Soil quality indicators and weed infestation in an Amazonian land-use system as affected by soil cover and residue quality

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Introduction

Due to the high temperatures and intense rainfall, mechanized land preparation tends to be inadequate in the humid tropics and no-tillage has been recommended as an important feature for sustainable land management (Moura, 2008). In such agroecosystems, both the aggressiveness and diversity of weeds are very high.

According to Maclean et al. (2003), alley cropping favours three strategies for weed control: light reduction during the growth period of the tree component can reduce the abundance of species sensitive to shading; pruning and application of tree branches serves as physical barrier and reduces seed germination; decomposition of pruning material improves soil quality indicators and thereby changes weed composition and the ability of cultivars to compete against these weeds in the long run.

This research was conducted in order to evaluate the effects of low- and high-quality prunings derived from different combinations of alley trees on weed density and biomass and on soil fertility in an Alfisol in the southeastern periphery of Amazonia.

Methods

The field experiment was installed in January 2002 within Maranhão State University, at 2º 30' southern latitude and 44º 18' western longitude. Climate of the region is classified according to Köppen as *Aw*, with two distinct seasons, a rainy season from January to June with mean precipitation of 2.100 mm year^{-1} and a dry season with strong hydric deficit between July and December. The soil of the site was classified as Alfisol (EMBRAPA, 2006), with 260 g kg^{-1} coarse sand, 560 g kg^{-1} fine sand; 80 g kg^{-1} silt and 100 g kg^{-1} clay.

We planted four different legume species, two with high-quality residues - *Leucaena leucocephala* (Lam.) De Wit.) ('leucena') and *Cajanus cajan* (L.) Millsp) ('guandu'), and two with low-quality residues - *Clitoria fairchildiana* R.A.Howard ('sombreiro') and *Acacia mangium* Willd. ('acácia'). Species were established by direct-seeding in 4 m long lines, so that each plot received two differing residue types, resulting in the following treatment combinations: Sombreiro + Guandu (S+G); Leucena + Guandu (L+G); Acácia + Guandu (A+G); Sombreiro + Leucena (S+L); Leucena + Acácia (L+A) and Control without legumes. We used a completely randomized block design with 4 replications per treatment. Legumes were established with 0,5 m plant distance, plot size was 21 x 4 m. In the alleys between the legumes we seeded four lines of maize with 1 m x 0,25 m planting distance, fertilized with 250 kg ha^{-1} of N-P_2O_5-K_2O 10-25-15 + 0,05% Zn. We also applied a second dose of 30 kg ha^{-1} as amonium-sulfate at formation of the fourth pair of maize leaves. Legume growth was insatisfactory in the first year and didn't allow for pruning in 2003, prunings were therefore conducted in January 2004, 2005, 2006 and 2007, after maize germination, at approximately 50 cm height. Pruning biomass was uniformly distributed throughout all plots of the same treatment.

In 2007, we conducted the following chemical soil analyses (0-5 and 5-10 cm depth): pH in $CaCl_2$, soil organic matter, P, K^+, Ca^{2+}, Mg^{2+}, H+Al, cation exchange capacity at pH 7

(CEC), sums of bases (SB) and base saturation (V), following the standard methodologies of the Instituto Agronômico de Campinas (2001).

We collected weeds in 2-year intervals at two distinct seasons: the first quantification after second pruning (February 2005) and the second quantification after the fourth pruning (February 2007). We took three random samples per plot, following Hyvönen et al. (2003) and Jakelaitis et al. (2003) and identified weeds according to Kissmann and Groth (1992; 1995) and Kissmann (1997). After weed collection, we subsequently counted and dried weeds at 70ºC until weight constancy for biomass determination.

Data were analysed with Statistica 6.0 (STATSOFT, 2007), applying ANOVA and subsequent Tukey test with 5% probability.

Results and Discussion

All different residue combinations affected the sums of bases (SB) at 0-5cm depth, to different degrees, but always significantly as compared to the control treatment, this also reflected positively the base saturation (V) (Table 1). Differences in calcium contents were responsible for these variations, since both magnesium and potassium didn't vary significantly. These results are relevant not only statistically, but also due to their agronomic consequences, elevating levels above the critical minimum threshold defined by Ribeiro et al. (1999).

At 5-10 cm depth, only the treatments leucena + acácia and leucena + guandu significantly increased Ca^{2+}, SB and V. Thus, these treatment combinations were the most efficient in sustaining favourable conditions for maize and weed growth, considering both soil depths. According to Vanlauwe et al. (2005), such efficiency is related to two factors: (i) (in the case of acácia and leucena) rooting pattern of these legume species permitted a better nutrient adsorption and nutrient accumulation in pruning residues, and (ii) (in the case of leucena and guandu) faster demobilization of nutrients during decomposition processes.

Treatments containing acácia had stronger effects on weed abundance at both sampling dates, with significant differences between these treatments and the control treatment. Merely the treatment sombreiro + guandu did not significantly reduce weed abundance in the first sampling year (Table 2). In the second sampling year, all treatments containing guando – with the exception of its combination with acacia had strongly reduced effects on weed suppression, due to the decline of biomass production of guandu. Importantly, all plots containing acácia had a much reduced weed abundance as compared to the other treatments.

Differences in weed biomass in the second year of sampling (2007) confirmed the high efficiency of acácia in reducing weed competitivity (Table 2), due to its weed suppression caused both by the quantity and the durability of its pruning residues. The L+G treatment which contained high-quality prunings was associated with na increase in soil fertility and absence of a durable soil cover, resulting in weed biomass higher than in any other treatment, including the control treatment. This indicates the importance of using species combinations which at the same time favour efficient nutriet cycling and soil cover, in order to reduce weed competitivity. In general terms, our results confirm the hypothesis of Maclean et al. (2003) in relation to the effects of shading and of the physical barrier of pruning residues in alley cropping, and also are in accordance with data from MAJOR (2005) on the impact of base saturation on weed biomass.

Weeds were altogether less competitive in plots with higher quantities of prunings with lower residue quality (A+G e A+L). This confirms the importance of the right choice of legume species for agroecosystem management in the region. Our results also indicate that although species with lower pruning biomass and higher residue quality can improve soil fertility indicators, but will not reduce or may even increase weed infestation. On the other hand, permanence of pruning residues on the soil surface is shown to be of central importance for weed control. The latter will depend on decomposition rates or the residue quality index as described by TIAN et al. (1995).

Conclusions

1) The combination of low- and high-quality pruning residues in alley cropping reduces weed infestation and competitivity and at the same time increases fertility in the topsoil (0-10cm)

2) High-quality residues such as leucena and guandu, if applied singly, turn the system less favourable for agroecological management, due to the absence of weed suppression and the increase of weed infestation with higher soil fertility.

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TABLE 1 – Atributos químicos do solo, nas profundidades de 0-5 e 5-10 cm, sob diferentes tipos de cobertura após seis anos do estabelecimento das aléias, em São Luís, MA, 2007.

Treatments	pH	SOM	P	K^+	Ca^{2+}	Mg^{2+}	H+Al	SB	CEC	V
	$CaCl_2$	g dm^3	mg dm^3	----------------------	mmol$_c$ dm^{-3}	----------------------				%
			---------------------------------		0 - 5 cm		---------------------------------			
Sombreiro + Guandu	4,5	22	11	0,4	19 a	3	26	22,4 a	48,4 a	46 a
Leucena+Guandu	4,4	18	11	0,4	16 a	2	23	18,4 ab	41,4 a	45 a
Acácia+Guandu	4,7	20	9	0,4	11 b	2	20	13,4 b	33,4 b	40 a
Sombreiro+Leucena	4,5	21	12	0,4	11 b	3	24	14,4 b	38,4 b	38 a
Leucena+Acácia	4,6	20	10	0,4	18 a	3	22	21,4 a	43,4 a	50 a
Testemunha	4,3	17	14	0,4	6 c	1	28	7,4 c	35,4 b	21 b
F	$1,41^{ns}$	$0,48^{ns}$	$0,67^{ns}$	$0,23^{ns}$	*	$2,10^{ns}$	$1,44^{ns}$	*	*	*
CV (%)	6	26	41	36	15	45	19	15	12	11
DMS	0,52	6,10	5,20	-	4,72	2,38	8,44	4,85	7,50	12,59
			---------------------------------		5 -10 cm		-------------------------------			
Sombreiro + Guandu	4,3	14	12 a	0,3	7 b	2	23	9,3 b	32	29,1 b
Leucena+Guandu	4,5	14	10 ab	0,3	13 a	2	24	15,3 a	39	39,2 a
Acácia+Guandu	4,4	14	8 b	0,5	7 b	2	22	9,5 b	31	30,6 b
Sombreiro+Leucena	4,3	14	10 ab	0,3	6 b	2	26	8,3 b	34	24,4 b
Leucena+Acácia	4,5	13	14 a	0,3	14 a	2	22	16,3 a	38	42,9 a
Testemunha	4,1	13	10 ab	0,5	6 b	1	27	7,5 b	35	21,4 b
F	$1,01^{ns}$	$0,10^{ns}$	*	$0,77^{ns}$	*	$0,64^{ns}$	$0,57^{ns}$	*	$0,81^{ns}$	*
CV (%)	6	17	13	63	22	40	22	18	12	25
DMS	0,45	1,33	2,30	0,29	1,69	1,23	5,48	2,51	8,68	9,00

Means with the same letter in the column indicate absence of significant differences of Tukey post-hoc comparisons at 5% significance level. NS = not significant; * = significant; SOM = soil organic matter; SB = sum of bases; CEC = cation Exchange capacity; V = base saturation.

TABLE 2 – Weed abundance and biomass three (2005) and five (2007) years after the installation of alley cropping, in São Luís, Maranhão state.

Treatments	Abundance (quantity m^{-2})		Biomass (g m^{-2})	
	2005	2007	2005	2007
Sombreiro + Guandu	75 a	100 a	40 a	105 b
Leucena + Guandu	28 b	70 ab	24 b	165 a
Acácia + Guandu	13 b	10 c	14 b	10 c
Sombreiro + Leucena	25 b	60 b	15 b	75 b
Leucena + Acácia	20 b	25 c	30 b	11 c
Testemunha	70 a	65 ab	55 a	90 b
CV%	65,4	102,6	69,7	87,8
DMS	16,74	37,82	15,50	30,61

Means with the same letter in the column indicate absence of significant differences of Tukey post-hoc comparisons at 5% significance level.