens</i> : (white)	480	474
(black)	39	10
<i>Neontonia wightii</i>	37	4
<i>Vigna unguiculata</i> : (cowpea K80)	19	17
(cowpea M66)	8	8

EMERGING GM LEGUME TECHNOLOGIES

Based on the cropping seasons prevalent in different regions of Kenya, three systems have emerged from the studies on the incorporation of green manure legume technologies into maize-based smallholder farming systems. These systems are:

Intercropping green manure legumes with maize

Intercropping of GM legumes with maize is feasible for the regions receiving bimodal rainfall where farmers plant two maize crops in a year. In this system, GM legumes are either planted at the same time with maize or delayed by one to two weeks to reduce competition. A single row of legumes is planted

between maize rows, although there is some evidence emerging from the Gatanga and Kitale sites that double rows are likely to yield higher legume biomass. After the maize is harvested, the legume is left to continue growing during the short fallow period preceding land preparation for the following crop. During land preparation the legume biomass is incorporated into the soil. This system has been found to work well in such sites as Mtwapa, Gatanga, and Kisii.

Late intercropped legumes in maize

In the regions receiving unimodal rainfall such as Kitale, the only maize crop of the year is usually planted in April. The legume GM system for such a region requires that legumes are planted in August between maize rows and lower maize leaves are pruned to reduce competition for light. The maize is harvested in November/December and the legume is left growing in the field as short-term fallow until land preparation for the long rainy season maize crop.

Rotational short-term fallow with GM legumes

Regions that receive bimodal rainfall but have an unreliable second season or where farmers do not grow maize crop during the second season are suited for a rotational system. The maize crop is planted as a pure stand during the long rains in February/March and harvested in July/August. Green manure legumes are planted in September as a short-term fallow crop and incorporated during land preparation in January/February of the following year. This system is practiced in areas like Kakamega and Machakos (Plate 6).

ADDITIONAL FARMER-IDENTIFIED NICHES FOR GM LEGUMES

As farmers got more familiar with green manure legumes, they were able to creatively identify niches within their farming systems for green manure technologies. Farmers in Gatanga identified the following potential niches (Plate 7) where green manure legumes could be introduced in the farming systems (Mureithi *et al*; 2000).

- *Under coffee bushes* – Five farmers said they did not always have enough farmyard manure to apply to the coffee fields and that green manure legumes could be used as an alternative. Velvet bean was preferred because of its quick establishment.
- *Intercropped with vegetables* – Some farmers indicated that legumes could be intercropped with vegetables like kales. Sunnhemp was most preferred for this purpose because it grows upright and does not coil on the kale plants.



Plate 6. Farmers in Kakamega on-farm site.
* It only costs very little to return land back to productivity using Sunnhemp (*Crotalaria ochroleuca*) fallow



Plate 7. Examples of legume green manure cover crop niches identified by the farmers in Gatanga, central Kenya

- *On steep land* – Farmers explained that green manure legumes could be planted on the steep land, especially velvet bean because of its ability to cover the ground quickly. This can help control soil erosion in the area.
- *Intercropped with maize* – Farmers in the study area have intercropped maize with legumes for several seasons and are aware of the benefits of the intercropping system in fertility management of their soils.
- *Under trees such as avocado and macadamia* – Some farmers are already planting legumes such as desmodium under avocado trees. The legumes are used to control soil erosion and also as fodder for livestock.

SPREAD OF THE GM TECHNOLOGY

The green manure technology has spread from the participating farmers to neighbouring farms. A farmer in Mtwapa was impressed with mucuna as a green manure and has intercropped it with maize for soil fertility improvement and for weed control. He has extended the technology to farmers around his farm and to his sister who lives far away. Some farmers in Thika have planted the legumes under coffee bushes as cover crops for soil erosion control. A farmer in the same area is rotating kales and tomatoes with crotalaria in vegetable beds. Farmers in Yala, western Kenya, who were involved in the green manure legume research, have formed a farmer research group to extend the technology in the region. In Embu, a farmer who has established coffee and bananas on a two acre plot has planted mucuna as a cover crop for soil erosion and weed control.

DISSEMINATION OF NETWORK RESULTS

LRNP newsletter

The LRNP publishes a biannual newsletter to provide a forum for highlighting Network activities and sharing its findings with other projects involved in similar work in Kenya. The newsletter covers short articles on legume research, especially those aimed at integrating legume into small-holder agriculture. Four issues have been released so far.

WAY FORWARD: RESEARCHABLE AREAS

Nitrogen fixing potential of best-bet legumes

During the legume screening study, the amount of N fixed by best-bet legumes was not quantified. It is therefore difficult to know whether those legumes were adding N to the soil or scavenging and recycling available N from the soil. Studies are proposed to determine amount of N fixed by the legumes.

Initial studies on the effects of rhizobia inoculation on nodulation and N fixation did not support inoculation as a strategy to improve productivity of best-bet GM, however, it is recommended that this subject be pursued further so that the N-fixing potential of the legumes can be fully exploited.

The importance of P in the biological nitrogen fixation process cannot be overemphasized and since the P studies were done on a few sites, it is recommended that P response studies be conducted in all the Network sites.

Legume residue mineralization and methods of incorporation

Detailed decomposition and mineralization studies should be conducted in order to improve crop nutrient demand-supply synchrony. The fertilizer equivalency values and residual effects of incorporated green manure legumes, including effects on soil physical properties, should also be established. Methods of incorporation of legume residue by hand, tractor, and oxen plough should be evaluated. Time of residue incorporation in relation to time of planting the companion crop should be ascertained.

Management of green manure cover crops in plantation crops

Legumes like velvet bean and jack bean have great potential as green manures as well as for weed control in plantation crops like coffee and avocado. However, it is important to develop management practises that minimize competition especially for light and moisture with plantation crops.

Use of legume forage and seed for human and livestock feed

Apart from conventional legumes such as cowpeas and lablab, little is known about the appropriate processing methods of most GM legumes studied by the Network for use as livestock feed and human food. Studies are necessary to test and develop appropriate methods that will eliminate anti-nutritional factors in the legume diets in a cost-effective manner.

Intercropping with food crops

Studies on resource use in green manure / food crop intercropping systems (maize and others) should be conducted. These should include research on manipulation of plant densities to minimize competition, and determining the most suitable time of planting the legume in maize-based systems.

Socio-economic studies

Profitability of green manure technologies, returns to labor (residue management, weed suppression), farmers perceptions, and potential for adoption need further assessment. Detailed studies to characterize green manure niches will be undertaken.

Screening of legumes tolerant to abiotic stresses

The “best-bet” species for different agroecological zones were screened under optimal conditions. It is important to screen the legume species and their cultivars under stress conditions (e.g., acidic and low P soils, competition with companion crops and prolonged drought), which are quite prevalent in many smallholder farming systems. There is also need to acquire and evaluate new species along with different cultivars of the already identified best bets. This is important in order to widen the range of GM legume options available to smallhold farmers in Kenya.

Seed bulking

Seed bulking of best-bet species in the region will continue to be done at sites with comparative advantage. Quality control in seed production and storage is to be guaranteed and issuance of minimum data to accompany seed exchanges in the region will be made routine. The Network will discourage provision of free seeds to farmers or potential collaborators and will charge a nominal fee that will ensure recovery of production costs of the seeds. Farmers/farmer groups will be encouraged to produce their own seed locally to save on seed costs.

ACKNOWLEDGEMENT

REFERENCES

The Network is indeed grateful to the Rockefeller Foundation for the financial and technical support it has continued to receive since its inception in 1994. The success this Network has achieved so far would not have been possible without the support it has also received from the Director KARI. Most of the scientists implementing Network activities are KARI employees and over 80% of the Network sites are in KARI Centers. The Center Director KARI-NARL is gratefully thanked for housing the Network and for providing administrative support. Special thanks go to Dr. Elizabeth Ann Dyck who initiated the Network and guided it up to early 1997. All Network members are thanked for their active participation in implementing Network activities and for their assistance in preparing this report. The contribution by all participating farmers and the staff of the Ministry of Agriculture and Rural Development to the implementation of the Network activities is indeed gratefully acknowledged.

- [1] Dyck, E., (1997). Screening legumes potential for soil productivity improvement in Kenya. Poster presented at Green Manure Cover Crops Conference in Santa Catarrina, Brazil 6 - 12, 1997. April.
- [2] Gachene, C.K.K., Jarvis, N.J., Linner, H. and Mbuvi, J.P., (1997). Soil erosion efforts on soil properties in a highland area of central Kenya. *Soil Sci. Soc. Am. J.* 61, 559-564.
- [3] Gachene, C.K.K. and Haru R. (1997). Controlling seasonal soil loss using purple vetch (*Vicia benghalensis*). African Crop Science Conference Proceedings, 3 pp 369-373.
- [4] Hassan, R.M., Muriithi F.M. and Kamau G. (1998). Determinants of fertilizer use and gap between farmers' maize yields and potential yields in Kenya. pp. 137- 161
- [5] Hudgens, R.E., (2000). Sustaining soil fertility in Africa: The potential for legume green manures. Proceedings of the 15th Conference of the Soil Science Society of East Africa. pp 63-78.
- [6] Lal, R., Reignier, E., Edwards, W.M. and Hammond, R. (1991). Expectations of cover crops for sustainable agriculture. In: Cover crops for clean water (ed Hargrove, W. M.). Proceedings of an international conference, West Tennessee Experiment Station, April 9-11 1991. Published by the Soil and Water Conservation Society. pp 1-11.
- [7] LRNP, (1998). Legume Research Network Project Newsletter, Issue No. 1. Kenya Agricultural Research Institute.
- [8] Lekasi, J.K., Tanner, J.C., Kimani, S.K. and Harris, P.J.C. (1998). Manure management in the Kenya highlands: Practices and potential. High potential production system portfolio for the Natural Resources Systems Program Renewable Natural Resources Knowledge Strategy. Department for International Development. A publication of the Henry Doubleday Research Association, UK. pp 35.
- [9] Maobe, S.N., Dyck, E. and Mureithi, J.G. (1998). Screening of soil improving herbaceous legumes for inclusion into smallholder farming systems in Kenya. In: Soil fertility research for maize-based farming systems in Malawi and Zimbabwe (eds Waddington S.R., Murwira H.K., Kumwenda, J.T.D., Hikwa D. and Tagwira F.) Proceedings of the Soil Fert Net results and Planning Workshop. 7-11 July 1997. Africa University, Mutare, pp. 105-111

- [10] Muinga, R.W., Saha H.M., Njunie, M.N. and Bimbuzi S. (2000). Milk production from Jersey cows fed on Napier grass and maize bran basal diet supplemented with mucuna, lablab, clitoria or gliricidia. Legume Research Network Project Newsletter. Issue Number. 4. pp 13-15.
- [11] Muli, M.B and Saha, H.M. (2000). Participatory evaluation of cowpea cultivars for adaptation and high grain yield in coastal Kenya. Paper presented at the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects, 26-30 June 2000, Mombasa Continental Resort, Kenya.
- [12] Mureithi, J.G., Maobe, S.N., Dyck, E., Gachene C.K.K., Gitari N., Kirungu B., Muli B.M., Ojiem J., Saha H.M. and Tana P. (1998). Screening of legume germplasm in Kenya: Effect of rhizobia inoculation on performance of best-bet legumes. Paper presented at the 16th Conference of Soil Science Society of East Africa held at Tanga. 13-19 December 1998.
- [13] Mureithi, J.G., Mwaura, P. and Nekesa, C. (2000). Introduction of legume cover crops to smallholder farms in Gatanga, central Kenya. Paper presented at the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects, 26-30 June 2000, Mombasa Continental Resort, Mombasa, Kenya.
- [14] Mureithi J.G. and Ojiem J. (2000). The role of green manure legumes in smallholder farming systems in Kenya: An overview of Legume Research Network Project. Paper presented in a symposium on fallow management in the tropics, Minneapolis, Minnesota, USA, (November 5-9)
- [15] Muller-Samann, K.M. and Kotschi, J. (1994). Sustaining Growth. Soil fertility management in tropical smallholdings. ICTA, GTZ. Transl.: Christine Ernsting and Simon Chaterj. - Weikersheim : Margraf. pp. 197-217.
- [16] Njarui, D.M.G. and Wandera, F.P. (2000). Evaluation of selected forage legumes as supplementary feeds for dual purpose goats in semi-arid region of eastern Africa. Legume Research Network Project Newsletter. Issue Number 2. pp 9-12.
- [17] Okoko, O. (2000). Introduction of improved pigeon pea (*Cajanus cajan*) in the marginal areas of lake Victoria region of southwest Kenya. Legume Research Network Project Newsletter. Issue Number 4, pp 4-5.
- [18] Ojiem, J.O, Mureithi, J.G., Maobe, S.N., Okwuosa, E.A. and Nekesa, C.O. (2000). The effect of phosphorus on legume green manure species dry matter yield and nodulation in the sub-humid highlands of Kenya. Paper presented at the 2 Scientific Conference of the Soil Management and Legume Research Network Projects, 26-30 June 2000, Mombasa Continental Resort, Kenya.

