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Full Length Research Paper

Causes of green manure legume - maize rotation on maize grain yield and wild plant infestation levels

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The use of green manure legumes (GLM) as cover crops in rotation with maize has the potential to enhance maize yields. The objectives of this study were to determine the effect of GML - maize rotation system on (i) maize growth and yield and, (ii) weed infestation levels. The two year (2007/8 and 2008/9 seasons) rotation system consisted of five GML cover crops, viz. mucuna, lablab, sunhemp, cowpea and butterfly pea followed by maize. GML biomass ranged between 0.8 and 13.6 Mg ha^{-1}, while nitrogen (N) content ranged between 10 and 279 kg N ha^{-1}. Maize grain yield following GML ranged between 2.6 and 10.59 Mg ha^{-1}. In 2007/8 season cowpea, mucuna, lablab and sunhemp plots had a lower weed dry matter (5.30, 11.97, 5.83 and 21.03 g m^{-2}, respectively) than the control (+N) (49.47 g m^{-2}). In 2008/9 season, at 6 - 8 WAP, control (+N) had a higher weed dry matter than the other treatments, except of butterfly pea. The dominant weed species were Mexican ricardia (*Ricardia brasiliensis*), Yellow nutsedge (*Cyperus esculentus*), Guinea-fowl grass (*Rottbollia cochinchinesis*), Witch weed (*Striga asiatica*), Bermuda grass and *Cynodon* species. Green manure legume fallows can increase maize grain yield significantly and suppress the weed population as compared to natural fallow. However, maximizing biomass production and N accumulation is critical in order to reap the benefits of green manure. Hence, integrating GML into the existing cropping system will require that appropriate timing for planting GML be well established.

Key words: Green manure legume, maize, rotation, weed infestation.

INTRODUCTION

Maize (*Zea mays* L.) is the main crop grown by small-holder farmers in Limpopo province. However, yields are often very low partly because of inadequate supply of nutrients due to declining soil fertility (Ramaru et al., 2000). With the increasing population pressure, long periods of fallowing are no longer practiced and land is cropped continuously after clearing. Moreover, fertilizer use is low because of high cost, and risks from erratic and limited rainfall. The integration of green manure legumes as cover crops into the cropping systems has the potential to enhance yields of subsequent crops, an effect which can be largely attributed to the increase in plant available nitrogen (N) in the soil as a result of (i) the conservation of soil N through atmospheric nitrogen gas (N_2) fixing by the legumes in comparison to non-fixing plants (Giller and Wilson, 1991) and (ii) the enhanced mineralization of soil organic N during decomposition of legume residues (Jenkinson et al., 1985).

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, *Crotalaria 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 of >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} (Lupatu and Kilimwiko, 1991).

Also, pulses such as cowpea, guar (*Cyamopsis tetragonoloba*), pigeon pea and groundnut were found to increase yield of subsequent cereal crops in semi-arid India by an equivalent effect of 30 - 40 kg N ha^{-1} (Lal et

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Abbreviations: GLM, Green manure legumes; **N,** nitrogen; **C,** carbon.

al., 1978; Kumar Rao et al., 1983). The authors noted that the N contribution of legumes to other crops in the system depends on the species, biological N_2 fixation and the growth of legumes as determined by climate and soil, and management of residues. Grain legumes contribute less N than herbaceous legumes to subsequent crops in rotation (Giller et al., 1997), because most of the N fixed biologically by grain legumes is translocated to grain and both the grain and the residues are invariably removed from field for human and livestock use. Although the accumulation of N in leguminous crops can exceed 500 kg N ha^{-1} under tropical conditions, the actual contribution of N to subsequent crops is more modest, 20-100 kg N ha^{-1} (Peoples and Craswell, 1992).

Legume cover crops can also suppress weeds more quickly than natural fallow. Chikoye and Ekeleme (2001) and Chikoye et al., 2001; 2002) reported that Mucuna [*Mucuna cochinsinensis* (Lour.) A. Chev.] reduced *Imperata cylindrica* (L) Beauv. dry matter by over 80% within 1 - 3 years in the moist savannah of West Africa. Mucuna has also been successfully used to control *Imperata cylindrica* in Benin (Bunch, 1995). The degree of reduction in weed density by cover crops depends largely on species, management systems, and climatic conditions (Bárberi and Mazzoncini, 2001; Ekeleme et al., 2003). Other soil related benefits attributed to legumes include breaks to crop pests and diseases during rotation, reducing erosion as cover crops, and improving soil physical properties (Peoples and Craswell, 1992).

Despite the use of green manure legume cover crops to improve soil fertility and control weeds being a well known practice in the tropics, it is yet to take root amongst the smallholder farmers in Limpopo province, South Africa. Therefore, the objectives of this study were to determine the effect of green manure legume cover crops - maize rotation system on (i) maize growth and yield and, (ii) weed infestation levels.

MATERIALS AND METHODS

Site description

This study was conducted at the University of Venda, School of Agriculture experimental farm 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 ±500mm per annumn and temperature range from a minimum of 10°C during winter to a maximum of 40°C during summer. The site is characterized by deep well-drained clay soil. Pre-sowing analysis of some soil physical and chemical properties indicated 62% clay, 27% silt and 11% sand, and pH 5.75. Organic carbon was 2.09%, total N 0.052%, while P level was low (3.49 mg kg^{-1}). Levels of exchangeable Na, K, Ca and Mg were 0.11, 0.31, 4.43 and 1.85 $cmol_c$ kg^{-1} soil, respectively.

Field experimental set-up

Five green manure legume cover crops, Mucuna (*Mucuna pruriens*), Lablab (*Lablab purpureus*), sunhemp (*Crotalaria juncea*), Cowpea (*Vigna unguiculata*) and butterfly pea (*Clitoria ternatea*) were planted in December 2006 in plots measuring 5 x 5 m. Two fallow plots were also included in the treatments giving a total of seven plots. The treatments were arranged in a randomized complete block with three replications. In March 2007, cover crop growth was terminated by slashing the above-ground biomass and leaving it on the surface. Prior to terminating the legume growth, above - ground biomass was sampled from an area measuring 1 x 1 m in each plot. Dry matter was determined after drying at 70°C until a constant weight was attained. A sub-sample was obtained, ground and analyzed for total C using Dumas dry oxidation method and N concentration using Kjeldahl method. Carbon : N ratio was then determined. Total N content was obtained by the product of N concentration and dry matter. In September 2007 (beginning of 2007/8 planting season), the plots were ploughed by hand-hoes to avoid mixing of the residues from different plots and maize was planted in all the plots at a spacing of 90 x 25 cm. Two fertilizer nitrogen treatments (0 and 100 kg N ha^{-1}) were imposed on the two fallow plots. The plots were designated control (-N) and control (+N), respectively. Nitrogen was applied as Lime Ammonium Nitrate (LAN, 28%N) in split application, with 75 kg N ha^{-1} at planting and 25 kg N ha^{-1} at tasseling. Phosphorus was applied uniformly to all the plots at a rate of 50 kg ha^{-1} as super grow (20.3%P). Maize and weed dry matter yield were determined in all maize plots at 6 - 8 WAP and at tasseling. Maize and weed samples were collected randomly from an area measuring 1 m^2 (1 x 1 m) in each plot by cutting at ground level. The dominant weed species were identified and recorded. At maturity, the maize plants were harvested and grain yield determined. The experiment was repeated in 2008/9 season in the same plots using the same methodology except that the green manure legumes were planted in April 2008, their growth terminated in August 2008 and maize planted in October 2008.

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).

RESULTS

Green manure legume biomass yield, N content and C : N ratio

In 2007, green manure biomass ranged between 2.1 and 13.6 Mg ha^{-1} at the time of termination of green manure growth (approximately 4 months after planting) (Figure 1). Sunhemp produced significantly higher biomass (13.6 Mg ha^{-1}) than all the other GML except mucuna. In 2008, GML biomass yield ranged between 0.8 and 2.9 Mg ha^{-1}, which was between 78 to 86% less biomass yield compared to 2007 (Figure 1). Sunhemp produced significantly higher biomass than all the other GML treatments.

The GML N content ranged between 73 and 279 kg N ha^{-1} and 10 and 51 kg N ha^{-1} in 2007 and 2008, respectively. Nitrogen content of GML in 2008 was between 74 to 88% lower than in 2007(Table 2). C : N ranged between 10.3 (cowpea) and 19.3 (lablab), and 11.8 (butterfly pea) and 25.6 (sunhemp) in 2007 and 2008, respectively (Table 2). In 2007, sunhemp had a significantly higher C : N ratio than all the other GML except lablab, while in 2008, sunhemp had a significantly higher C : N ratio than all the other GML (Table 2).

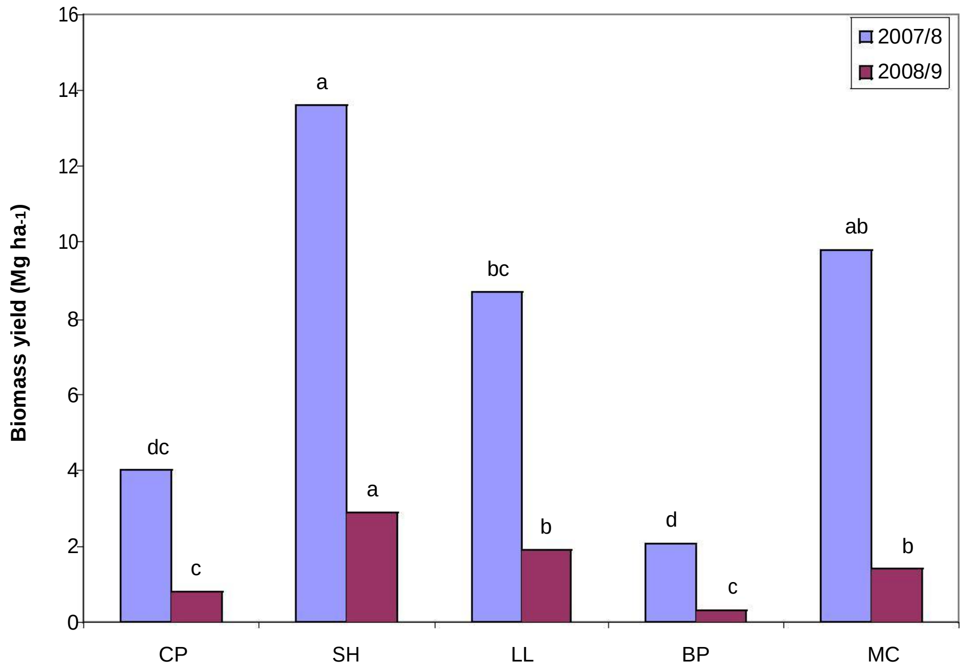

Figure 1. Green manure legume biomass yield in 2007 and 2008. (CP = cowpea; SH = sunhemp, LL= lablab; BP = butterfly pea, MC = mucuna).

Table 1. Green manure legume N content and C:N ratios in 2007 and 2008.

Green manure	2007/8 Season		2008/9 Season	
	N content (kg ha^{-1})	C : N ratio	N content (kg ha^{-1})	C : N ratio
Mucuna	279a	15.9bc	43ab	13.2b
Sunhemp	302a	20.9a	50a	25.6a
Lablab	198ab	19.3ab	51a	15.7b
Cowpea	168ab	10.3d	20bc	16.5b
Butterfly pea	73b	13cd	10c	11.8b

Within columns, means followed by the same letter are not significantly different at P ≤ 0.05.

Maize dry matter yield

In 2007/8 season, maize DM ranged between 0.2 and 1.2 and 3.7 and 11.2 Mg ha^{-1} at 6 - 8 WAP and at tasseling, respectively (Figure 2a). Increase in DM yield from 6 - 8 WAP to tasseling ranged between 88 to 95%. All treatments, with the exception of control (-N), produced DM yield >4 Mg ha^{-1} at tasseling. In 2008/9 season, DM ranged between 0.8 and 1.9 and 4.7 and 9.1 Mg ha^{-1} at 6 - 8 WAP and at tasseling, respectively (Figure 2b). Increase in DM yield from 6 - 8 WAP to tasseling ranged between 74 to 87%. All treatments with the exception of control (-N) produced DM yield >5 Mg ha^{-1} at tasseling.

Maize grain yield

In 2007/8 season, a significant difference in grain yield was observed between control (-N) and all the other treatments (Figure 3). Average grain yield ranged between 4.52 Mg ha^{-1} [control (-N)] to 10.59 Mg ha^{-1} (lablab). Addition of 100 kg N ha^{-1} gave an increase in yield of 74% (3.33 Mg ha^{-1}) above the control (-N). Cowpea, Mucuna, lablab, butterfly pea, and sunhemp treatments gave yield increases of 77% (3.48 Mg ha^{-1}), 85% (3.85 Mg ha^{-1}), 134% (6.07 Mg ha^{-1}), 125% (5.63 Mg ha^{-1}) and 103% (4.66 Mg ha^{-1}), respectively, above the control (-N) treatment. In 2008/9 season, a similar trend yield in grain yield was observed, although the yield was lower than in 2007/8 season (Figure 3). Average grain ranged between 2.6 Mg ha^{-1} [control (-N)] to 8.7 Mg ha^{-1} (lablab) which was between 18 to 63% less than in 2007/8 season.

Lablab treatment produced a significantly higher grain yield than control (-N) but was not different from the other GLM treatments. Addition of 100 kg N ha^{-1} gave an increase in yield of 10% (0.29 Mg ha^{-1}) above the control

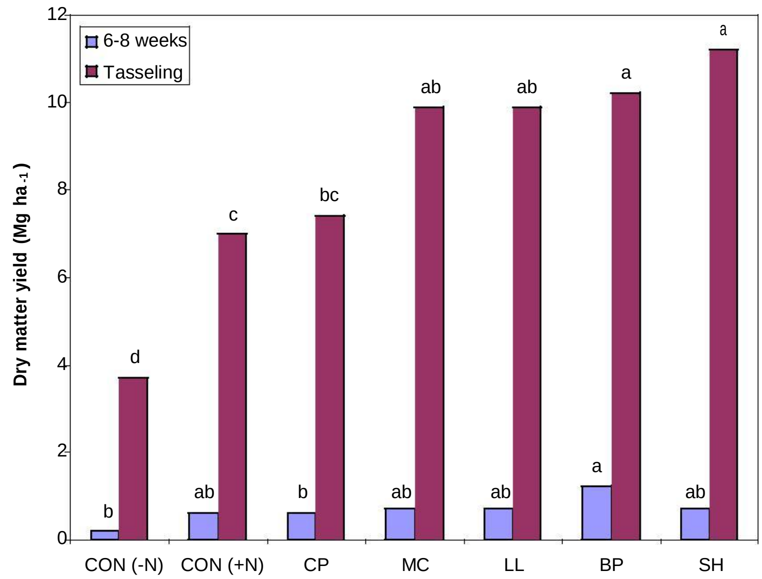

Figure 2a. Maize dry matter yield at 6-8 WAP and at tasseling in 2007/8 season. [Con (-N) =Control (-N); Con (+N) = Control (+N); CP = Cowpea; MC = Mucuna; LL = Lablab; BP = Butterfly pea; SH = Sun hemp].

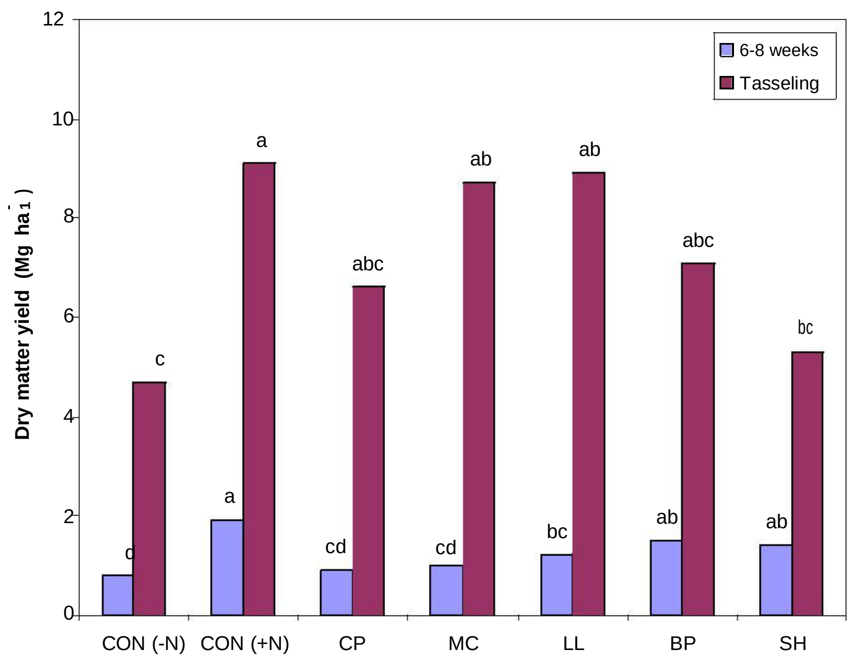

Figure 2b. Maize dry matter yield at 6-8 WAP and at tasseling in 2008/9 season. [Con (-N) = Control (-N); Con (+N) = Control (+N); CP = Cowpea; MC = Mucuna; LL = Lablab; BP = Butterfly pea; SH = Sun hemp].

(-N) treatment. Cowpea, Mucuna, lablab, butterfly pea, and sunhemp treatments gave yield increases of 55% (3.14 Mg ha^{-1}), 61% (3.95 Mg ha^{-1}), 70% (6.12 Mg ha^{-1}), 66% (4.93 Mg ha^{-1}) and 64% (4.55 Mg ha^{-1}), respectively, above the control (-N) treatment.

Weed DM yield

In 2007/8 season, there was a significant difference in weed dry matter among the treatments at 6 - 8 WAP (Figure 4a). Cowpea, mucuna, lablab and sunhemp plots

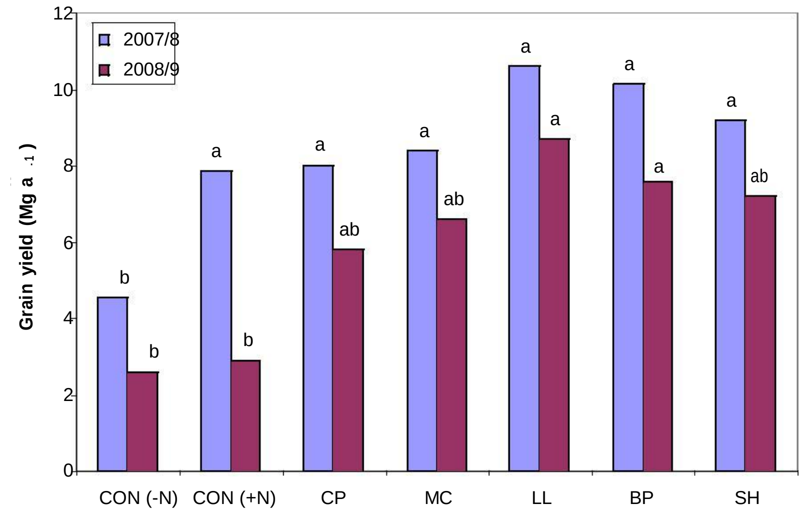

Figure 3. Maize grain yield in 2007/8 and 2008/9 seasons. [Con (-N) = Control (-N); Con (+N) = Control (+N); CP = Cowpea; MC = Mucuna; LL = Lablab; BP = Butterfly pea; SH = Sun hemp].

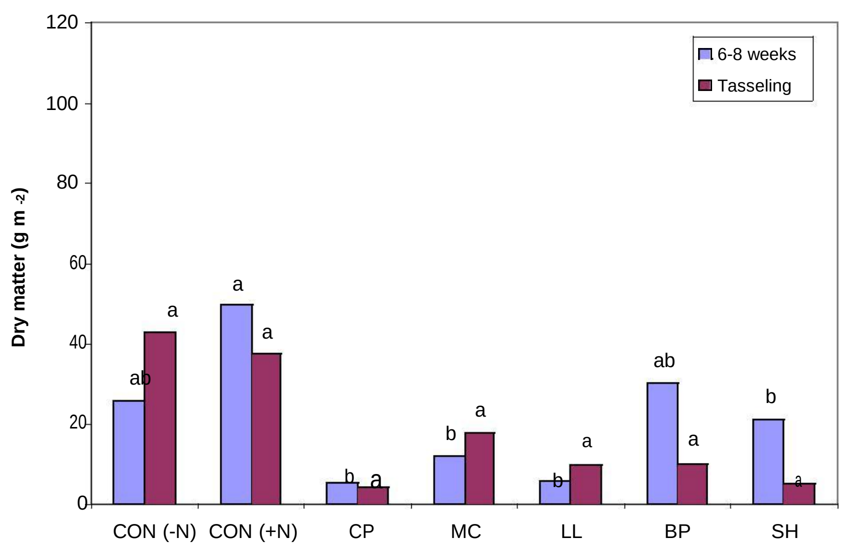

Figure 4a. Weed dry matter (DM) at 6 - 8 WAP and at tasseling in 2007/8 season. [Con (-N) = Control (-N); Con (+N) = Control (+N); CP = Cowpea; MC = Mucuna; LL = Lablab; BP = Butterfly pea; SH = Sun hemp].

had a significantly lower weed dry matter (5.30, 11.97, 5.83, and 21.03 g m^{-2}, respectively) than the control (+N) (49.47 g m^{-2}). However, no difference in weed dry matter was observed between the control (+N) plot and control (-N) and butterfly pea plots. In 2008/9 season, at 6-8 WAP, control (+N) had a significantly higher weed dry matter than all the other treatments with the exception of butterfly pea (Figure 4b). At tasseling, there was no difference in weed dry matter in both 2007/8 and 2008/9 seasons (Figures 4a and 4b). However, in 2007/8 season, all the green manure legume plots had lower weed dry matter than the control (-N) and control (+N) plots, while weed biomass in 2008/9 season, with the exception of cowpea and sunhemp treatments, were between 15 to 92% less than in 2007/8 season.

Weed species

The dominant weed species identified in all the plots were Mexican ricardia (*Ricardia brasiliensis*), Yellow nutsedge (*Cyperus esculentus*), Guinea-fowl grass

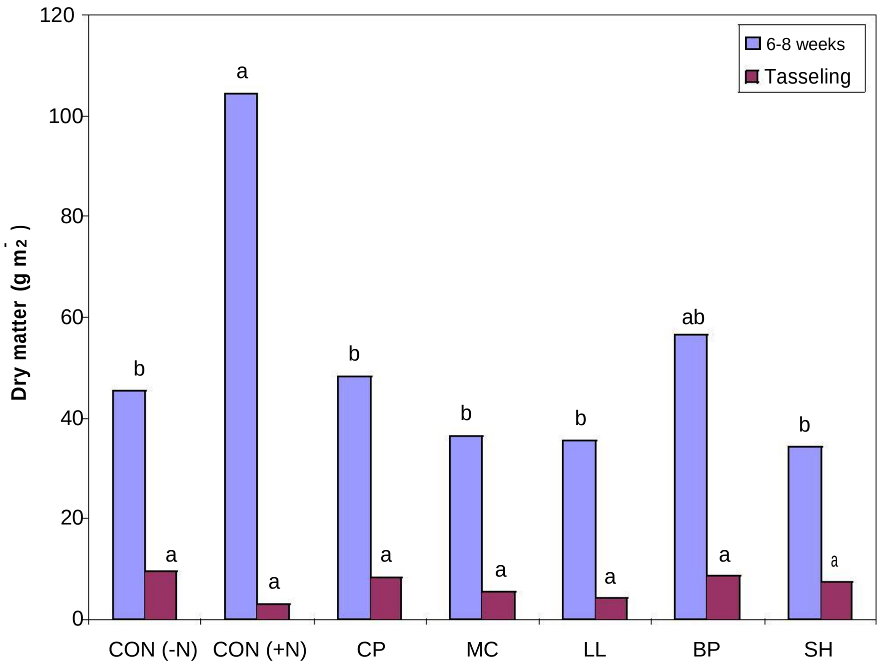

Figure 4b. Weed dry matter (DM) at 6 - 8 WAP and at tasseling in 2008/9 season. [Con (-N) = Control (-N); Con (+N) = Control (+N); CP = Cowpea; MC = Mucuna; LL = Lablab; BP = Butterfly pea; SH = Sun hemp].

(*Rottbollia cochinchinesis*) and Witch weed (*Striga asiatica*), Bermuda grass and *Cynodon* species. Proportions of the various weeds species varied greatly at both 6 - 8 WAP and at tasseling in all the plots.

DISCUSSION

Green manure legume biomass obtained in 2007/8 season compared well with biomass obtained elsewhere (Fischler, 1997; Gachene et al., 2000). The low GML biomass in 2008/9 season could be attributed to the low temperatures during the growing period. The GML were established in April 2008 which was in early autumn and growth terminated in August which was in early spring. Thus most of the GML growth occurred during the winter period, June to August 2008. As a result of the low temperatures and reduced day length, significantly less biomass was produced in 2008/9 season as compared with the 2007/8 season. This effect was also reflected in the N content of the GML which ranged from 73 to 279 kg N ha^{-1} and 10 to 51 kg N ha^{-1} in 2007/8 and 2008/9 seasons, respectively. According to Hudgens (1996), the amount of N accumulated by legumes in the above-ground residues varies from 17 - 300 kg N ha^{-1}. This compares well with the range of legume N content obtained in this study. The amount of N accumulated; particularly in the first season 2007/8 suggest that GML species have the potential for supplying most, if not all, of the N requirement by cereal crops. However, recovery of legume N is generally poor. For example, McDonagh et al. (1993) found that groundnut residue returned 100-300 kg N ha^{-1} to the field but the subsequent crop of maize recovered only 10-20 kg N ha^{-1}. The C : N ratio of the legumes was low enough to allow for net N mineralization. Rapid release of nutrients has been reported in most organic residues with >3% N content, low lignin : N and C : N ratios (Gachengo et al., 1999; Zaharah and Bah, 1999; Pypers et al., 2005). However, depending on the other chemical composition of the legumes such as the cellulose, hemicellulose, polyphenol and lignin contents, the pattern of N release may have differed among the legumes leading to differential N uptake by the subsequent maize crop, hence the influence on the final grain yield.

The amount of GML biomass produced and N accumulated in the two seasons appears to have been the primary factor affecting the observed differences in maize yield. Green manure legumes gave grain yield increases of between 77 -134% and 55 - 70% above the control, in 2007/8 and 2008/9 seasons, respectively. These yield increases were fairly high compared with yield obtained in studies elsewhere (Fischler et al., 1999; Ojiem et al, 2000). This may be due to the high amount of green manure dry matter produced in this study, especially in 2007. Ideally, any rotational system involving legumes must provide a large (maize) yield response [more than doubling continuous (maize) yields] to justify their use

(Robertson et al., 2004). Other non-controllable factors which may have also contributed to the low grain yield observed in 2008/9 season were damage by monkeys and birds. Weed dry matter yield obtained in this study indicate that GML have the potential to suppress weed population as compared with natural fallow. These results are consistent with studies done elsewhere. Onyango et al. (2000) reported that plots previously planted with legumes had low striga weed population counts compared to the control plot. The authors concluded that the low population of striga weed in legume plots could be attributed to the fact that legumes are not hosts to striga weed. The study also found that sunhemp was the most effective in striga weed control.

Conclusion

Green manure legume fallows can increase maize grain yield significantly as well as suppress the weed population as compared to natural fallow. Given that most smallholder farmers are resource poor, and therefore cannot afford to purchase the required amount of fertilizers, encouraging the use of green manure fallows in smallholder farms maybe the best option to increase maize yield, control weeds and build-up soil organic matter. However, maximizing biomass production and N accumulation is critical in order to reap the benefits of green manure. Hence, integrating GML into the existing cropping system will require that appropriate timing for planting GML be well established.

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