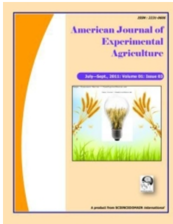

American Journal of Experimental Agriculture
2(4): 616-625, 2012

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Effects of Tillage on Forage Legumes Growth and Subsequent Dry Matter Yields of Corn Planted for Livestock Feeding

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Authors' contributions

This work was carried out in collaboration between all authors. IGMON designed the study, managed the literature search, wrote the protocol and wrote the first and final draft of the manuscript. IGAMSA performed the statistical analysis, managed the analysis of the study and revised the first and final draft of the manuscript. All authors read and approved the final manuscript.

Research Article

Received 16th June 2012
Accepted 1st October 2012
Published 2nd November 2012

ABSTRACT

Two field experiments were conducted to find a simple tillage method to introduce centro (*Centrosema pubescens* Benth.) and calopo (*Calopogonium mucunoides* Desv.) on native grasslands and to find out the effects of the tillage and legume phase on the growth of subsequent corn planted for livestock feeding.
A 4 x 3 factorial experiment in a randomized complete block design was conducted with three replications. The first factor was the methods of tillage viz. undisturbed, cutting followed two weeks afterwards by glyphosate application at 3.0 kg ha^{-1} active ingredients (a.i.), burning which was cutting followed after two weeks by burning and conventional tillage. The second factor consisted of three treatments viz. introducing centro, calopo and no legume introduction. After one year, using the same plots and design that had been used in Experiment 1, the Experiment 2 was conducted, by planting corn for cattle feeding.
Cutting the native grasses followed two weeks afterwards by glyphosate application was superior compared to other methods of tillage for the growth of legumes. Combining these treatments with legume inclusion resulted in 300% increase in dry matter of corn planted

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after the legume phase compared to without legume introduction, with nitrogen absorbtion increased almost seven fold. However there was no difference between using centro or calopo. Nitrogen content of corn stover and nitrogen absorption of corn plants were similar to those in conventional tillage.

Keywords: Tillage; cutting; glyphosate; forage legumes; corn.

1. INTRODUCTION

In dry zones of Indonesia, native grasslands and crop residues are the main sources of feed for ruminants. Farmers generally plant corn or other crops and feed the residues to the animals. The low rates of N application adopted by subsistence farmers have resulted in low yields of crops. The fields are normally invaded by a variety of weeds reducing the yields (Reynold, 1995). Due to a short rainy season in the areas, a second crop is not possible, the land is left fallow which is subsequently occupied by native grasses and broad leaved weeds. It is generally known that native grasses have a low productivity and a low quality of feed on offer to the animals especially during the dry season, resulting in reduced animal performance, and generally requiring longer periods to achieve market weight (McDowell, 1972).

Recently, due to a demand for good quality meat, farmers have practiced handfeeding to cattles kept in stalls. Corn and other fast growing high producing tropical grasses were planted at high density and harvested at the flowering stage for animal feeding. Inability to apply required nitrogen fertilizers has resulted in low dry matter (DM) yields.

Introducing tropical legumes to these native grasslands is regarded as a way to increase N supply to the soil, hence increasing the quality and productivity of feedstuffs on offer to the animals. The beneficial effects of the legume phase in terms of increase in soil N are already known (Norman and Wetselaar, 1960). However, the effects of this treatment on corn planted in the tropics specially for cattle feeding have never been investigated. Many tropical grass and forage legume species have been introduced to Bali to increase feedstuff production (Nurjaya et al., 1983; Nurjaya et al., 1991; Rika et al., 1991). However, farmers are commonly reluctant to introduce forage legumes to native grasslands by conventional tillage (ploughing the land with handhoe, hand breaking the soil clogs and cleaning the plant residues to favour the growth of legumes), because it is time consuming, labour demanding and an expensive method.

Recently, glyphosate (N-(phosphonomethyl) glycine), a potent, systemic herbicide is available, but the rates recommended are high, expensive and beyond the resources of subsistence farmers. An alternative easy and inexpensive method has to be found if introducing legumes to the native grasslands is to be adopted by farmers. Cutting the old grasses, drying in situ followed by burning and oversowing the legume seeds over the ashes is a cheap method of introducing legumes to the native grasslands. However, the competition caused by the regrowth of sprouting grass buds and broad- leaved weeds renders the land less productive.

Generally, legumes have lower competitive ability compared to grasses (Haynes, 1980; Nurjaya, 1996; Nurjaya and Tow, 2002) hence tillage is necessary to suppress the growth of grasses and broad-leaved weeds and to encourage the growth of legumes to achieve a 30% or higher proportion of legumes in the swards for meaningful contribution of nitrogen to the soils (Mason, 1993).

Experiments have been conducted to find simple ways to introduce legumes to native grasslands. Nurjaya (1987), in pot experiments in glasshouse found, on soil dominated by blady grass (*Imperata cylindrica* (L.) Beauv.), that cutting followed after two weeks with the application of 1.0 kg ha^{-1} a.i. of glyphosate gave better results for stylo (*Stylosanthes guianensis* cv. Endeavour) DM yields compared to clean cultivated seedbeds. In a field experiment under coconut plantation, Nurjaya (2002) found that cutting the native grasslands dominated by Axonopus (*Axonopus compressus*) and blady grass, combined with spraying with a low concentration of glyphosate (2.0 kg ha^{-1} glyphosate) two week after cutting to be superior for the growth of the oversown centro compared to other tillage viz. conventional method, the application of 1.0 kg ha^{-1} a.i. glyphosate or cutting followed after two weeks with the application of 1.0 kg ha^{-1} a.i. of glyphosate. It was suggested that cutting the old grasses would cause buds under the soil surface to sprout, and the young regrowths of leaves after two weeks would intercept and absorb the herbicides and translocated the herbicides to the roots, resulting in a complete kill of the native species. Centro (*Centrosema pubescens* Benth.) and calopo (*Calopogonium mucu*noides Desv.) were used in these experiments because they are widely planted in the areas as cover crops, green manure and animal feeds. Centro offers a high quality of feedstuffs that are palatable, relished by animals, relatively tolerant to drought but slower to establish compared to calopo (Mannetje and Jones, 1992). Calopo is quick to establish, relatively more competitive to grasses but intolerant to cutting compared to centro (Skerman, 1988). However the extent of corn DM yields after the legume phase is not known.

The experiments reported here were aimed at finding a suitable tillage method for introducing forage legumes on dryland soils and to find out the extent of dry matter yields of corn planted after the legume phase.

2. MATERIALS AND METHODS

Two experiments were conducted in a field at Surabrata village 8º 40’ 58” S, 115º 12’ 36” E (40 km west of Denpasar, Bali) at 50 m above sea level. The soil is Inceptisol, clay soil with 33.54% sand, 22.62 % silt and 43.84% clay. Soil pH was 6.09, with a high organic carbon, and low nitrogen, phosphorus and potassium. Basal fertilizers consisted of 50 kg ha^{-1} urea, 75 kg ha^{-1} superphosphate and 75 kg ha^{-1} potassium chloride were broadcasted a week prior to planting. The botanical compositions of the native grasslands before the experiment were Axonopus (40%), blady grass (30%), broad leaved weeds (15%) and others (15%).

The first experiment was conducted during the growing season of 2003 (February – July, 2003). Mean monthly rainfall values were 296 to 5 mm for February and July periods respectively. Mean monthly temperatures at the same periods were 24.4 to 27.4ºC.

The experiments were a 4x3 factorial in a randomized complete block design with three replications, with the first factor was methods of tillage (undisturbed, herbicide which was cutting followed at two week time with the application of 3.0 kg ha^{-1} a.i. of glyphosate, burning which was cutting followed after two weeks by burning and conventional tillage which was ploughing with a hand hoe, uprooting the rhizomes, crushing the soil clogs and leveling) and the second factor was legume introduction (without species introduction, planting centro and calopo). A higher rate of glyphosate was used in this experiment in anticipation for harsh field conditions which might prevent optimal absorption of the chemicals. Glyphosate was applied using a handheld sprayer.

The size of plots was 4 x 3 m. Two weeks after glyphosate application scarified seeds of centro and calopo were planted in rows 40 cm apart, at the rates of 5 and 3 kg ha^{-1}, respectively. Specific inoculants were used to inoculate the seeds before planting. Inoculations were repeated two weeks after planting by spraying with solution containing *Rhizobium*. Harvests were conducted twice, 12 weeks and 18 weeks after planting by cutting the middle 2 m x 1.5 m plot at 3.0 cm above the soil surface. After the second cutting the plots were left fallow.

The second experiment was conducted from February to April 2004, using the same sites and experiment layout and plots that had been used in Experiment 1. Drier months were experienced during the experiments with rainfall varied from 47.1 to 2.5 mm for February to July, respectively. The mean monthly temperatures during the same periods were 26.9 – 27.2ºC. Vegetation was cut and corn seeds of Bisma variety, were planted in holes 2.0 cm deep, in rows with plant population of 140 000 plants ha^{-1}, with planting distance of 10 x 70 cm. A high population density was used as the plants were cut at the flowering stage for animal feed. Basal fertilizers consisting of superphosphate and potassium chloride at 100 kg ha^{-1} were broadcasted a week prior to planting. Harvest was conducted at flowering stage (50 days after planting) by cutting 2.1 m^2 of the middle rows. Dry matter (DM) was obtained after drying in an oven at 70ºC for three days, the ash content was measured after burning at 500ºC, and organic matter was obtained by substitution. Nitrogen analysis was conducted using Kjeldahl methods (AOAC, 1990), and N absorption was calculated by multiplying dry matter yields with nitrogen concentration.

Data were subjected to the analysis of variance after transformation where necessary to stabilize the variance, and mean separations of the interaction effects when significant were conducted by Duncan's Multiple Range Test (Steel and Torrie, 1960) using MSTAT-C Statistical Program Version 2.10 (Russell, 1986).

3. RESULTS AND DISCUSSION

3.1 Experiment 1

In undisturbed plot, the introduction of calopo decreased the DM of grasses but not the introduction of centro (Table 1) implying that calopo was better able to reduce the growth of native grasses compared to centro. These results are in line with Skerman (1988) who found that calopo was more competitive than centro against grasses. Grass DM yield in undisturbed and no legume introduction was similar to that in treatments with herbicide and burning (Table 1). These results are in line with Nurjaya (1987), suggesting that native grasses are relatively able to escape burning and herbicide application probably through the germination and growth of their soil seed reserves. These results also indicate that repeated treatments are necessary to suppress native grasses further. The conventional method of tillage decreased the grass growth by more than 50% compared to other tillage.

At 12 weeks after planting, the interactions between tillage and kinds of legume introduction on DM of legumes and broad-leaved weeds were non significant but the data were presented to show the effects. The main effect of glyphosate application and legume introduction (data not presented) resulted in highest DM of legume compared to other treatments, which might be caused by less competition and presumably through better soil conditions caused by the death roots of residence vegetation. These results are in line with those of Nurjaya (1987) who found that in pot experiment glyphosate application (1.0 kg ha^{-1} a.i) killed blady grass resulted in highest growth of *S*. guianensis cv. Endeavour, but 13% of the buds in the underground rhizomes escaped the herbicide and pose a future potential competition on the legumes.

At 18 weeks after planting, the introduction of legumes, especially calopo, decreased grass DM yields (Table 2) suggesting that the legumes were able to reduce grass growth. Centro produced higher DM yields compared to calopo (Table 2), except in undisturbed tillage, indicating that calopo was intolerance to cutting in line with Skerman (1988).

At 12 weeks after planting complete area cover was achieved using centro in conventional tillage, and calopo in herbicide, burning and conventional tillage (Table 3), however at 18 weeks after planting the area covers decreased with calopo decreasing more compared to centro, suggesting that calopo was intolerance to cutting.

Broad-leaved weed DM yields were lowest in undisturbed method of tillage (Table 1 and 2) indicating the severest competition of native grasses in this treatment compared to other treatments.

All treatments resulted in more than 30% legume component in the swards (Table 4 and 5). Mason (1993) suggested that a botanical composition consisted of 30% or more legumes in the swards was required if the legumes are to make a significant contribution to the DM production and hence animal production.

3.2 Experiment 2

Without legume introduction, all tillage methods produced similar amount of corn DM except in conventional tillage which had higher corn DM compared to herbicide and undisturbed control (Table 6). Herbicide combined with legume planting resulted in corn DM similar to that in conventional tillage. Compared to herbicide treatment and without legume introduction, herbicide and legume introduction increased corn DM 300% while burning and conventional tillage combined with centro or calopo increased the DM yields of corn at flowering stage by more than 100% (Table 6). These results indicate that cutting the native grasses followed by the application of 3.0 kg ha^{-1} glyphosate can be used as an alternative to conventional tillage. Conventional tillage involving ploughing the soils with handhoe, breaking the soil clogs, cleaning the roots, stolons and rhizomes of the native vegetation, and leveling the soils disrupt soil structures, increased soil surface temperatures and left the soil prone to erosion especially during the rainy season (Nurjaya, 1987). The methods are also expensive and time consuming. As a result farmers are generally reluctant to cultivate their land for growing feed for animals using conventional tillage, especially in the dry land areas. However, the increasing demand for good quality feed for their cattles has forced farmers to make use the dry land areas which are normally left fallow, to grow plants for their cattles. In addition the short growing periods at the end of rainy season make a second crop of corn planted for seeds generally unable to complete their growth cycles.

Table 1. The effects of interactions between tillage and legume introduction on dry matter yields of grasses, legumes and broad-leaved weeds (t ha^{-1}) at 12 weeks after planting

Tillage	No**	Centro	Calopo	No	Centro	Calopo	No	Centro	Calopo
	Grasses			Legumes			Broad-leaved weeds		
	----------- (t ha^{-1}) -----------								
Undisturbed	2.83^{a*}	2.19^{a}	1.08^{bc}	-	1.32***	1.62	0.80	0.54***	0.71
Herbicide	2.53^{a}	1.16^{bc}	1.03^{b}	-	2.46	2.32	1.16	1.00	1.00
Burning	2.39^{a}	1.50^{b}	1.29^{b}	-	1.51	1.89	1.32	0.94	0.96
Conventional	1.04^{bc}	1.14^{bc}	$0,81^{c}$	-	1.54	1.99	0.82	1.08	1.05

**Means at each variable followed by similar letters are not significantly difference (P>0.05).*
No legume introduction.interactions were not significantly difference (P>0.05).*

Table 2. The effects of interactions between tillage and legume introduction on dry matter yields of grasses, legumes and broad-leaved weeds (t ha^{-1}) 18 weeks after planting

Tillage	No **	Centro	Calopo	No	Centro	Calopo	No	Centro	Calopo
	Grasses			Legumes			Broad-leaved weeds		
	--------------------t ha^{-1}--------------------								
Undisturb	2.58^{a*}	1.67^{a}	0.72^{cd}	-	1.01^{c}	1.08^{bc}	0.54^{bc}	0.49^{c}	0.47^{c}
Herbicide	2.37^{a}	1.26^{b}	0.53^{d}	-	1.34^{a}	1.00^{c}	0.63^{b}	0.73^{b}	0.60^{bc}
Burning	1.55^{b}	1.12^{bc}	0.67^{d}	-	1.18^{ab}	0.68^{d}	1.14^{a}	0.73^{b}	0.54^{bc}
Conventional	1.09^{cd}	0.76^{cd}	0.39^{d}	-	1.24^{a}	0.60^{d}	1.24^{a}	0.75^{b}	0.52^{bc}

**Means at each variable followed by similar letters are not significantly difference (P>0.05)*
***No legume sowing*

Table 3. The effects of tillage on area cover (%) of centro and calopo at 12 and 18 weeks after planting

Tillage	Area cover (%)			
	12 weeks a.p.		18 weeks a.p.	
	Centro	Calopo	Centro	Calopo
Undisturbed	42.3^{d*}	49.2^{c}	10.8^{c}	7.5^{d}
Herbicide	78.5^{b+}	100^{a}	32.9^{b}	12.6^{c}
Burning	81.0^{b}	100^{a}	28.8^{b}	12.2^{c}
Conventional	100^{a}	100^{a}	39.6^{a}	13.7^{c}

**Means at each measurement followed by similar letters are not significantly difference (P>0.05); $^{+}$After arcsin transformation*

Table 4. The effects of interactions between tillage and legume introduction on botanical composition of grasses, legumes and broad-leaved weeds (%) 12 weeks after planting

Tillage	No*	Centro	Calopo	No	Centro	Calopo	No	Centro	lopo
	Grasses			Legumes			Broad-leaved weeds		
	--------------(%)--------------								
Undisturbed	83^{a**}	55^{c}	32^{e}	-	32	49	17^{g}	13^{h}	
Herbicide	68^{b}	26^{ef}	24^{f}	-	55	54	32^{bc}	22^{ef}	22^{def}
Burning	64^{b}	38^{d}	31^{e}	-	38	46	36^{b}	24^{def}	23^{ef}
Conventional	57^{c}	30^{e}	21^{f}	-	41	52	43^{a}	29^{cd}	27^{cde}

**No legume introduction; **Means at each variable followed by similar letters are not significantly difference (P>0.05)*

Table 5. The effects of interactions between tillage and legume introduction on botanical composition of grasses, legumes and weeds (%) 18 weeks after planting

Tillage	No**	Centro	Calopo	No	Centro	Calopo	No	Centro	Calopo
	Grasses			Legumes			Weeds		
	-------------------%------------------------								
Undisturbed	86.2^{a*}	53.1^{c}	31.8^{ef}	-	32^{f}	48^{a}	14^{g}	15^{g}	21^{f}
Herbicide	79.0^{b}	37.3^{e}	24.7^{fg}	-	41^{c}	47^{a}	21^{ef}	21^{ef}	28^{d}
Burning	57.7^{c}	37.1^{e}	35.2^{e}	-	39^{d}	36^{e}	42^{b}	24de	29^{d}
Conventional	46.8^{d}	27.9^{f}	25.7^{fg}	-	45^{b}	40^{d}	53^{a}	27^{d}	34^{c}

**Means at each variable followed by similar letters are not significantly difference (P>0.05); ** No legume introduction*

Table 6. The effects of interaction between tillage and legume introduction on dry matter yield of corn (t ha^{-1}) at flowering (50 days after planting).

Tillage	Legumes		
	Without legumes	Centro	Calopo
	---------- t ha^{-1} -----------		
Undisturbed	2.48^{e*}	5.17^{c}	5.20^{c}
Herbicide	2.60^{e}	10.87^{a}	11.68^{a}
Burning	3.68^{de}	8.51^{b}	8.42^{b}
Conventional	4.12^{cd}	10.42^{a}	11.56^{a}

**Means followed by similar letters are not significantly difference (P>0.05)*

Burning and introduction of legumes increased DM of corn significantly, but the increase was less than that for herbicide or conventional tillage. These results also indicated the beneficial effects of legume phase before planting corn, by the nitrogen contribution of the legumes through nitrogen fixation by root nodule *Rhizobium*.

Tillage methods resulted in similar crude protein, ash and organic matter content in corn stover (Table 7a) but legume sowing increased crude protein content in corn stover (Table 7b). Without legume planting, the crude protein content of corn stover was slightly less than 7.0% suggested as critical level of crude protein in feedstuffs for rumen bacteria to digest the DM (Milford and Minson, 1966).

Table 7. The main effects of (a) tillage and (b) variety of legume introduction on crude protein content, ash, and organic matter content of corn stubble at flowering (50 days after planting).

Treatments	Crude protein (%)	Ash (%)	Organic matter (%)
(a) Tillage			
Undisturbed	8.9^{a*}	9.4^{a}	90.6^{a}
Herbicide	9.6^{a}	9.4^{a}	90.6^{a}
Burning	8.6^{a}	9.3^{a}	90.7^{a}
Conventional	9.5^{a}	10.0^{a}	90.0^{a}
LSD (0.05)	1.1	1.1	1.1
(b) Variety of legumes			
Without legumes	6.8^{b}	9.0^{a}	91.0^{a}
Centro	10.6^{a}	9.7^{a}	90.3^{a}
Calopo	10.0^{a}	9.8^{a}	90.2^{a}
LSD (0.05)	1.5	0.9	0.9

**Means at each variable and treatment followed by the same letters are not significantly difference (P>0.05)*

Without legume inclusion, all tillage resulted in similar nitrogen absorption by corn plants, but herbicide treated native grasslands with legume inclusion markedly increased nitrogen absorption by corn plants to level similar to that in conventional tillage (Table 8).

Table 8. The effects of interactions between tillage and legume introduction on nitrogen absorption by corn plants (kg ha^{-1} N) at flowering (50 days after planting)

Tillage	Legumes		
	Without legumes	Centro	Calopo
	--------------- kg ha^{-1} N ----------------		
Undisturbed	29.47^{ef}	76.71^{cde}	84.14^{cd}
Herbicide	26.00^{f*}	200.95^{a}	199.79^{a}
Burning	42.24^{def}	134.27^{cd}	115.77^{bc}
Conventional	43.44^{def}	189.79^{a}	197.81^{a}

**Means followed by similar letters are not significantly difference (P>0.05)*

4. CONCLUSION

Cutting the native grasses followed two weeks afterwards by glyphosate application at 3.0 kg ha^{-1} active ingredients was superior compared to other methods of tillage for the growth of legumes. Combining these treatments with legume inclusion resulted in 300 % increase in dry matter yields of corn planted after the legume phase compared to without legume introduction, with nitrogen absorption increased almost seven fold.

ACKNOWLEDGEMENT

The Indonesian Department of Education provided funds for these researches which were greatly appreciated. Luh Suariani and Noh Nesimnasi were thanked for their technical expertise during the field experiments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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