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Full Length Research Paper

Potential use of green manure legume cover crops in smallholder maize production systems in Limpopo province, South Africa

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Much of the smallholder farming sector in Limpopo province of South Africa is located on infertile degraded soils, with nitrogen being one of the predominantly deficient nutrient. The use of green manure legume cover crops in combination with Nitrogen (N) fertilizers is one option for improving N inputs into such farming systems. The objectives of this study were to (1) screen a number of green manure legume cover crop species, mucuna (*Mucuna pruriens*); sunhemp (*Crotalaria juncea*), lab-lab (*Lablab purpureus*); cowpea (*Vigna unguiculata*) and butterfly pea (*Clitoria ternatea*) in order to determine their suitability for the region and (2) to determine the effect of the green manure and nitrogen fertilizer on maize yield. The legumes were screened during the winter seasons of 2005 and 2006 and the summer seasons of 2005 - 2006 and 2006 - 2007. The best-bet legumes (mucuna, sunhemp and lab-lab) were then evaluated to determine their effect on maize grain yield with or without nitrogen fertilizer. The treatments imposed were mucuna, sunhemp, lab-lab, and a control with (75 kg N ha^{-1}) or without (0 kg N ha^{-1}) N fertilizer. Maize was harvested at maturity to determine the grain yield. In the screening trials, legume biomass yield ranged between 41 to 1,672 kg ha^{-1}, while the N content ranged between 2 to 58 kg N ha^{-1} in the winter trials. In the summer trials, biomass yield ranged from 899 to 13,586 kg ha^{-1}, while the N content ranged between 27 to 302 kg N ha^{-1}. Maize yield ranged between 4.0 to 6.4 tons ha^{-1} in the 2006 - 2007 seasons and between 5.8 to 8.4 tons ha^{-1} in the 2007- 2008 season. Control (-N) treatment had the lowest yield in both seasons. Overall, legume treatments, with or without N fertilizers produced between 19 to 58% more grain yield than control (-N). Of the green manure legumes screened, mucuna, lablab and sunhemp seem to be the most suitable green manure legume cover crops for this area and should be planted in the early summer season to maximize biomass production and N accumulation. Use of green manure legumes has the potential to increase maize yield in smallholder farms in Limpopo province.

Key words: Green manure legumes, maize, N fertilizer, smallholder farms.

INTRODUCTION

In Limpopo province of South Africa, the smallholder farms are located mostly in the former homeland areas and they cover approximately 30% of the provincial land surface (White Paper on Agriculture, 1995). Most of the farms are located on infertile degraded soils, where nutrient deficiencies, predominantly nitrogen limit the production of maize which is the main staple food. In addition, vast part of the province where majority of the smallholder farms are located is semi-arid. Due to the limited financial resources of these smallholder farmers, very little or no fertilizers are applied to their crops, leading to very low production, primarily for subsistence and little marketable surplus.

Therefore, in order to maintain maize productivity in these smallholder systems, the integration of the small amounts of nitrogenous (N) fertilizers applied by the farmers along with N from Green Manure Legume (GML) cover crops may offer a strategy to meet the N needs of the smallholder farmers. Short duration fallows with cover crops and grain legumes have been shown to considerably increase succeeding maize yields (Balasubramanian and Nguimgo, 1993; Horst and Haerdter, 1994; Ile et al., 1996; Carsky et al., 2001). Maize grain yields of greater than 4 Mg ha^{-1} were

Table 1. Some chemical and physical properties of the soil from the 0-20 cm depth at the experimental site.

Parameter measured	Value
pH[1]	5.53
Organic Carbon (%)[2]	1.94
Phosphorus (mg kg^{-1})[3]	2.55
Total Nitrogen (%)[4]	0.061
Na ($cmol_c$ kg^{-1})	0.142
K ($cmol_c$ kg^{-1})	0.14
Ca ($cmol_c$ kg^{-1})	3.08
Mg ($cmol_c$ kg^{-1})	1.75
CEC ($cmol_c$ kg^{-1})[5]	10.08
Sand (%)	11.2
Silt (%)	24.8
Clay (%)	64

[1]pH was determined in 1:2.5 (Soil: water). [2]Organic carbon was determines by Walkley Black method. [3]Phosphorus was determined by Bray 1. [4]Total N determined by the Kjeldhal method. [5]Exchangeable cations and CEC determined by Ammonium acetate extraction. Particle size was determined by the hydrometer method.

obtained in southern Cameroon after a short term fallow with *Mucuna pruriens* (Hauser and Nolte, 2002). Green manuring may also help maintain or build organic matter which will in turn help improve the soil's structure, pore size, water holding capacity and inorganic fertilizer use efficiency (through increased cation exchange capacity).

Despite the widespread use of GML cover crops by smallholder farmers in most tropical areas to improve soil fertility (N and organic matter), this practice is yet to take root amongst smallholder farmers in Limpopo province. GML are widely used to improve soil fertility in some commercial farms and in the sugarcane belt area in Kwazulu Natal province.

The objectives of this study was therefore to (1) screen a number of green manure legume cover crop species in order to determine their suitability for the region and (2) to determine the effect of green manure and nitrogen fertilizer on maize yield.

MATERIALS AND METHODS

This study was conducted in Thohoyandou, Limpopo province of South Africa located approximately 22°35'14.0"S and 30°15'50.3"E. The climate is characterized by arid and semi-arid, with an annual rainfall of ±500 mm per annumn and temperature range from a minimum of 10℃ during winter to a maximum of 40℃ during summer. The site is characterized by deep well-drained clay soil.

Field experimental set-up

Green manure legume screening experiment

Five GML cover crops, mucuna, sunhemp, lab-lab, cowpea and butterfly pea were screened during the winter seasons of 2005 and 2006 and the summer seasons of 2005 - 2006 and 2006 - 2007. The legumes were planted in plots measuring 5 × 5 m and arranged in a randomized complete block design with three replications. The legumes were allowed to grow for a period of between 3 - 4 months before biomass production was determined. Above-ground and root biomass production was determined by sampling from an area measuring 1m×1m randomly within the plots, by uprooting whole plants and separating the shoots from the roots. The roots were then washed thoroughly to remove all the soil particles. The plant material was dried at 70° C for at least 48 h before weighing to determine the biomass yield. The material was then ground, and analyzed for total nitrogen and carbon using Dumas dry combustion method.

Maize, N fertilizer and green manure experiment

The best-bet legumes based on the screening experiment (mucuna, sunhemp, and lab-lab) were then evaluated to determine their effect on maize grain yield with or without nitrogen fertilizer. The three legumes were planted in plots measuring 5 m × 5 m arranged in a completely randomized block design. Two control plots [(control (+N) and control (-N)] were also included in the treatments. After 3 - 4 months, biomass was determined and the legumes incorporated into the soil. The treatments imposed were mucuna, sunhemp, lab-lab, and a control with (75 kg N ha^{-1}) or without (0 kg N ha^{-1}) N fertilizer. The N source used in the fertilizer treated plots was Lime Ammonium Nitrate (LAN) (28% N). The 75 kg N ha^{-1} was split applied with 50 kg N ha^{-1} applied at planting and 25 kg N ha^{-1} applied as top-dress. Phosphorus was applied uniformly to all the plots at a rate of 50 kg ha^{-1} as super grow (20.3%P). Maize (hybrid SNK 2147) was then planted at a spacing of 90 cm × 25 cm (44444 plants per ha^{-1}) approximately 2 weeks after incorporation of GML residues. Maize was harvested at maturity to determine the grain yield.

Statistical analysis

Using randomized complete block design model, analysis of variance was conducted using the General LINEAR Model (GLM) procedure of SAS software version 9.1 (SAS Institute, Inc., 2003). The LSD test was used to separate the treatment means.

RESULTS

Soil characteristics and temperature data

Some soil physical and chemical properties of the experimental site are shown in Table 1. Average daily temperature during the winter screening trials was 19.5 and 17.7℃ in 2005 and 2006, respectively. Average daily temperature during the summer screening trials was 23.8 and 25.4℃ in 2005-2006 and 2006-2007 seasons, respectively.

Green manure screening

In the screening trials, legume biomass yield ranged between 41 (sunhemp) to 1672 kg ha^{-1} (lablab), while the N content ranged between 2 (sunhemp) to 58 (cowpea)

Table 2. Green manure above-ground and root biomass and N uptake during winter screening.

Cover crop	Winter 2005			
	Biomass (kg ha^{-1})	N Uptake (kg ha^{-1})	Root biomass (kgha^{-1})	N uptake (kg ha^{-1})
Mucuna	644 a	17 a	175 a	3 a
Sunhemp	41 b	2 b	20 b	0.3 b
Lablab	767 a	24 a	222 a	4 a
Cowpea	NS	NS	NS	NS
Butterfly pea	DNG	DNG	DNG	DNG
CV (%)	41.6	43.6	49.8	48.0
			Winter 2006	
Mucuna	685 ab	25 ab	43 bc	0.8 b
Sunhemp	705 ab	23 ab	91 ab	1 b
Lablab	1,672 a	52 a	106 a	1 b
Cowpea	1,473 a	58 a	145 a	3 a
Butterfly pea	54 b	3 b	25 c	0.6 b
CV (%)	62.2	59.2	40.3	50.4

NS - No sufficient biomass to sample. DNG - Did not germinate due to very low precipitation.

Table 3. Green manure above-ground and root biomass and N uptake during summer screening.

Cover crop	Summer 2005-2006			
	Biomass (kg ha^{-1})	N Uptake (kg ha^{-1})	Root biomass (kg ha^{-1})	N uptake (kg ha^{-1})
Mucuna	3,681 b	70 b	449 ab	7 b
Sunhemp	1,561 c	28 c	390 bc	4 b
Lablab	6,979 a	124 a	624 a	10 a
Cowpea	899 c	27 c	223 c	4 b
Butterfly pea	1,623 c	56 b	306 bc	5 b
CV (%)	18.6	21.6	28.8	27.1
			Summer 2006 - 2007	
Mucuna	9,772 ab	279 a	808 bc	16 b
Sunhemp	13,586 a	302 a	4,009 a	40 a
Lablab	8,701 bc	198 ab	947 b	15 b
Cowpea	4,044 cd	168 ab	234 d	3 c
Butterfly pea	2,108 d	73 b	594 c	12 b
CV (%)	32.9	35.4	14.1	16.4

kg N ha^{-1} in the winter trials (Table 2). Biomass yield produced during the winter period of 2005 were generally lower than in winter period of 2006. Root biomass yield ranged between 20 (sunhemp) to 222 (lablab) kg ha^{-1} and contributed between 0.3 (sunhemp) and 4 (lablab) kg N ha^{-1}. High coefficients of variations (CV's) were observed in both periods of the screening trial.

In the summer trials, biomass yield ranged from 899 (cowpea) to 13586 kg ha^{-1} (sunhemp), while the N content ranged between 27 (cowpea) to 302 kg N ha^{-1} (sunhemp) (Table 3). In the 2005-2006 summer seasons, lablab produced significantly higher aboveground biomass and accumulated significantly higher amount of N than all the GML. In the 2006-2007 seasons, sunhemp produced significantly higher biomass than lablab, cowpea and butterfly pea, but was not different from mucuna. Root biomass ranged between 223 to 4009 kg ha^{-1} for cowpea and sunhemp, respectively and contributed between 4 (cowpea and sunhemp) and 40 (sunhemp) kg N ha^{-1}. Generally, the coefficients of variations recorded during the summer season trials were much lower than during the winter screening trials.

Maize, N fertilizer and green manure experiment

Green manure above-ground and root biomass and N uptake prior to incorporation and planting of maize in

Table 4. Green manure above-ground and root biomass and N uptake preceding the maize crop planted in 2006/7 and 2007/8 seasons.

Cover crop	2006-2007 Season			
	Biomass (kg ha^{-1})	N Uptake (kg ha^{-1})	Root biomass (kg ha^{-1})	N uptake (kg ha^{-1})
Mucuna	482 ab	20 a	36 ab	1 a
Sunhemp	642 a	21 a	70 a	0.8 ab
Lab-lab	313b	13 a	25 b	0.4 b
CV (%)	16.4	23.8	35.2	27.3
	2007- 2008 Season			
Mucuna	4,563 a	150 a	224 b	ND
Sunhemp	5,773 a	162 a	984 a	ND
Lab-lab	4,677 a	141 a	319 b	ND
CV (%)	19.2	22.3	17.8	ND

ND. Not determined

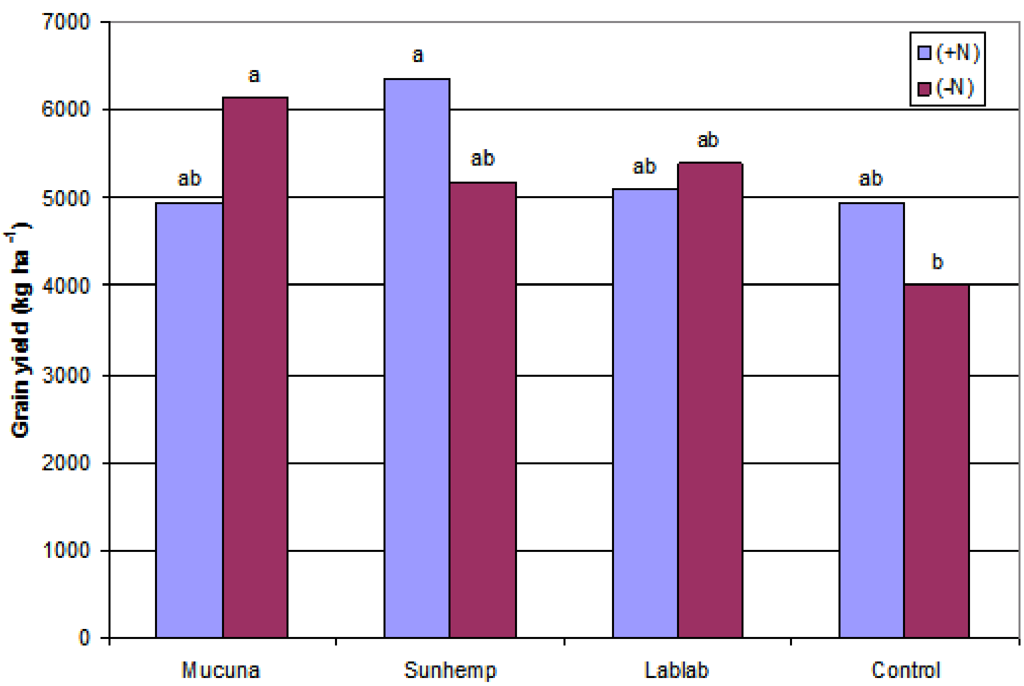

Figure 1. Maize grain yield 2006 – 2007.

2006-2007 and 2007-2008 seasons are shown in Table 4. Aboveground biomass yield ranged from 313 (lab-lab) to 5773 kg ha^{-1} (sunhemp), while the N content ranged between 13 (lab-lab) to 162 kg N ha^{-1} (sunhemp). Aboveground biomass production was much lower in 2006 as compared to 2007. Root biomass ranged between 25 (lablab) to 984 (sunhemp) kg ha^{-1}.

Maize yield following GML ranged between 4.0 to 6.4 tons ha^{-1} in the 2006-2007 seasons (Figure 1) and between 5.8 to 8.4 tons ha^{-1} in the 2007-2008 seasons (Figure 2). Control (-N) treatment had the lowest yield in both seasons.

DISCUSSION

Results obtained from the screening trials indicate that best GML growth, biomass production and N accumulation are attained when the legumes are planted during the summer season.

The low temperatures during winter severely limit the growth, biomass production and N accumulation of the legumes. However, with the exception of winter 2005, the biomass yield and N content obtained in winter 2006 compared well with results obtained elsewhere (Jeranyama et al., 2000) except for butterfly pea.

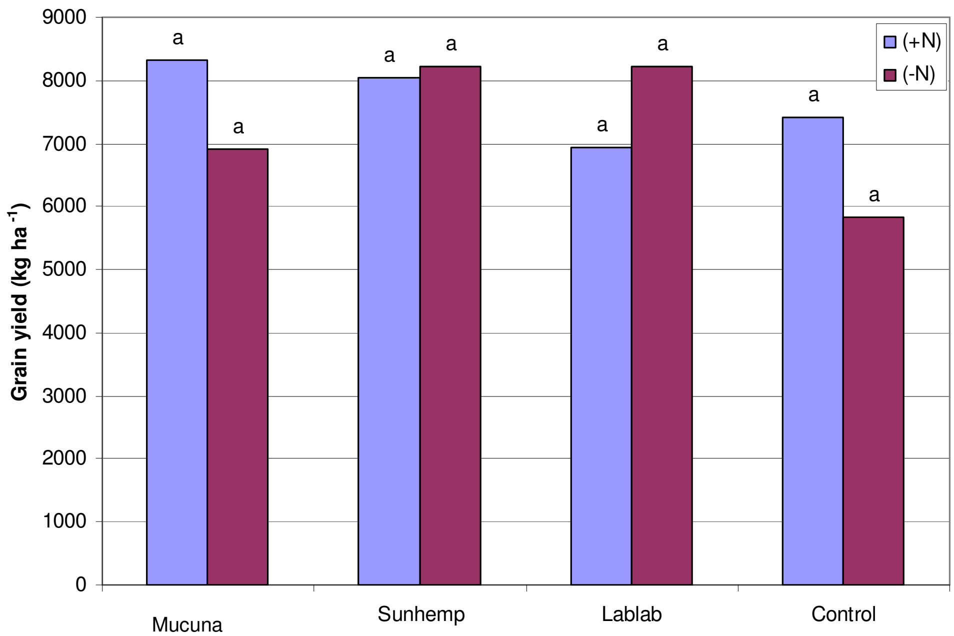

Figure 2. Maize grain yield 2007-2008 seasons.

Biomass yield and N accumulation obtained during summer season is however much higher than reported in most literature. This may be attributed to the high rainfall and temperatures during the summer season which may be favourable for the growth of the GML.

Based on biomass production and N accumulation, sunhemp, mucuna and lablab seem to be the best-bet legumes for this region. However, because the main cropping season in this region is during summer, and given the shortage of land due to high population density, very few farmers may be willing to have their land under GML instead of food crops.

Three viable options may be adopted by the farmers. The first option may be suitable for farmers with enough land to allow for green manure fallow during summer, or rotation system (green manure-maize) and terminate the green manure growth at flowering time and leave the residues on the soil surface to decompose until the next planting season. Results obtained by Odhiambo et al. (2009) from a two year study on green manure-maize rotation system in Limpopo province showed that cowpea, mucuna, lablab, butterfly pea and sunhemp treatments gave yield increases of 77, 85, 134, 125 and 103%, respectively, above the control (-N) treatment.

The limitation of using this option is that land in this region is communally owned and after harvest, livestock is allowed to graze communally in the farms and therefore poses the risk of the residues being eaten up by the animals.

The second option may be to establish the GML in the early spring and incorporate during summer, prior to planting maize. Due to the dry conditions that prevail during early spring, this approach may be suitable for farmers in irrigation schemes who normally start planting maize in early spring due to availability of water. A study by Odhiambo and Netshivhodza (2008) conducted in smallholder farms at two irrigation schemes using this option showed that green manure alone increased maize grain yield significantly compared to the control (-N). A combination of GML (mucuna, sunhemp, lablab and cowpea) and 60 kg N ha^{-1} gave yield increment of between 23 to 118%. The third option maybe to relay plant or intercrop the GML with maize. This approach was not evaluated in this study but remains a viable option.

In terms of maize grain yield following green manure incorporation, overall, legume treatments, with or without N fertilizers produced between 19 to 58% more grain yield than control (-N). Studies conducted in the mid-altitude areas of Uganda have shown that *Crotalaria ochroleuca* green manure can increase maize yield by 39% (Fischler et al., 1999). In Kenya, averaged over two years, *C.ochroleuca* and *Mucuna pruriens* green manure improved maize grain yield by 1.5 t ha^{-1} compared to no incorporation (Ojiem et al., 2000), while in southern Cameroon, Hauser and Nolte (2002) obtained maize yields greater than 4 t ha^{-1} after a short-term fallow with mucuna. In Tanzania, farmers have used sunhemp to increase their maize yield from 12.4 to 45 bags ha^{-1} (1116 to 4050 kg ha^{-1}) (Lupatu and Kilimwiko, 1991).

Conclusions

Of the green manure legumes screened, mucuna, lablab and sunhemp appear to be the most suitable green manure legume cover crops for this region. However, to maximize biomass production and N accumulation, the GML must be established at the appropriate time based on the farmer's circumstances, for example, availability of enough land for fallow, water for irrigation, or practicing of relay cropping or intercropping of the GML with maize. Use of green manure legumes in combination with N fertilizers has the potential to increase maize yield in smallholder farms in Limpopo province.

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