EVALUATION OF LEGUMES AS COVER CROPS FOR SOIL AND WEED MANAGEMENT IN SMALLHOLDER COFFEE CROPPING SYSTEMS IN CENTRAL KENYA

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Abstract
The performance of 14 legume species sown under coffee was studied during the long rains season 2005 in two experimental sites in Kiambu and Murang'a Districts in Central Kenya. *Crotalaria Oclroleuca* (G.Don) produced the highest biomass at 9 and 10 Weeks After Planting (WAP) on average of 1.5 t ha^{-1}. By 24 and 29 WAP *Desmodium uninatum* (Jacq,) DC, *Desmodium intortum* (Mill.) Urb, *Mucuna pruriens* (L) DC, *Vicia benghalensis* L. and *Neontonia wightii* (Arn.) had the highest biomass on average of 4t ha^{-1}. *Crotalaria Ochloleuca* (G.Don) had the highest percentage crop cover (73%) by 9WAP, late maturing and perennial legumes developed cover slowly but maintained the cover longer as compared to the early maturing legumes which developed cover rapidly and dried up in about 100 days after planting. By 24 and 29 WAP *Desmodium uncinatum* (Jacq,) DC, *Mucuna pruriens* (L.) DC (mottled) and *Desmodium intortum* (Mill.) Urb had a percentage crop cover of over 80%. Intercropping with late and maturing LCC reduced weed counts by 369 m^{-2} at 7 WAP to 52m^{-2} at 52 WAP. Late maturing legumes like *Mucuna pruriens* (L.) DC, *Desmodium uninatum* (Jacq,) DC, *Desmodium intortum* (Mill.) Urb maintained high ground cover longest and suppressed weeds better than all the other legumes. *Desmodium uncinatum* (Jacq,), *Crotalaria Ochroleuca* (G.Don) and *Neoutonia wightii* (Arn.) extracted the highest soil moisture at all levels tested (0-100 cm) with *Mucuna pruriens* (L) showing no significant difference from the sole coffee. *Mucuna pruriens* (L) DC (mottled) recorded the highest litter fall (433 kg ha^{-1}) at 24 WAP while *Neontonia wightii* (Arn) recorded the lowest (115 kg ha^{-1}) in same period.

Introduction

Coffee is the world's second most traded commodity in terms of value after petroleum. In Kenya it contributes significantly to the economy in terms of foreign exchange earnings. It contributed 1.8 % to the gross domestic product in 1999 and about 10% of total foreign exchange earnings (CBK, 2005). Currently coffee is ranked fourth after tea, tourism and horticulture. All Kenya coffee is of the *Arabica* spp. grown on the rich volcanic soils in the highlands of Kenya. It is grown on both large-scale commercial farms/estates (greater than 2 ha) and small-scale holders farms (cooperatives) (less than 2 t ha^{-1}). The estates and cooperatives both account for about 33 and 67% of the total area under coffee respectively (CBK, 2003a). Smallholder farms contribute 76% of the total coffee produced and approximately 60% of the total national clean coffee (Anon, 1999).

The average national coffee yields have declined by 60% over the last 40 years due to low coffee prices and high cost of inputs (fertilizers, pesticides and labour) (FAOSTAT, 2004; Anon, 1999). The unit cost of labour, fertilizer and fungicides increased by 430%, 599% and 400% respectively between 1986 and 1998, labour, fertilizer and fungicide costs comprised 15%, 11% and 16% of the production costs respectively (Anon 1999). Smallholders produce much less per unit area compared to the estates, i.e. in 1993/94 cooperatives registered average yields of 342.7 kg ha^{-1} compared to 1,012.6kg ha^{-1} produced by the estates (Ministry of Agriculture and Livestock Development, 1996). Today the average production is much lower compared to previous years with cooperatives producing 200 kg ha^{-1} and estates 700 kg ha^{-1} of coffee respectively (CBK, 2003b). Due to these declining trends, majority of the smallholder farmers have resorted intercropping coffee with food/forage crops to maximise on profitability per unit area land and this has lead to soil nutrient mining and poor husbandry practices. As a result the soils in most of these smallholder coffee cropping areas are highly eroded and infertile leading to low coffee and food production. This has resulted in high poverty levels, food insecurity and unemployment.

Most of the coffee in Central Kenya is grown on gentle to steep slopes where soil erosion is a severe problem. Construction and maintenance of soil conservation structures to control soil erosion is labour intensive and expensive. This coupled with low coffee prices has made farmers to neglect maintenance and construction of these structures leading to soil erosion (Ngugi and Kabutha, 1989). Soil erosion and nutrient mining result in depletion of soil nutrients. The most depleted nutrient in most coffee growing areas is nitrogen, which is lost through leaching, volatilisation and erosion (Nandwa *et al*., 2000).

Weeding in smallholder farmers' fields is mainly done manually using traditional tools such as the hoe and machete. Manual labour is intensive and tedious and is also both expensive and scarce during the peak periods of crop growth. This leads to late and poor weed control resulting in substantial crop losses (Chui *et al.,* 1996). Weeds are a serious problem in coffee mainly because of the wide inter row spacing in coffee especially during the first 2-3 years of early growth and during change of cycle encourages fast weed growth. The superficial nature of coffee tree roots makes the plant vulnerable to weed competition for moisture (Akobundu 1987). Weeds have been shown to depress coffee yields and quality (Jones and Wallis 1963.

Weeds have been cited as a major problem in coffee in this country with weeds depressing coffee yields by 50% and above (Njoroge and Kimemia, 1990). Most emphasis on weed research in Kenya has been on mechanical and chemical weed control. These 2 methods of weed control are expensive for most of the smallholder farmers who are struggling with the poor coffee prices which has caused a lot of poverty and food insecurity in their areas. Research on use of cover crops as a means of weed control in coffee in Kenya is lacking. Growing green manure legume cover crops (GMLCC) as part of the smallholder coffee cropping system can play an important role in improving soil fertility, reduce soil erosion and control weeds in coffee farms (Kimemia, 1998). Integration of high yielding green manure legumes can increase plant nutrient supply in the soil especially nitrogen and improve soil physical properties (Mureithi *et al*., 2003). Legumes can also provide good ground cover minimising soil erosion through raindrop impact and runoff (Gachene and Haru, 1997). Some GMLCC are a source of food (Veesteeg *et al*., 1998) and fodder (Njarui *et al*., 2000), an important attribute especially in the high population density areas with zero grazing dairy production systems (Ngugi and Kabutha, 1989).

The aim of the study was to evaluate several LCC in coffee to come up with the best bets that can be used in these cropping systems. The evaluation was being carried in a participatory farm approach method by the farmers, researchers and agricultural extension staff. The first stage of the project involved a stakeholders meeting, Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA). These activities aimed at: Bringing together all the stakeholders involved in the project; Gathering information to add to existing knowledge on smallholder coffee production and other cropping systems; Assessing the current condition, of soil, water and weed management and the farmers copping strategies; Contributing to the design of the evaluation study to be carried on farms fields.

Materials and Methods

Study team

The study was conducted by a multi-disciplinary research team from Kenya Agricultural Research Institute, University of Nairobi and Coffee Research Foundation and Agricultural Extension staff of Murang’a District.

Study sites

The field work was carried out in 3 divisions in Murang'a District which is a major coffee growing area in the Mt Kenya region.

Socio-economic survey

The socio-economic survey involved a stakeholders meeting, Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA).

Stakeholders meeting

This was a one day meeting. It was held at the beginning of the project in February 2005. This meeting brought together and linked up the researchers, agricultural extension officers, farmers and NGO's working in agricultural related activities in the District

Rapid Rural Appraisal (RRA)

This activity was carried out after the stakeholders meeting by the Researchers and Ministry of agriculture extension staff. The RRA was done along a transect across the agro-ecological zones (UM_1, UM_2 & UM_3) where coffee is grown. During the RRA the group had a chance to meet some farmers chosen at random in the different AEZ. They were interviewed by the group using a questionnaire.

Participatory Rural Appraisal (PRA)

The PRA meetings were conducted with a group of farmers in the areas where work was to be done after the RRA. During the PRA meetings the farmers were introduced to the researchers, and the agricultural extension staff who were going to work with them. It was an open forum where the farmers were able to talk about the different cropping systems they practice in the area and also on socio-economic and agronomic factors affecting them and information on their coping strategies. During these meetings the farmers selected the contact farmers among them and give on-farm evaluation sites. A questionnaire was used to guide the meeting.

On farm evaluation trials

The trials were carried out in Murang'a District in all the three divisions i.e. Mathioya, Kangema and Kahuro. These divisions also represented the 3 agro-ecological zones i.e. UM_1, UM_2 & UM_3 . Each site had 3 contact farmers selected during the PRA meeting giving a total of 9 contact farmers. The experimental design was completely randomised block design researcher designed and farmer managed. There were 15 plots each measuring 5 m by 2.7m. Each farm had 15 treatments and each farmer was a replicate in each agro-ecological zone.

Treatment names

- *Lablab purpureus* (Dolichos Rongai)
- *Crotalaria ochroleuca* (sunhemp)
- *Desmodium intoticum* (green leaf)
- Control (coffee alone)
- *Phaseolus vulgaris* (common bean KK8)
- *Phaseolus vulgaris* (common bean KK22)
- *Glycine max* (TGX 1893-10F)
- *Phaseols lunatus* (Butter bean)
- *Mucuna pruriens* (Mucuna white)
- *Canavalia ensiformis* (Jack bean)
- *Vigna unguiculata* (Cowpea K80)
- *Desmodium uncinatum* (Silver leaf)
- *Mucuna pruriens* (Mucuna mottled)
- *Neontonia wightii*
- *Glycine max* (TGX 1871-12E)

Data collection

Soil samples were collected randomly from each site at the beginning of experiment. The samples were taken from 0-15 cm and 15-30 cm depth from five points in each site then bulked. This was done in all the farms 3 weeks after planting (WAP). Weed counts and identification was done at 3 WAP and 9 WAP. This was done by placing randomly a quadrat of 0.25 m^2 in each plot twice. Weeds in each plot were identified and rated by species using a scale of 1 - 4 i.e.

0 = no weeds	1 = 1 weed	2 = 2 - 5 weeds
3 = 6 - 20	4 = over 20 weeds	

After counting the weeds, in each quadrat they were harvested at soil level, dried and weighed. Time taken to weed in each plot was recorded. This is being done at different stages of crop growth using a ceptometer and also bead method procedure.

The treatments were assigned randomly to each plot in each farm. Planting was done during 2nd week of April 2005 following recommended agronomic practices. Data on soils, weed growth, LCC growth and their effect on weed growth, and weeding labour were recorded.

Results and Discussions

Socio-economic survey

During the socio-economic survey several factors were cited as the causes of high poverty levels, low coffee and crop yields and a decline in soil fertility in the smallholder coffee farms in this region. These were:

- Lack of extension support in regard to soil conservation measures.
- High levels of poverty due to lack of income from coffee which is the main cash crop.
- They remarked that large portions of their farms were under coffee leaving very little land for food production leading to food insecurity.
- There were fears of coffee by-laws preventing farmers from growing other crops in coffee.
- Labour shortage to weed the coffee and other crops was cited as acute especially because the young people are not interested in weeding coffee which belongs to their parents and also not income generating. The farmers showed a lot of interest when the importance and benefits of LCC were explained to them and asked of where they could purchase the seeds from.

Soils Analysis

Soil analysis was done for the 0-15 cm depth from soil collected from all the trial sites. There was significant difference in the soil exchange acidity me% with Mathioya having the highest level. All the soils in all the sites were extremely acidic. Nitrogen, phosphorus, calcium mg, zinc were reported to be low. The blanket recommendation for the soils is that the farmers apply 3t/ha/year of decomposed farmyard manure or compost and 700 kg ha^{-1} dolmax lime. The also apply 200 kg ha^{-1} 23:23:0 at planting for legumes. All these inputs are very expensive and at the moment coffee prices are very low so it is very difficult for the farmers to afford.

Table 1–Soil analysis for Murang'a District

Soil properties	Division		
	Mathioya	Kangema	Kahuro
Calcium (me%)	2.4	2.0	1.7
Copper (ppm)	195.9	75.7	89.5
Exch. Acidity (me /100 g)	0.8	1.8	2.1
Iron (ppm)	47.2	38.1	39.8
Magnesium (me%)	1.2	0.0	0.0
Manganese (me%)	0.8	0.7	0.7
Org. carbon (%_	2.2	1.8	1.8
Phosphorus (ppm)	55.0	22.0	38.7
Potassium (me%)	0.7	0.4	0.5
Sodium (me%)	0.3	0.3	0.2
Soil pH	5.0	4.5	4.3
Total nitrogen (%)	0.3	0.2	0.2
Zinc (ppm)	13.5	5.0	8.0

* Source; KARI-NARL Soil Test Report June 2005

Legume establishment

Legume establishment was generally poor in all the sites, this was attributed to a dry spell, which followed after planting. However, the germination percentage was higher in Mathioya (UM_1) and Kangema (UM_2) and the lowest was Kahuro (UM_3), which is the drier (Table 2a). The small seeded legumes germinated better than the large seeded mainly because they required less moisture to germinate (Table 2a). Gapping was done the establishment thereafter was good, contributing to good ground cover and weed control.

Table 2a–Germination percentage, Weed dry matter (gm2) and time taken to weed (md/ha) (Long rains 2005) Murang'a District

Division	Germination %	Weed dry wt per gm^2		Time taken to weed Mandays/ha	
		1st weeding 3 WAP	2nd weeding 9 WAP	1st weeding 3 WAP	2nd weeding9 WAP
Mathioya	50.7	2.3	3.1	23.4	36.5
Kangema	43.4	2.2	3.1	28.0	43.8
Kahuro	35.6	0.6	1.9	16.7	30.4
LSD	5.99	0.93	NS	8.3	10.3
cv	33.09	132.37	43.83	48.54	66.5

Table 2b–Percentage groundcover, crop biomass (t ha^{-1}) and germination percentage of legumes (Long rians 2005) Murang'a District

Treatments	Germination %	Ground Cover %	Ground Cover %	Crop Biomass t/ha	Crop biomass t/ha
		9 WAP	29 WAP	9 WAP	29 WAP
Lablab	16.6	22.2	56.2	0.17	1.98
Crotalaria ochloleuca	97.2	73.0	*	1.37	*
Greenleaf desmodium	97.2	44.5	79.7	0.92	3.01
Control	0	0	-	0	-
Common bean KK8	42.0	33.7	*	0.27	*
Common bean KK22	36.3	29.0	*	0.21	*
Glylcine max (TGX 1893-10F)	32.0	24.3	*	0.28	*
Scarlet runner	30.4	36.9	*	0.38	*
Mucuna white	9.9	20.9	51.8	0.60	1.28
Canavalia ensiformis	27.8	16.1	-	0.17	-
Cowpea K80	37.3	16.2	*	0.25	*
Silver leaf desmodium	98.9	59.1	85.5	0.35	3.45
Mucuna mottled	14.9	26.3	83.4	0.24	2.02
Neontonia wightii	70.0	11.4	-	0.18	-
Glycine max (TGX1871-12E)	36.9	17.8	*	0.34	*
LSD	13.58	17.56	24.9	0.46	1.39
CV	33.09	65.10	36.4	56.6	61.6

* Legumes had dried

- No legume

Weed growth

Weed count and identification

The most common weeds the during the long rains 2005 were: - *Oxalis latifolia, sedges, Galinsoga parviflora, annual grasses, Commelina benghalensis, Oxygonum sinuatum, Ageratum conyzoides and Bidens pilosa Sonchus oleraceus and Conza bonariensis.*The other weeds occurred in small numbers (Figures 1a and b).

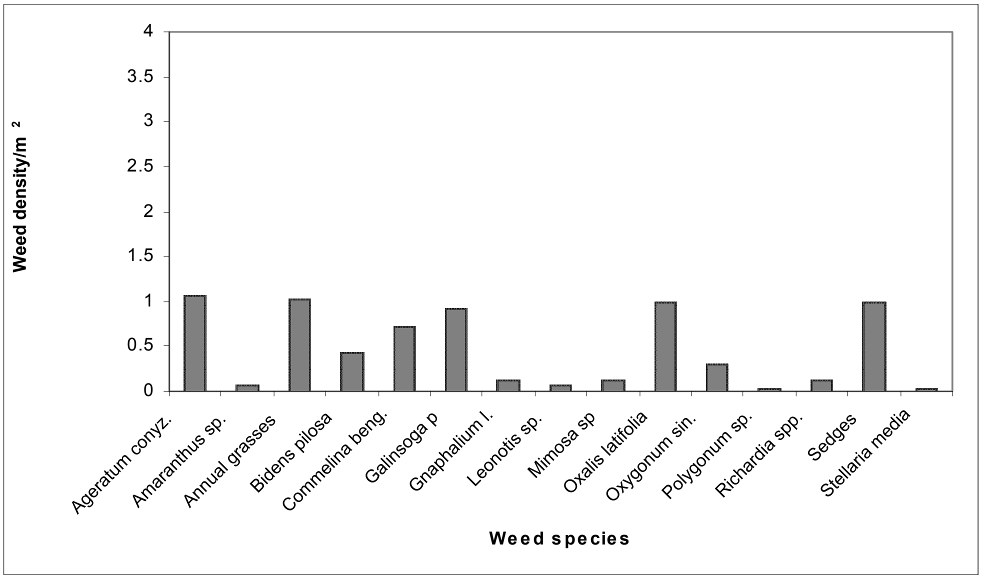

Fig. 1a: Weed composition and density in Murang'a District 1st Weeding at 3WAP

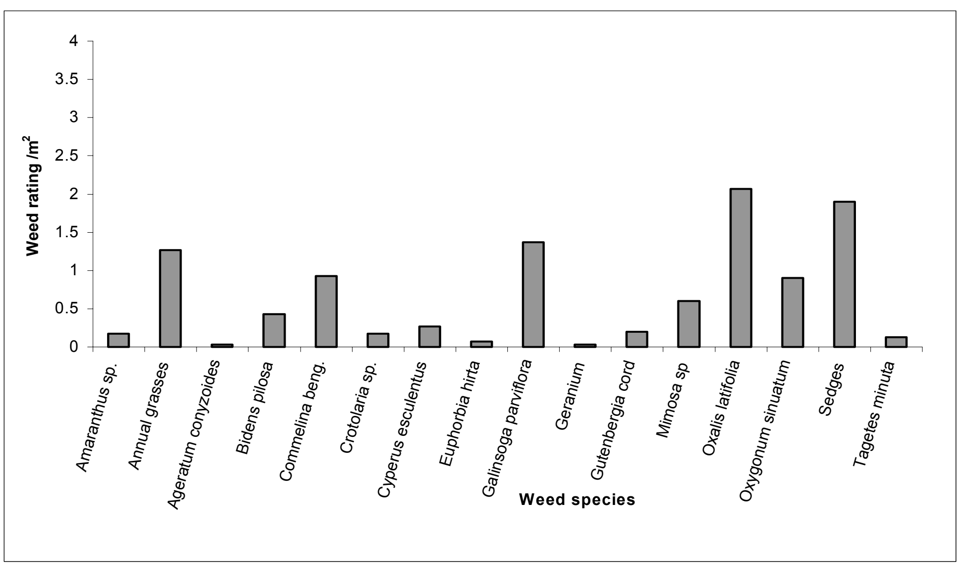

Fig. 1b:Weed composition and density in Murang'a District 2nd Weeding at 9 WAP

Weed dry weights

There was significant difference in the weed dry matter in the different AEZ at 3WAP (Table 2a). Mathioya (UM_1) Kangema (UM_2) had higher weed dry matter than Kahuro (UM_3). Both UM_1& UM_2 are wetter than UM_3, therefore the growth of weeds are more prolific resulting in more weeds. No significant difference was noted in the weed dry weights between the treatments at 3 and 9 WAP in Murang'a. This was expected because the LCC were not well established due to poor germination resulting in low weed suppression. When gapping was done the germination improved considerably but by the second weeding time, the LCC still were not well established to have any significant effect on the weed.

Weeding labour

Time taken to weed differed significantly ($P<0.05$) in the three sites. Mathioya (UM_I) and Kangema (UM_2) took relatively more time to weed than $UM_{3.}$ The AEZ UM_1 and UM_2 are wetter and supported more weed growth therefore more time was spent in weeding. It took relatively longer time to do the 2^{nd} weeding. 1^{st} and 2^{nd} weeding required on average 23 and 37 mandays/ha respectively.

Percentage ground cover

There was significant ($P< 0.05$) difference in the percentage crop cover measurement between the treatments at 9 and 29 WAP in Murang'a (Figure 2a and b). *Crotalaria ochroleuca* had the highest ground cover at 9 WAP at (73%) followed by Silverleaf desmodium (59%) and *green leaf desmodium* at (45%). By 29 WAP there was significant ($P< 0.05$) difference in terms of legume ground cover development in the *silver leaf desmodium, mucuna (mottled), green leaf desmodium* which ranged from (80-85%) lablab and mucuna (white) had (56 and 51%) respectively. All the other legumes had dried up by this time.

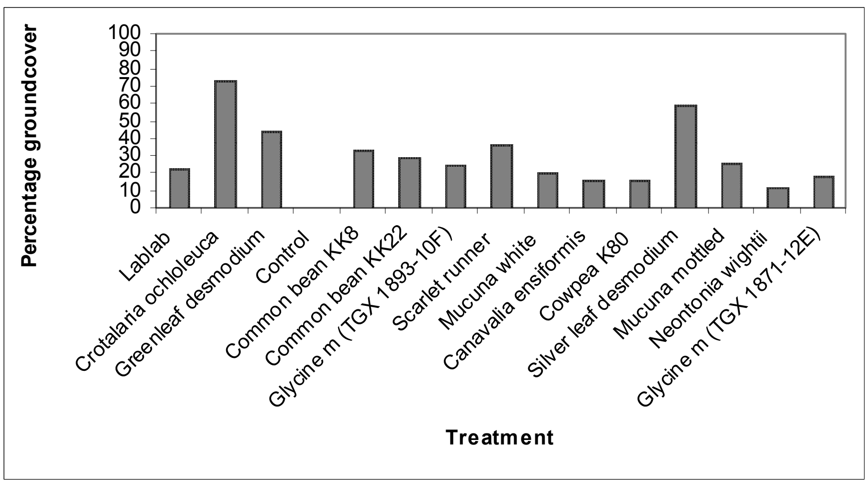

Fig. 2a: Legume Groundcover at 9 WAP (Long rains 2005) Muranga District

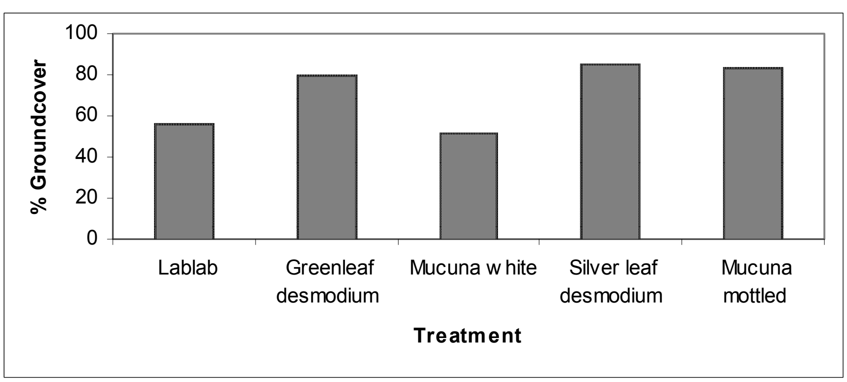

Fig. 2b: Legume Groundcover at 29 WAP (Long rains 2005) Muranga District

Crop biomass

The legumes differed significantly (P<0.05) in the crop biomass at 9 and 29 WAP (Figures 3a and b), *Crotalaria ochloleuca*, *green leaf desmodium* and *mucuna (white)* produced significantly higher biomass yield than the other legumes at 9 WAP. At 29 only five legumes had survived. *Silver leaf desmodium, mucuna mottled* and *green leaf desmodium* produced the highest biomass. *Lablab* and *mucuna white* produced significantly (P<0.05) less dry matter than the others.

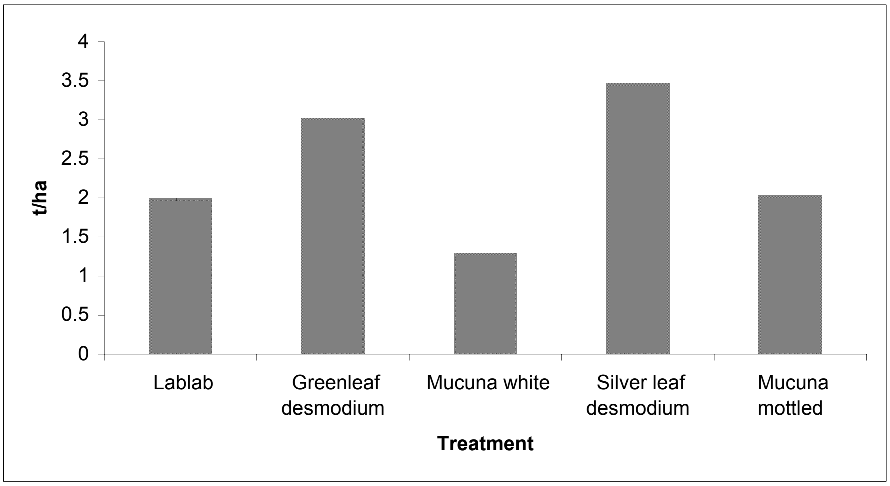

Fig. 3a: Legume biomass in t/ha at 9 WAP (Long rains 2005) Murang'a District

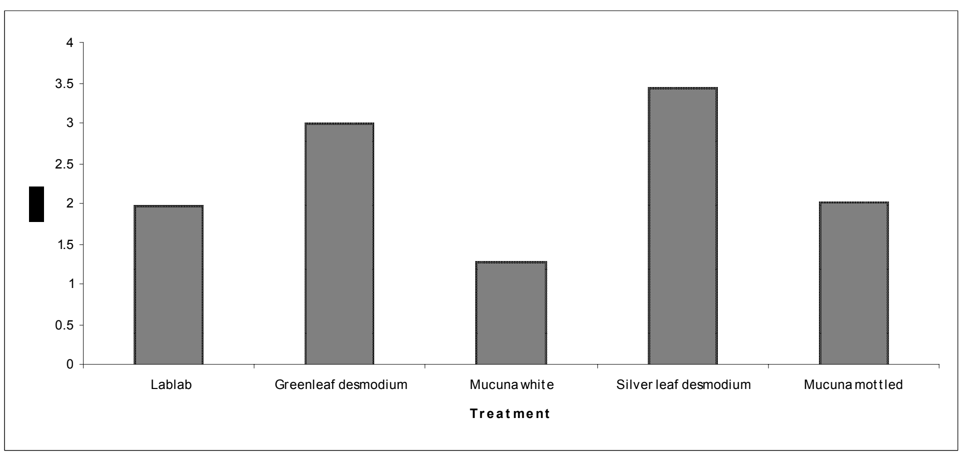

Fig. 3b: Legume biomass in t/ha at 29 WAP (Long rains 2005) in Murang'a District

Conclusions recommendations and the way forward

The study shows that some of the legumes tested can do well when under sown in coffee. They established good crop cover and crop biomass. These legumes can offer an effective method to weed control suggesting that farmers growing legumes may cut down on weeding costs and therefore increase crop profitability. Weed growth is usually highest during the early wet period of the season. Legumes such as crotalaria *ochroleuca,* green leaf desmodium, silver leaf desmodium*,* Mucuna (white), Mucuna *(mottled) and Lablab* which established good crop cover and biomass and also maintained the crop cover for a long time would be more effective in weed control than fast maturing legumes like beans whose cover would last for a very short period. Silver leaf and green leaf desmodium, mucuna mottled, mucuna white and *lablab* maintained ground cover of 51-85 % unto 29WAP. All these legumes can be used as forage by the farmers to supplement feed for their livestock. Lablab will also provide grain seed for food, which is very high in proteins

Different management practices are necessary for different legumes because of their varying growth habits. *Mucuna,* butter bean and lablab are indeterminate and have to be trimmed or trained to prevent them from climbing on to the coffee bushes. *Crotalaria ochroleuca* can be cut back early to open up coffee farms for ease of harvesting. Perennial legumes such as *Neontonia* and *Desmodium* would have to be cut back during the dry spell to minimise root moisture extraction and enhance moisture conservation through mulching.

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