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NUTRITIVE VALUE OF TOP-CANOPY HERBAGE OF *MUCUNA* AND *LABLAB* RELAY CROPPED IN MAIZE IN THE SUB-HUMID HIGHLANDS OF NORTHWESTERN KENYA

E.M. Nyambati[1]* and L.E. Sollenberger[2]

[1] *National Agricultural Research Center, P.O. Box 450, Kitale, Kenya*

E-mail: elkananyambati@yahoo.com

[2] *University of Florida, Gainesville, FL, USA*

**Corresponding Author*

SUMMARY

Declining soil fertility and inadequate and low quality feed resources limit smallholder crop yields and dairy production in Kenya. Herbaceous legumes provide an alternative to the use of commercial-nitrogen (N) sources for cereal crops and livestock production. The objectives of this study were to 1) determine the herbage yield from relay-cropped *Mucuna* [*Mucuna pruriens* (L.) DC. Var. *utilis* (Wright) Bruck] and *Lablab* [*Lablab purpureus* (L.) Sweet cv. Rongai] and 2) evaluate the nutritive value of these two herbaceous legumes. Defoliation to 10 cm above ground provided an average of 0.9 and 1.8 t ha^{-1} of *Mucuna* and *Lablab* fodder, respectively, with crude protein of 154 and 122 g kg^{-1} and digestibility of 638 and 692 g kg^{-1}, suggesting that these legumes were of good quality. Harvested fodder was 52 and 76% of the above-ground leaf + stem herbage from *Mucuna* and *Lablab*. Upper canopy herbage of these legumes has potential as a dry-season supplement, but this practice significantly reduces the quantity of nutrients to be incorporated into the soil for subsequent crops.

Key words: Cropping systems, fodder quality, nutritive value.

INTRODUCTION

In the tropics, declining soil fertility and the inadequacy of livestock feeds, particularly the lack of protein during the dry season, are major production constraints in many smallholder, mixed crop-livestock farming systems. These constraints partly arise from land limitations, which cause farmers to practice continuous cropping and grazing, and partly from inadequate or lack of use of fertilizers. Although cycling of crop stover through livestock and the use of manure and urine to fertilize soil have been an important link between livestock and soil fertility worldwide (Powell and Valentine, 1998), the quantities of manure typically available on tropical smallholder farms are not enough to replenish nutrients removed in grain and crop residues (Williams *et al*., 1995). In recent years, intercropping of leguminous green manure/cover crops has been evaluated in many parts of the tropics where the use of commercial N fertilizers is not economically feasible. The use of forage legumes in smallholder farms in the tropics has generally been low (Thomas and Sumberg, 1995). For increased adoption, legume-based forage technologies in smallholder farms must fit into the overall farming strategy based on food production for the family household.

Mucuna and *Lablab* are among the species adapted to cropping systems in sub-Saharan Africa that could be relay-cropped into maize-based cropping systems (Weber, 1996). This study is one part of a larger project evaluating the use of *Mucuna* and *Lablab* for both soil fertility improvement and as livestock feed in the subhumid highlands of northwestern Kenya (Nyambati, 2002). The broad objectives of the larger project were to 1) determine if the introduction of additional legume intercropping and green manuring to the current maize-bean system affects maize and bean yields, 2) evaluate fodder production and the nutritive value of legumes in alternative cropping systems and assess their value as a supplement to lactating cows during the dry season, and 3) determine the extent to which harvesting the topgrowth of legumes for fodder reduces their beneficial impact on soil fertility as measured by yield of subsequent maize and beans. The specific objective of the experiment reported here was to assess the nutritive value of the harvested top-canopy biomass of *Mucuna* and *Lablab* when they were relay cropped in maize in the subhumid highlands of northwestern Kenya.

MATERIALS AND METHODS

Study site and treatments

The study was conducted at the National Agricultural Research Center (NARC), Kitale (1ºN and 35ºE) and on six farmers' fields in the community of Tumaini, 25 km north of Kitale, in the subhumid highlands of northwestern Kenya. The altitude in the region is 1860 m and the soil a humic ferralsol (oxisol) (pH=5.5). The area has a unimodal rainfall pattern lasting from mid-March to mid-November, followed by a dry season of 3-4 months. This pattern allows for one late maturing hybrid maize crop and two short duration crops of common bean intercropped with maize. Annual rainfall averaged 1080 mm year^{-1} during the trial. Other characteristics of the site and treatments were described (Nyambati, 2002).

The treatments were two legume species (*Mucuna* and *Lablab*) arranged in three replications of a randomized block design. The legumes were relay cropped in maize in August 1999 and 2000 after harvest of a crop of common bean that was intercropped with maize from April to August each year. Maize was planted in April at an inter- and intra-row spacing of 75 cm by 30 cm (target population of 44 444 plants ha^{-1}), respectively, using two seeds per hill of hybrid 614D maize seed. The legumes were planted between the maize rows at an intra-row spacing of 30 cm using two plants per hill (target population of 88 888 plants ha^{-1}). At planting the maize received a basal application of 13 kg P ha^{-1}.

Top-canopy biomass sampling

After harvesting maize in November each year, the legumes were hand weeded and continued growing into the dry season. The legumes were cut to stubble of 10 cm before land preparation in mid-March, 210 days after planting (DAP). Prior to clipping the entire plot, two representative 0.5-m^2 quadrats were sampled. Herbage above 10 cm (top canopy) was composited across the two sites and part of the sample was separated into leaf and stem fractions. Fractions were dried, weighed, and ground for laboratory analysis. In these same quadrats, all material below 10 cm was removed at soil level (lower canopy), composited across the two sites, and separated into leaves and stems. Fresh weights of each fraction were taken, fractions were sub-sampled, and the remainder of the herbage (below 10 cm only) was returned to the two sampling sites. The sub-sample was weighed fresh, dried at 60ºC for 48 h, weighed again, and then ground for analysis.

Chemical and statistical analysis

First-year samples of live leaf, stem, and leaf plus stem top-canopy fractions were analyzed for crude protein (CP), ash, neutral detergent fiber (NDF), and *in vitro* dry matter (DM) digestibility (IVDMD). Second-year samples were analyzed for CP only. Total plant N was analyzed by Kjeldahl digestion with concentrated sulfuric acid, followed by colorimetric determination (Anderson and Ingram, 1993; AOAC, 1990). The NDF was determined by the method of Goering and Van Soest (1970) as modified by Van Soest *et al.* (1991). *In vitro* DM digestibility was determined using the procedure of Tilley and Terry (1963).

The general linear models procedure of SAS was used to test legume species effects on legume biomass and nutritive value (SAS, 2001). The models for biomass and plant-part proportions include the legume and year effects and their interaction, but only the legume effect was tested for chemical composition because these data were collected only in the first year. Treatment effects were considered significant at $P \leq 0.10$.

RESULTS AND DISCUSSION

Mass and plant-part proportions

The dry matter yields of August-intercropped *Mucuna* and *Lablab*, of about 2 t ha^{-1} (Table 1), were low compared to the yields of over 5 t ha^{-1} when planted as monocrops at the beginning of the growing season in April (Nyambati, 2002). This type of yield reduction is consistent with previous reports (Wortmann *et al.*, 2000) and can be attributed primarily to a shift in the season of growth to include the dry season. In addition, when planting was done during the relatively heavy rains of August, the germination of *Mucuna* was slow and uneven and the *Lablab* seedlings were susceptible to aphid damage (*Aphis craccivora*) and leaf rust (Anthracnose, caused by *Colletotrichum spp.*). After harvesting maize, the legumes were able to survive and continued to grow during the dry season. *Mucuna* had not flowered at the time of defoliation (210 DAP) while *Lablab* had set mature seed (360 kg ha^{-1}). The results show that relay cropping *Mucuna* or *Lablab* into maize after harvesting a first crop of common bean in August, and defoliating them to a 10-cm stubble at 210 DAP could provide from 1 t ha^{-1} yr^{-1} of *Mucuna* herbage to 1.8 t ha^{-1} yr^{-1} of *Lablab* herbage (averages of two seasons) in soils with relatively good soil fertility (Table 1). On farmers' fields where soil fertility was typically lower, defoliation of *Mucuna* and *Lablab* yielded less herbage, and the average was only about 0.9 t DM ha^{-1} for both species (Table 2).

In on-station conditions, herbage production did not differ by year ($P > 0.10$) for DM mass and plant-part proportions, except for lower canopy (below 10 cm) leaf and leaf + stem fractions ($P = 0.002$). Because the primary focus of this work was top-canopy herbage and to simplify presentation of the data, means across the 2 yr are reported in Table 1. There was no difference ($P = 0.461$) between *Mucuna* and *Lablab* in the top-canopy leaf mass, however, *Lablab* had greater stem ($P = 0.023$) and leaf + stem fractions ($P = 0.096$).

Table 1. Herbage dry matter mass and plant-part proportions of top-canopy (above a 10-cm stubble) and lower canopy (below a 10-cm stubble) *Mucuna* and *Lablab* relay cropped in maize at NARC, Kitale in 2 yr.

Fraction	Treatment		SEM	Legume effect
	Mucuna	*Lablab*		
Top canopy (TC)	-------------t ha^{-1} -------------			--- P value ---
TC-Leaf	0.72	0.87	0.08	0.461
TC-Stem	0.29	0.94	0.13	0.023
TC-Leaf + stem	1.01	1.81	0.20	0.096
TC-Leaf:stem	2.94	1.01	0.34	0.001
Lower Canopy (LC)				
LC-Leaf	0.48	0.08	0.09	0.021
LC-Stem	0.58	0.50	0.08	0.389
LC-Leaf + stem	1.05	0.58	0.16	0.064
LC-Leaf:stem	0.84	0.17	0.11	0.024
Total	2.06	2.39	0.27	0.485
TC:Total	0.52	0.76	0.04	0.011

The top-canopy herbage of *Mucuna* had a higher (P = 0.001) leaf:stem ratio. *Mucuna* leaf mass in the lower-canopy herbage was greater (P = 0.020) than that of *Lablab*, but there was no difference (P = 0.389) in lower-canopy stem mass. Also *Mucuna* leaf + stem in the lower canopy was greater (P = 0.064) than for *Lablab*. The greater mass in the top canopy for *Lablab* than *Mucuna* can be explained by growth morphology of the two legumes. *Lablab* has an upright growth habit, and defoliation to a 10-cm stubble resulted in a greater (P = 0.011) percentage (76%) of total DM removed than with *Mucuna* (52%) which both climbs and trails (Table 1).

Chemical composition

Under on-station conditions, there were no differences in CP (P = 0.461) or NDF (P = 0.582) in the leaf fraction of top-canopy herbage of *Mucuna* and *Lablab*, but *Lablab* leaf had higher (P = 0.003) IVDMD (Table 3). The CP concentration of *Mucuna* stem was greater (P = 0.022) than that of *Lablab*, and *Lablab* stem fraction contained higher (P = 0.006) NDF concentration than *Mucuna*. There was no difference (P = 0.681) in stem IVDMD between the legumes. The CP and IVDMD of total (leaf + stem) herbage were also not different between the two legumes, although IVDMD tended to be greater (P = 0.110) for *Lablab* (Table 3). *Lablab* contained greater (P = 0.003) NDF concentration than *Mucuna*. Top-canopy herbage harvested on station during the 2000/2001 growing season was analyzed only for CP, and there was no difference (P = 0.174) in leaf CP concentration, but the stem fraction of *Mucuna* contained higher (P = 0.064) CP concentration than *Lablab* (Table 4). The *Mucuna* leaf + stem fraction removed from farmers' fields contained a higher mean CP (177 g kg^{-1}) than *Lablab* (133 g kg^{-1}), *Lablab* contained higher NDF concen-tration than *Mucuna*, and there was no difference in IVDMD (Table 2).

The CP of top-canopy herbage of *Lablab* harvested at 210 DAP in this study was comparable to total above-ground herbage harvested at 140 DAP (Agyemang *et al.*, 2000). The NDF concentration of top-canopy herbage was lower than that reported for above-ground, whole-plant herbage (Agyemang *et al.*, 2000).

Table 2. Biomass and nutritive value of the top-canopy (above a 10-cm stubble) herbage of *Mucuna* and *Lablab* relay cropped in maize on farmers' fields in Tumaini at Kitale, Kenya. Means are across farms (n = 6).

Biomass constituent	Treatments[1]			P value
	Mucuna	*Lablab*	SEM	
Herbage mass	-------------t ha^{-1}-------------			
1999/2000	1.18	1.47	0.18	0.293
2000/2001	0.67	0.30	0.09	0.106
Nutritive value†	-------------g kg^{-1} ------------			
1999/2000				
CP	175	118	11.5	0.007
Ash	94	73	4.3	0.022
NDF	374	520	43.4	0.001
IVDMD	659	691	18.4	0.442
2000/2001				
CP	179	147	16.2	0.217

† CP = Crude protein; NDF = Neutral detergent fiber; IVDMD = *In vitro* dry matter digestibility.

The higher NDF concentration in *Lablab* was expected because *Lablab* had lower leaf:stem ratio than *Mucuna* (Table 1). The IVDMD of top canopy biomass of *Mucuna* and *Lablab* in this study was higher compared to *Mucuna* and *Lablab* forages harvested at maximum biomass yield (16 and 18 weeks after planting (WAP), respectively; Maasdorp *et al*., 1997). This could partly be attributed to the higher proportion of leaves in the top-canopy biomass compared to total above-ground biomass (Nyambati, 2002). Although *Lablab* contained greater NDF concentration than *Mucuna*, it tended to have greater IVDMD than *Mucuna*, in agreement with the results of Maasdorp *et al.* (1997) and those from another component of the work by Nyambati (2002). This could be attributed in part to the higher lignin concentration in *Mucuna* biomass compared to that in *Lablab* (Nyambati, 2002).

Previous studies have shown that *Mucuna* has an aggressive twining and trailing habit (Singh and Relwani, 1978) that could reduce the yield of maize when the legume is interplanted earlier than 5 WAP maize (Maasdorp *et al*., 1997; Versteeg *et al*., 1998). Our results show that upper canopy herbage obtained after defoliating *Mucuna* and *Lablab* at 10 cm above the ground is of higher nutritive value than that of whole biomass hay. Thus, defoliation is a management option that can provide high quality fodder for livestock while reducing the competitive ability of the legumes. Moreover, the adoption of green manures has been shown to be higher when they provide benefits in addition to soil fertility improvement (Versteeg *et al.*, 1998). A complementary study (Nyambati, 2002) found that defoliation reduces the quality of the *Mucuna* residue and may enhance the efficiency of N uptake by succeeding maize. Also, at the time of residue defoliation and incorporation, relay-cropped *Lablab* produced a higher seed yield than a second crop of common beans.

Results from this study show that *Mucuna* and *Lablab* have potential to provide from 0.9 to 1.8 t ha^{-1} yr^{-1} of livestock fodder when relay cropped in maize and defoliated to 10 cm at 210 DAP. A smallholder farmer keeping one dairy cow would need 0.225 or 0.125 ha yr^{-1} of relay-cropped *Mucuna* or *Lablab*, respectively, to produce sufficient herbage for supplementation (2.5 kg cow^{-1} d^{-1}) for the 3-mo dry season when feed scarcity is most severe.

Table 3. Nutritive value of top-canopy (above a 10-cm stubble) biomass of *Mucuna* and *Lablab* relay cropped in maize during the 1999/2000 growing season at NARC-Kitale.

Fraction†	Treatment		SEM	Legume effect
	Mucuna	*Lablab*		
	--------------g kg^{-1} --------------			-- P value --
Leaf				
CP	145	152	4.4	0.461
Ash	65	90	5.7	≤ 0.001
NDF	337	365	15.3	0.582
IVDMD	613	764	34.3	0.003
Stem				
CP	115	86	6.7	0.022
Ash	49	88	8.8	0.001
NDF	419	517	24.4	0.006
IVDMD	601	649	46.1	0.681
Leaf + stem				
CP	130	111	9.4	0.281
Ash	68	86.3	4.3	0.002
NDF	325	446	29.3	0.003
IVDMD	617	693	20.1	0.110

† CP = Crude protein; NDF = Neutral detergent fiber; IVDMD = *In vitro* dry matter digestibility.

Table 4. Crude protein concentration of top-canopy (above a 10-cm stubble) biomass leaf and stem fractions of *Mucuna* and *Lablab* relay cropped in maize during the 2000/2001 growing season at NARC, Kitale.

Fraction	Treatment		SEM	Legume effect
	Mucuna	*Lablab*		
	--------------g kg^{-1} ---------------			-- P value --
Leaf	246	281	10.6	0.174
Stem	135	111	8.61	0.064

These areas are feasible given that the same piece of land on which the legumes grow is used for maize and common bean production. In a feeding experiment to evaluate the potential of *Mucuna* or *Lablab* hay as protein supplements for dairy cows (Nyambati, 2002), supplementation resulted in an extra 0.41 kg milk cow^{-1} d^{-1} and an additional 208 kg cattle manure DM yr^{-1}. The additional manure could supply 5 kg N, 0.6 kg P, 0.53 kg K, 1.4 kg Mg, and 5.5 kg Ca yr^{-1} (13 kg of nutrients yr^{-1}).

CONCLUSION

This study has shown that *Mucuna* or *Lablab*, relay cropped into maize after harvesting a first crop of common beans and defoliated to a 10-cm stubble, can provide fodder that could be a valuable protein supplement during the dry season. By giving direct and immediate benefits to farmers, this practice could alleviate a significant bottleneck to greater adoption of green manure legumes for soil fertility improvement.

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