INCORPORATION OF GREEN MANURE COVER CROPS IN MAIZE BASED CROPPING SYSTEM IN SEMI -ARID AND SUB-HUMID ENVIRONMENTS OF KENYA

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ABSTRACT

The study involved two experiments; the first experiment was at Machakos Farmers Training Centre (semi-arid) while the second was at Kabete Campus Field Station (sub-humid). The aim of the first experiment was to assess the effect of different residue management practices using green manure cover crop (GMCC) on maize yield. The treatments, which were repeated during the subsequent seasons were: maize without fertiliser, maize with fertiliser, maize intercropped with Lima bean (*Phaseolus lunatus)*, maize+Sunhemp (*Crotalaria ochroleuca)* and maize+Mucuna (*Mucuna pruriens)*. The biomass obtained was either incorporated or left as surface mulch or removed during the subsequent seasons. The second experiment aimed at assessing the effect of short-duration fallows of green manure cover crops on maize yield. The species planted during the fallow period were *Mucuna pruriens*, Purple vetch (*Vicia benghalensis)* and *Crotalaria ochroleuca*. Two additional plots were planted with a pure stand of maize, with or without fertiliser. The biomass obtained after the fallow period was either incorporated in the soil, removed or left as surface mulch during the subsequent season when all the plots were planted with maize. Biomass accumulation during the first season of the first experiment ranged from 2.8 to 5.9, 5.6 to 18.5 and 11.5 to 20.9 t DM ha^{-1} for *P. lunatus*, *C. ochroleuca* and *M. pruriens* respectively. Maize grain yields were generally higher in the incorporation followed by mulching. The removal treatment had the lowest yield. However, in seasons of low rainfall, the trend especially for mucuna changed, the mulching treatment gave the highest grain yield (4.01 t ha^{-1}) followed by the incorporation treatment (1.90 t ha^{-1}) and the removal treatment gave the lowest yield (1.51 t ha^{-1}). The increase in yields in the mulched plots was attributed to soil moisture conservation. Biomass accumulation for the short duration fallows ranged from 2.0 to 15.6, 11.2 to 18.0 and 15.6 to 20.0 t DM ha^{-1} for *V. benghalensis*, *C. ochroleuca* and *M. pruriens,* respectively. Maize grain yield after residue incorporation was higher than from maize+fertiliser plots although no fertiliser had been applied in the former plots. Incorporating *V. benghalensis* and *C. ochroleuca* more than doubled the yields when compared with the control. Yield increments of 16 to 58% compensated loss of yields during green manuring.

Key words**:** legume green manure, improved fallow, biomass, soil fertility, maize yield

INTRODUCTION

Soil fertility has continued to be a major constraint to food production in many parts of the tropical region. Low soil fertility has been attributed to the low inherent soil fertility, loss of nutrient through erosion and crop harvests (Pfeiffer, 1990, Gachene *et al.,* 1997, Palm *et al.,* 1997). The outflow of nutrients in most smallholder farms thus exceeds input flows. To address these problems, several technological interventions, especially geared towards addressing declining soil fertility and soil moisture conservation have been suggested (Gachene *et al.,* 1999, Lathwell, 1990). The use of green manure cover crops (GMCC) has in this respect been suggested as an option for improving soil fertility. Green manure cover crops have several advantages, among them, regulating soil surface temperatures due to their high surface ground cover, increasing soil organic matter content to the soil thus improving soil physical properties, controlling soil erosion and conserving soil moisture during some parts of the year (Buckles *et al.,* 1998). In Brazil, Nigeria and Ghana, surface applied mulch created more favourable soil moisture and temperature regimes than buried mulch (Carsky *et al.,* 1998).

The high mineralisation rates, which characterise the semi arid areas, warrant a technology, which adds high amount of biomass into the soil. However, there are some management problems associated with the introduction of GMCC into the existing smallholder farming systems. For example, extra labour is required during incorporation, decline in crop yields when the GMCC are intercropped with food crops and loss of a food crop season if the GMCC are rotated with food crops (Gachene *et al.,* 1999). In the latter case, one can however argue that there exists infertile pieces of land in farmers fields which are no longer productive (Kapkiyai *et al.,* 1998) and that such pieces of land can be productive through improved short-duration fallows (Yamoah and Mayfield, 1990; Raquet, 1990). In West Africa the effect of mucuna fallow significantly increased the subsequent rice yields compared to weedy fallow when the mucuna biomass was incorporated or mulched and not when removed (Carsky *et al.,* 1998; Buckles *et al.,* 1998).

The objective of the first experiment was therefore to assess the effect of different residue management practices, namely incorporation, mulching and removal of GMCC biomass on crop response. The GMCC tested for the area, *Phaseolus lunatus*, *Mucuna pruriens* and *Crotalaria ochroleuca,* were selected based on an earlier screening study carried out in the area by Gachene and Makau, (2000a).

The objective of the second experiment was to assess the effect of GMCC short-duration fallows on maize yield in central Kenya highlands. The study also compared the yields realised under different GMCC residue management practices.

MATERIALS AND METHODS

Experiment I. The experiment was conducted at Machakos Farmers Training Centre, Machakos district. The site is at an altitude of 1600 m asl and is representative in terms of soils (lixisols) and climate (biomodal with 750 mm per annum) of large areas of semi-arid Machakos, Kitui and Makueni districts. The experiment involved the following treatments each replicated four times.

T1: Lima bean (*Phaseolus lunatus)* + maize (variety KCB)
T2: Crotalaria (*Crotalaria ochroleuca*)+ maize
T3: Mucuna (*Mucuna pruriens*)+ maize
T4: Maize with fertiliser (DAP at 200 kg ha^{-1})
T5: Maize without fertiliser
The above experiment was repeated in subsequent seasons. Agronomic practices such as time of planting and weeding were carried out according to the prevailing local conditions. The plot size was 4.0 x 6.5 m.

Experiment II. The study was conducted at Kabete Campus Field Station, College of Agriculture and Veterinary Sciences. The area is at an altitude of 1940 m asl and has a bimodal rainfall distribution (mid-March-May, long rains; October-December, short rains). Average annual rainfall is 1000 mm. The soils of the study area are well drained, very deep and mainly clay humic nitisols.

The species planted during the fallow period were *Mucuna pruriens*, Purple vetch (*Vicia benghalensis)* and *Crotalaria ochroleuca*. Each plot measured 5 x 5 m. Mucuna was planted at a spacing of 30 x 60 cm while *V. benghalensis* and *C. ochroleuca* seeds were drilled at the rate of 45 and 25 kg ha^{-1}, respectively, both at a an inter-row spacing of 60 cm. Two additional plots were planted with a pure stand of maize with or without fertiliser. Maize was planted at a spacing of 30 by 75 cm while fertiliser was applied at the rate of 24 kg P ha^{-1}. Weeding operations were carried out as necessary. After the first season, the biomass was either incorporated in the soil or removed or left as surface mulch during the subsequent season.

RESULTS AND DISCUSSIONS

Experiment I

Rainfall. The rainfall varied both in amount and distribution during the experimental period. The *El Nino* weather phenomenon, which was experienced in 1997 short rains (SR), had a major influence both in amount and distribution of the rainfall. The 1998 SR and 1999 long rains (LR) were below average and this greatly affected the trials. Thus, only the results for 1998 LR and 1999 SR are presented in this paper.

Biomass accumulation. The average GMCC biomass accumulation during the 1997 SR, before introducing the test crop was 5.9, 18.5 and 20.9 t DM ha^{-1} for lima, crotalaria and mucuna, respectively.

Maize grain yield. Grain yields for the 1998 LR season, after incorporating the GMCC biomass obtained during the previous season is shown in Table 1. Except for Mucuna, there were no treatment differences in the other species. However, leaving the green manure residues as surface mulch had higher yields than removing the biomass. In terms of biomass production, Mucuna had highest amount in the previous season than the other GMCC species and this may account for the high yields obtained in Mucuna plots (Table 1). In particular, mulching with Mucuna biomass more than doubled the yields when compared with the plots where the material was either incorporated or removed. This may be attributed to enhanced soil moisture conservation when Mucuna is left as surface mulch rather than improved soil fertility. Gachene *et al.,* (2000b) while working in the same area recorded high soil moisture content in the first 30 cm topsoil in sole cropped mucuna plots than in plots planted with other GMCC species. This was attributed to surface mulching provided by mucuna. This confirms that soil moisture conservation is an important issue in semi-arid conditions, perhaps in this case even more than the nutrients supplied by the GMCC.

During the 1999 SR season, when adequate amount of rainfall was received, average maize grain yields were higher for mucuna than for the other treatments (Table 2). During this period, soil moisture was not a major constraint and maize grain yields were 29% higher in incorporated than in mulched plots. Similar observations were made in Brazil where maize yields were 26% higher where residue had been incorporated than yields following a mulch treatment (Carsky *et al.*, 1998). The average yields were in the order incorporation >mulching >removal. The least yields was recorded in the control and lima plots. This showed that lima bean is not a good GMCC species for improving soil fertility or for conserving soil moisture in the study area. However, it's main advantage is that it can be used as a food crop unlike the other GMCC species.

Experiment II

Rainfall. The amount of rainfall received during the 1997 SR was 682 mm. This was far much higher than the 18-year average (285.2 mm). This was the time when Kenya experienced the *El Nino* weather phenomenon. The amount received during the subsequent season (1998 LR) was still higher than the 18-year average and this favoured crop growth during the season.

Biomass accumulation. Biomass accumulation during the short-duration fallow is given in Table 3. Mucuna produced the highest biomass (18.0 t ha^{-1}) while Vicia gave the lowest (9.2 t ha^{-1}). The biomass accumulation was far much higher than average (Dyck, 1997) and this was attributed to the high amount of rainfall received during the season. The high biomass yield may be attributed to the fact that the species were planted as sole crops. Sole cropped GMCC species produce greater yields of biomass as there is no competition for water, nutrient or light (Fischler, 1997). In Uganda, Fischler, (1997) recorded 10.7 t DM ha^{-1} for sole cropped crotalaria while Siriri ,(1999) recorded values of 18 t DM ha^{-1} of sole

TABLE 1. Maize yields (t ha^{-1}) for 1998 LR, Machakos FTC

Treatment	Incorp.	Rem.	Mulched	LSD 0.05	Av. yield
Lima bean	1.29	1.51	1.74	1.54	1.51
Crot.	3.03	1.23	2.79	2.45	1.51
Mucuna	1.90	1.51	4.01	2.12**	2.35
Control	1.05	1.05	1.05		1.05
Maize + Fertiliser	2.13	2.13	2.13		2.13
LSD 0.05	2.34	1.78	2.81		

TABLE 2. Maize grain yields (t ha^{-1}) for 1999 SR, Machakos Farmer Training Centre

Treatment	Incorp	Removed	Mulched	Av. Yields
Lima bean	0.74	0.80	0.62	0.72
Crotalaria	1.02	0.65	0.86	0.84
Mucuna	1.48	1.11	1.05	1.21
Average yields	1.08	0.85	0.84	
Control	0.74	0.74	0.74	
Maize + Fertiliser	0.80	0.80	0.80	
LSD 0.05	0.40	0.33	0.43	

TABLE 3. Biomass accumulation (t DM ha^{-1}), short-duration fallow, 1997 SR season

Species	Range	Av.
M. pruriens	15.6 to 20.0	18.4
C. ochroleuca	11.2 to 18.0	14.6
V. benghalensis	2.0 to 15.6	9.2

cropped *V. benghalensis*. In Honduras, close to 20 t DM ha^{-1} of mucuna was recorded (Buckler *et al.,* 1998). However the yields are reduced once the legumes are intercropped with cereal crops (Fischler, 1997) because of competition for growth resources and reduced plant population per unit area.

Maize grain yield. Maize grain yields obtained from mucuna plots are shown in Table 4. During the season of biomass production, the maize yields were highest in the fertilised plots. In the first subsequent season, average grain yields from plots where mucuna biomas was mulched were the highest (5.42 t ha^{-1}). This yield was significantly different ($p<0.05$) from yields of the removal, fertilised and non-fertilised plots. Although the mulched and incorporated treatments were not significantly different from each other, there was a slight increase in yields in mulched over the incorporated plots.

There was a decline in maize yield during the second season for the plots, which were previously planted with maize under fertilised and non-fertilised conditions (Table 4). However, when the total yields for the different systems were considered the control and fertilized plots had higher yields (5.51 and 7.46 t ha^{-1}) than the single crop yields obtained from plots previously under fallow. It should however be pointed out that other aspects, such as inputs (seeds and fertilisers) and labour should be taken into consideration when comparing these systems. Very little labour was needed for weeding during the short-duration fallows in plots planted with sole mucuna and even during the first subsequent season in plots where legume biomass was left as surface mulch. Thus, the tradeoffs should be an important aspect to be considered when introducing the GMCC technologies on-farm.

Removing mucuna had no significant effect on yields when compared with the control and fertilised plots. Plots from which mucuna biomass was removed after the fallow period gave yields that were similar to those from fertilised plots. This may be attributed to the below ground biomass (roots) and probably also to mucuna litter fall which may have already decomposed and released some of the nutrients to the soil.

TABLE 4. Maize grain yields (t ha^{-1}) obtained from mucuna plots after the fallow period

Treatment	Season of biom. Prod.	1st subsequent season	Total yield
Incorp.	0.0	4.23	4.23 (1 crop)
Mulched	0.0	5.42	5.42 (1 crop)
Removed	0.0	3.26	3.26 (1 crop)
Control	2.96	2.55	5.51(2 crops)
Maize + Fertiliser	4.22	3.24	7.46(2 crops)
LSD 0.05		2.08	

TABLE 5. Maize grain yields (t $ha^{-1)}$) from crotalaria plots after the fallow period

Treatment	Season of biomass	1st subsequent season	Total yield
Incorp.	0.0	5.40	5.40 (1 crop)
Mulched	0.0	3.64	3.64 (1 crop)
Removed	0.0	4.47	4.47 (1 crop)
Control	2.96	2.55	5.51 (2 crops)
Maize + Fertiliser	4.22	3.24	7.46 (2 crops)
LSD 0.05		2.03	

TABLE 6. Maize grain yields (t ha^{-1}) from vetch plots after the fallow period

Treatment	Season of biomass production	1st subsequent season	Total yield
Incorp.	0.0	5.80	5.80 (1 crop)
Mulched	0.0	5.02	5.02 (1 crop)
Removed	0.0	4.19	4.19 (1 crop)
Control	2.96	2.55	5.51 (2 crops)
Maize + Fertiliser	4.22	3.24	7.46 (2 crops)
LSD 0.05		2.07	

Trends in maize yields for crotalaria and vetch plots after the short duration-fallow was in the order incorporation > removal > mulching and incorporation > mulching > removal (Tables 5 and 6). In all the fallow plots, maize yield was higher when compared with the control and fertilised plots after the fallow. However, there was no significant difference in maize yield between plots where legume biomass was removed. Although there was loss of a crop during the fallow period, this may be compensated for by reduced inputs costs, which were not incurred in fallow plots. In Rwanda, Raquet, (1990) made similar observations.

The highest maize grain yield during the first subsequent season was obtained in plots, which were previously under sole vetch (5.80 t ha^{-1}). Differences in maize yield were not significant between the plots where vetch was either left as surface mulch or removed (Table 6). At the time of incorporating the residues, most of the above ground biomass of crotalaria and vetch had already disappeared through litter fall and decomposition. This may explain the relatively higher yields obtained in plots where residue had been removed.

CONCLUSIONS AND RECOMMENDATIONS

The above study shows that Mucuna have the advantage of improving soil fertility as well as soil moisture conservation especially in the semi-arid environments. As a result of resource competion, maize yield was reduced by 30-45% when intercropped with GMCC. However, there was an increase in maize yield (16-58% increment) during the subsequent seasons after incorporating the GMCC residues.

For all the species tested, there was no significant increase in maize yields when GMCC biomass was removed, indicating that the below ground biomass has no significant influence on soil fertility and hence crop yields. Although there is a loss of crop in one of the seasons, the increase in yields after the short duration fallow can compensate for this loss especially where labour for weeding and inputs such as seeds and fertilisers are taken into consideration. The trend in maize yield with respect to the species tested under semi-arid conditions were in the order Mucuna > Crotalaria > Lima. Yield trends with respect to Mucuna residue management was mulching > incorporation > removal and, incorporation > mulching > removal in periods of low and high rainfall, respectively. Problems related to intercropping of GMCC with food crops need to be addressed especially on the manipulation of relative planting dates and densities in order to minimise competition for resources such as light, nutrients and water.

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REFERENCES

Buckles, D., Triomphe, B. and Sain, G. 1998. Cover crops in Hillside Agriculture. Farmer innovation with mucuna. IDRC/CIMMYT, Canada, pp 218.

Carsky, R.J., Tarawali, S.A., Becker, M., Chikoye, D., Tian, G. and Sanginga, N. 1998. Mucuna-herbaceous cover legume with potential for multiple uses. Resource and Crop Management Research Monograph No. 25. IITA, Nigeria. pp 52.

Dyck, E. 1997. Screening legumes for potential soil productivity improvement in Kenya: Kenyan legume research network. Poster presentation at Green manure cover crops conference in Sante Catarrina, Brazil 6-12 April, 1997.

Fischler, M. 1997. Legume green manures in the management of maize-bean cropping systems in Eastern Africa with special reference to Crotalaria (*C. ochroleuca*). Ph.D. thesis No. 12099, ETH Zwich, Switzerland.

Gachene C.K.K., Jarvis N., J. Harry, L. and Mbuvi, J.P. 1997. Soil erosion effects on soil properties in a highland area of Central Kenya. SSSAJ 61: 559-564.

Gachene, C.K.K., Palm, C. and Mureithi, J.G. 1999. Legume cover crop for soil fertility improvement in the Eastern African Region. AHI/TSBF, Nairobi, 26 pp.

Gachene, C.K.K. and Makau, M. 2000a. Screening legume cover crops for dry-season survival in a semi-arid environment of Kenya. In: (eds) J.G. Mureithi, C.W. Mwendia, F.N. Muyekho. M.A. Onyango and S.N. Maobe. Participatory technology development for soil management by smallholders in Kenya. Special Publ. of Soil Management and Legume Research Network Projects, KARI/ LRNP, p 77-86.

Gachene, C.K.K., Makau, M. and Haru R. 2000b. Soil moisture extraction by different legume covers. pp. 133-144. In: (eds) J.G. Mureithi, C.W. Mwendia, F.N. Muyekho. M. A. Onyango and S.N. Maobe. Participatory technology development for soil management by smallholders in Kenya. Special Publ. of Soil Management and Legume Research Network Projects, KARI/LRNP, p 77-86.

Kapkiyai, J.J., Karanja, N.K. Woomer, P.L. Qureshi, J.N. 1998. Soil organic carbon fractions in a long-term experiments and the potential for their use as a diagnostic assay in highlands farming systems of Central Kenyan Highlands. African Crop Science Journal 6 (1): 19-28

Lathwell, D.J. 1990. Legume green manures. Principles for management based on recent research. Tropical Soils Bulletin No. 90-01. Soil management collaborative research support program. North Carolina State University, Raleigh, NC, pp 30.

Palm, C.A., Myers, R.J.K. and Nandwa, S., 1997. Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. In: R.J. Bureshi, P.A.

Sanchez and F. Calhoun (eds). Replenishing soil fertility in Africa. SSSE Special Publ. No. 51, Madison, Winconsin, pp 193-218.

Pfeiffer, R. 1990. Investigating possiblities of combining fodder production with erosion control and agroforestry in the West Usambara Mountains of Tanzania. In: J. Kotschi (ed) Ecofarming practices for tropical smallholding. Tropical Agroecology, 5. pp 81-106.

Raquet, K. 1990. Green manuring with fast-growing shrub fallow in the tropical highland of Rwanda. In: J. Kotschi (ed) Ecofarming practices for tropical smallholding. Tropical Agroecology 5. pp 50-55.

Siriri, D. 1999. Cover crops research and dissemination in the Kigezi highlands of South Western. ICRAF/AFRENA Project, Kabale, Uganda

Yamoah, C.F. and Mayfield, M. 1990. Herbaceous legumes as nutrients sources and cover crops in Rwanda highlands. Biological Agric. and Horticulture, 7:1-15.