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The effect of plant biomass from pruning of trees on maize (*Zea mays* L.) and weeds

O efeito da biomassa de podas de árvores no milho (*Zea mays* L.) e em plantas espontâneas

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ABSTRACT: Agroforestry systems combine different plant species among which several interactions occur. Some tree species could inhibit the annual crops through allelochemicals, but could also favor them by releasing mineral nutrients via litter or prunnings. This work measured the effect of prunings of three tree species in the development of maize and weeds. The treatments were 1. Control, 2. Control + fertilizer, twigs and leaves of 3. *Schinus molle* L., 4. *Parapiptadenia rigida* (Bentham) Brenan and 5. *Cordia trichotoma* Vell., 6. Mixture of the three species. The addition of prunning was applied in May, 2012, the weed biomass was measured in August, 2012, and the maize was seeded in September, 2012. All leaf pruning treatments inhibited the weeds and *C. trichotoma* presented the highest inhibition (96.7%). Comparing with control, *S. molle* increases significantly the height of maize plants and the ear biomass, and *C. trichotoma* increases the total maize biomass. No inhibition effect in the maize was detected.

KEY WORDS: allelopathy, facilitation, environmental restoration, nutrient cycles.

RESUMO: Sistemas Agroflorestais consorciam diversas espécies vegetais, entre as quais ocorrem diversas interações. Certas espécies arbóreas podem inibir as culturas anuais através de aleloquímicos, mas também podem favorecê-las com liberação de nutrientes via serapilheira ou podas. Este trabalho mensurou o efeito do folhedo oriundo da poda de três espécies arbóreas nativas sobre o desenvolvimento do milho (*Zea mays* L.) e plantas espontâneas. Os tratamentos foram 1. Controle; 2. controle com adição de fertilizantes; ramos de folhas de 3. *Schinus molle* L., 4. *Parapiptadenia rigida* (Bentham) Brenan e 5. *Cordia trichotoma* Vell.; 6. mistura das três espécies. A adição do folhedo foi realizada em maio de 2012, a biomassa das plantas espontâneas foi analisada em agosto de 2012, e o milho semeado em setembro de 2012. Todos os tratamentos inibiram as plantas espontâneas, e *C. trichotoma* destacou-se com redução de 96,7%. Em comparação com o controle, *S. molle* aumentou significativamente a altura das plantas de milho e a biomassa de espigas, e *C. trichotoma* aumentou significativamente a biomassa total. Não houve efeito detectável de inibição sobre o milho.

PALAVRAS-CHAVE: alelopatia, facilitação, recuperação ambiental, ciclagem de nutrientes.

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Introduction

A greatest challenge of agriculture is to optimize land use in environmentally and economically sustainable ways (LAMÔNICA; BARROSO, 2006), especially for small-scale family farming. In seeking maximum income, small farmers frequently promote inappropriate land use, resulting in environmental damage (ABDO et al., 2008). Agroforestry systems are an alternative to optimize the use of resources, increasing the sustainability through diversification of products and increasing yields.

The agroforestry systems (AFS) are a consortium of tree and crop species, eventually including livestock (silvipastures). They bring advantages such as incrementing organic matter in the soil, reduction of erosion and nutrient loss, increasing income, protection against extreme weather conditions, and food security due to crop diversity (COELHO, 2012).

Maize may be cultivated in the initial phase of rotation systems with silviculture every five or six years (SOMARRIBA; KASS, 1998) or in intercalary strips between tree lines in simultaneous AFS. In analogous or successive AFS (HART, 1980), maize cultivation is only viable in the early phase, since as a C_4 plant it presents a low shade tolerance (MAGALHÃES, 2002; PENG et al., 2009).

Maize cultivation is feasible in simultaneous AFS and the biomass from prunings of tree crowns can substitute total or partial chemical fertilizers (BERTALOT et al., 2010). Yield increases of maize in alley crop systems are reported in some situations (ZHAOHUA et al., 1991, RADERSMA et al., 2005). In others, productivity may be reduced by the lower plant population of maize in the AFS when compared with monoculture (MARIN et al., 2007), or through inhibition effects caused by the tree species (GILLESPIE et al., 2000). Frequently, the trees are pruned to accelerate the return of nutrients to the soil, minimizing the competition between trees and crops (DE COSTA et al., 2008; SIRIRI et al., 2012). On the other hand, this inhibition could occur through allelochemicals released in the soil by the roots or the litterfall (BATISH et al., 2008), in a phenomenon denominated as allelopathy (RICE, 1984). The balance between inhibition and facilitation depends of concentration and rate of degradation of allelochemicals, on the one hand, and nutrient mineralization (especially N) on the other. However, in multiple cropping allelopathy is not easily distinguished from competition for resources, including water, light, and nutrients. Although many investigations report significant allelopathic effects in laboratory tests, such effects are not easily detectable in the field (KAMARA et al., 2000, BATISH et al., 2008). This occurs as a function of the differences between field conditions and the artificial laboratory environment. The mineral structure of the soils can minimizes the allelopathic effects through chemical interactions (INDERJIT; DAKSHINI, 1994). Moreover, the soil microorganisms could modify or degrade the allelochemicals, or increase nutrient mineralization from plant residues (BATISH et al., 2008; CIPOLLINI et al., 2012).

In the South and Southeast of Brazil several native tree species have economic importance and vocation to AFS (SOUZA et al., 2010). Our work addressed three of them, *Schinus molle* L. (Anacardiaceae), *Parapiptadenia rigida* (Bentham) Brenan (Fabaceae) and *Cordia trichotoma* Vell. (Boraginaceae).

S. molle (aroeira-salso) is a heliophile species resistant to low temperatures and recommended for shading orchards (CARVALHO, 1994). *P. rigida* (angico-vermelho) is an aggressive pioneer tree with a heavy, elastic and quite durable wood, appreciated in carpentry and rural construction (MATTOS, 2002). It presents biological fixation of nitrogen (CARVALHO, 1994). *C. trichotoma* (louro-pardo) is a promising species for reforestation, with a fast early growth, easy regeneration in degraded sites and a monopodial architecture. Moreover, some observations indicate that *C. trichotoma* does not show inhibition over pastures and intercalary crops (MATTOS, 2002). On the other hand, it increases the pH and cations in the topsoil (MONTAGNINI, 2001).

The present investigation aimed at measuring the interference of pruning material in the development and yield of maize. The evaluations were made in a monoculture of maize, avoiding the interference of root competition or shading effects which could occur in alley cropping. Additionally, biomass accumulation of weeds was evaluated three months after the application of pruning.

Materials and Methods

The experimental site was located at Quilombo municipality, Santa Catarina State, Brazil, 26º 41' 38'' S and 52º 44' 55'' W, 510 m a. s. l. The climate is Cfa according to Koppen classification (EPAGRI, 2002). The annual average rainfall is 2000 mm and the average annual temperature is 18 ºC. The soil pertains to the Oxisoil-Oxic Dystrudept class. The physical-chemical profile was determined from 10 random sub-samples throughout the experimental area in 0-20 depth. The analysis were provided by the EPAGRI soil laboratory in Chapecó-SC. The soil presented a water pH of 5.5, 3.0 % (m/v) of organic matter, 0.0 (m/v) of Al, 4.26 cmolc/dm^3 of H+Al, CEC at pH 7.0 = 14.12 cmolc/dm^3, exchangeable Ca and Mg of 7.4 and 2.0 cmolc/dm^3, extractable P = 3.0 mg/ dm^3, exchangeable K = 183.9 mg/ dm^3 and 41 % (m/v) of clay. The experimental area (288 m^2) was divided in four blocks divided in six parcels of 3 x 4 m. The six treatments were prunings of *S.molle* (***SCHI***), *P. rigida* (***PARA***), *C. trichotoma* (***CORD***), a mixture of the pruning of the three species (***MIXT***), control (***CTRL***) and control with fertilizer addition (***CFER***). In this last case 10 g/m^2 of NPK formula (09-20-15) was added in seeding maize, and 20 g/m^2 of urea was added 50 days later.

The soil was revolved with a disk plough, removing the weeds in the first week of May 2012. In the next week, 3 kg/m^2 of fresh pruning was added over the soil surface. The corresponding dry biomass was estimated by subsamples of each species, which were dried in an air forced circulating oven at 55 °C for 48 hours. The estimated dry biomass was 1.77, 1.42 and 1.80 kg/m^2 for *S. molle*, *P. rigida* and *C. trichotoma*, respectively. Subsamples of dried material were destined for chemical analyzes, the results (Table 1) of which were provided by Soil Laboratory of UFRGS (Porto Alegre, Rio Grande do Sul State). The total of nutrients added to the soil with the fresh prunings was estimated considering the dry biomass of each species and the chemical contents (Table 1).

The weed biomass was measured in August 2012 by applying a wood rectangle with 0.70 X 0.40 m randomly. Three samples were obtained from each plot, totalizing 12 samples from each treatment. The samples were dried in an air forced circulating oven at 55 °C for 48 hours and identified at species level. The CFER treatment was not included, since the fertilizer was applied after this analysis.

In September 2012 the weeds were removed manually immediately before the maize seeding. The variety of maize was a landrace named "Palha Roxa". The spacing was 0.80 m between lines and 0.20 between seeds. Thirty days after seeding, the weeds were removed manually again, to avoid the interference of differences in weed biomass among treatments. After 11 weeks, the stem diameter and the height were measured with a caliper and a ruler, respectively. On each plot 20 maize plants were sampled, restricted to the central rows and avoiding the extremities of the lines (1 m of border was excluded).

The maize biomass was estimated in February and March 2013. The plants were sampled within 1.0 m of the line, including three samples (the three central lines) from each plot. The samples were

Table 1: A. Mineral contents of leaves and twigs of tree prunings and B. Estimate of nutrients added to the soil with prunings (m^2).

	Unit	S. molle	P. rigida	C. trichotoma
N	%	2.0	2.1	1.7
P	%	0.23	0.11	0.1
K	%	1.1	0.57	0.86
Ca	%	1.3	2.4	4.8
Mg	%	0.19	0.25	0.56
S	%	0.11	0.08	0.13
B	mg/kg	26	29	63
Zn	mg/kg	15	18	17
Cu	mg/kg	7	7	8

dried in an air forced circulating oven at 55 °C for 48 hours.

The numerical data was transformed according to:

$$x' = \sqrt{x + 0.5}$$

according recommendations of Zar (1999), since heterocedasticity was observed throughout the variables and the variances were proportional to the means. The treatments were compared with a Tukey test (α=0.05) in the software Prism 3.0. The values are graphically expressed through the means±HSD (honestly significant difference) according to Andrews et al. (1980). Non-overlapping means±HSD intervals indicate significant differences in the pair wise test.

Results

Oxalis corniculata L. was the most abundant species except with the *CORD* and *MIXT* treatments. The three most abundant species reached 76.5% of the total biomass in the Control (Table 2). *CORD* and *MIXT* showed the highest inhibition of weeds, 96.7% and 93.7% of reduction when compared to the Control. Moreover, *CORD* exhibited a higher inhibition of *O. corniculata* than *PARA* and *SCHI*.

CORD and *CFER* presented the highest values of stem diameter of maize, both significantly higher than the *CTRL* (Figure 1A).

CORD, *SCHI* and *MIXT* had the highest values of height, which were significantly higher than *PARA* and *CFER* (Figure 1B).

There were not significant differences among treatments in the stem and leaf biomass fractions (P > 0.05 in the Tukey test, data not showed).

CORD yielded the highest total aerial biomass, which was significantly higher than the *CTRL*. *SCHI* presented the highest biomass of ears, which was significantly higher than *CTRL* (Figure 2B).

The treatments did not differ in regard to grain biomass (P = 0.1829, one-way ANOVA) and the

Table 2: Weed Biomass (g/m^2).

		S. molle	*P. rigida*	*C. trichotoma*
N	g	35.0	30.2	30.6
P	g	4.1	1.6	1.8
K	g	19.5	8.2	15.5
Ca	g	23.0	34.6	86.4
Mg	g	3.4	3.6	10.1
S	g	1.95	1.15	2.3
B	mg/kg	46.0	41.8	113.4
Zn	mg/kg	26.6	25.9	31.0
Cu	mg/kg	12.4	10.1	14.4

Letters indicates differences in the line for the Tukey test (P < 0.05).
The CFER treatment was not included as it was started only at the sowing of the maize (See Mat. and Methods).

overall average was 7.127 kg · ha^{-1}.

Discussion

The addition of prunings can contribute to weed control, thus benefitting farmers with reduction of costs, especially in organic agriculture. Previous reports highlight that *S. molle* presents in vitro allelopathy (MATERECHERA; HAE, 2008, ZAHED et al., 2010, BORELLA et al., 2011) and inhibits other wood species under its crown (TRINDADE; COELHO, 2011). Allelopathic effects of *P. rigida* and *C. trichotoma* are unknown. However, from the three species tested, *CORD* promoted the greatest weed control. Further research is needed to elucidate the mechanism of weed inhibition, if it is a chemical process or a physical mechanism related to light interception, since the leaves of *C. trichotoma* presents higher area than the other two species. Nonetheless, it should be stressed that the tree species with the highest weed inhibition (*S. molle* and *C. trichotoma*) presented the highest benefit to the maize yield.

The prunings added to the soil did not reduce the growth and the biomass yield of the maize plants. On the contrary, the treatments *CORD*, *SCHI* and *MIXT* presented greater height growth than *CFER*. *CORD* also had a superior value of total biomass and *SCHI* stood out in the amount of ear biomass. These superior yields are probably related to the high amounts of P and K from *SCHI* prunings, and of Ca and Mg of *CORD*. Surprisingly, *P. rigida* did not present higher nutrient values, especially N, since this species is a Fabaceae with biological fixation of N. The low nutrient contents and the high phenolics quantities in this species (CARVALHO, 1994) may have contributed to the low performance of maize in this treatment when compared to the other tree species.

The time interval between pruning deposition and maize seeding may have minimized any

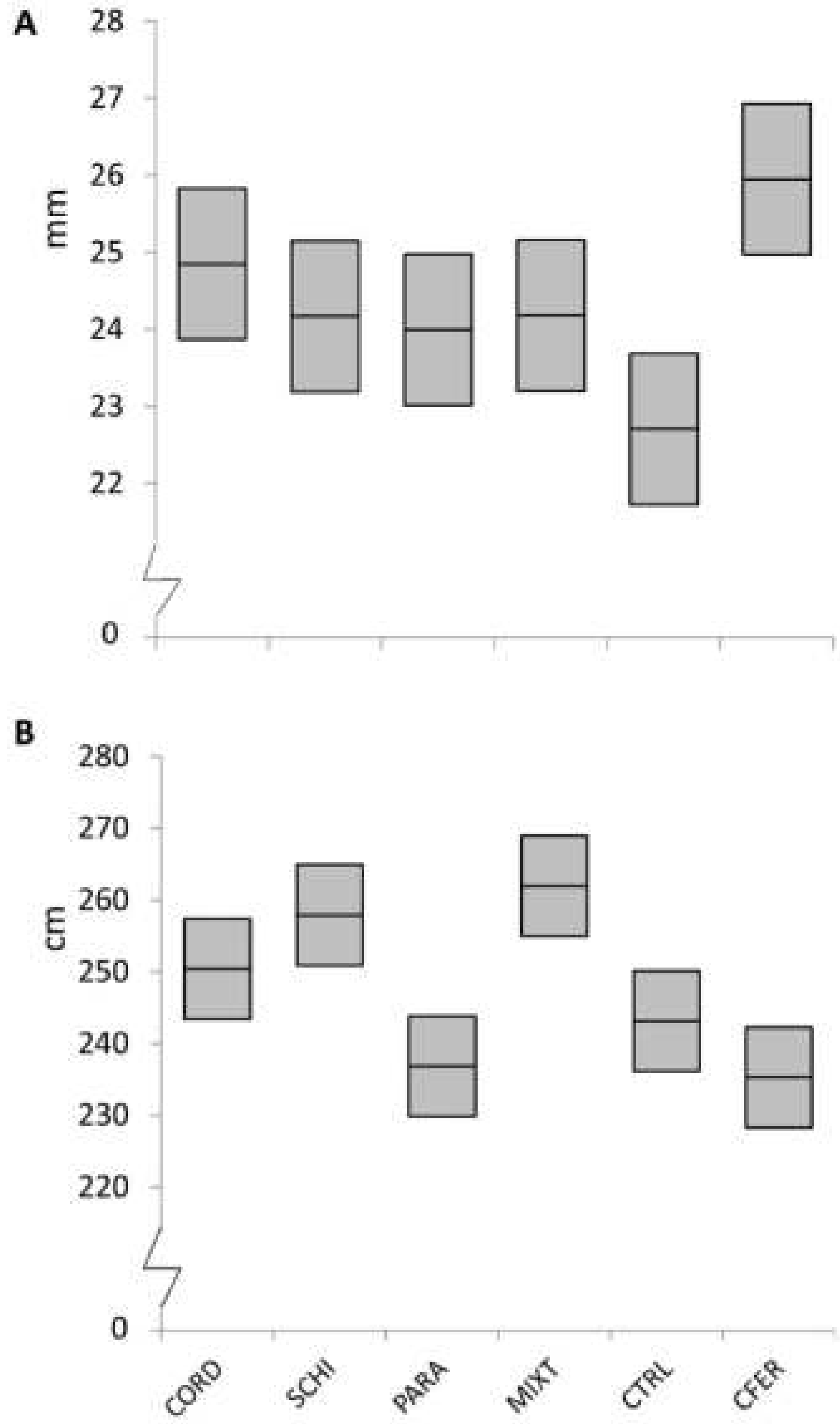

Figure 1: Mayze plant stem diameter (A) and height (B) after 11 weeks after planting.
Mean values ± HSD; non-overlapping intervals did not differ in the Tukey test ($P<0.05$).

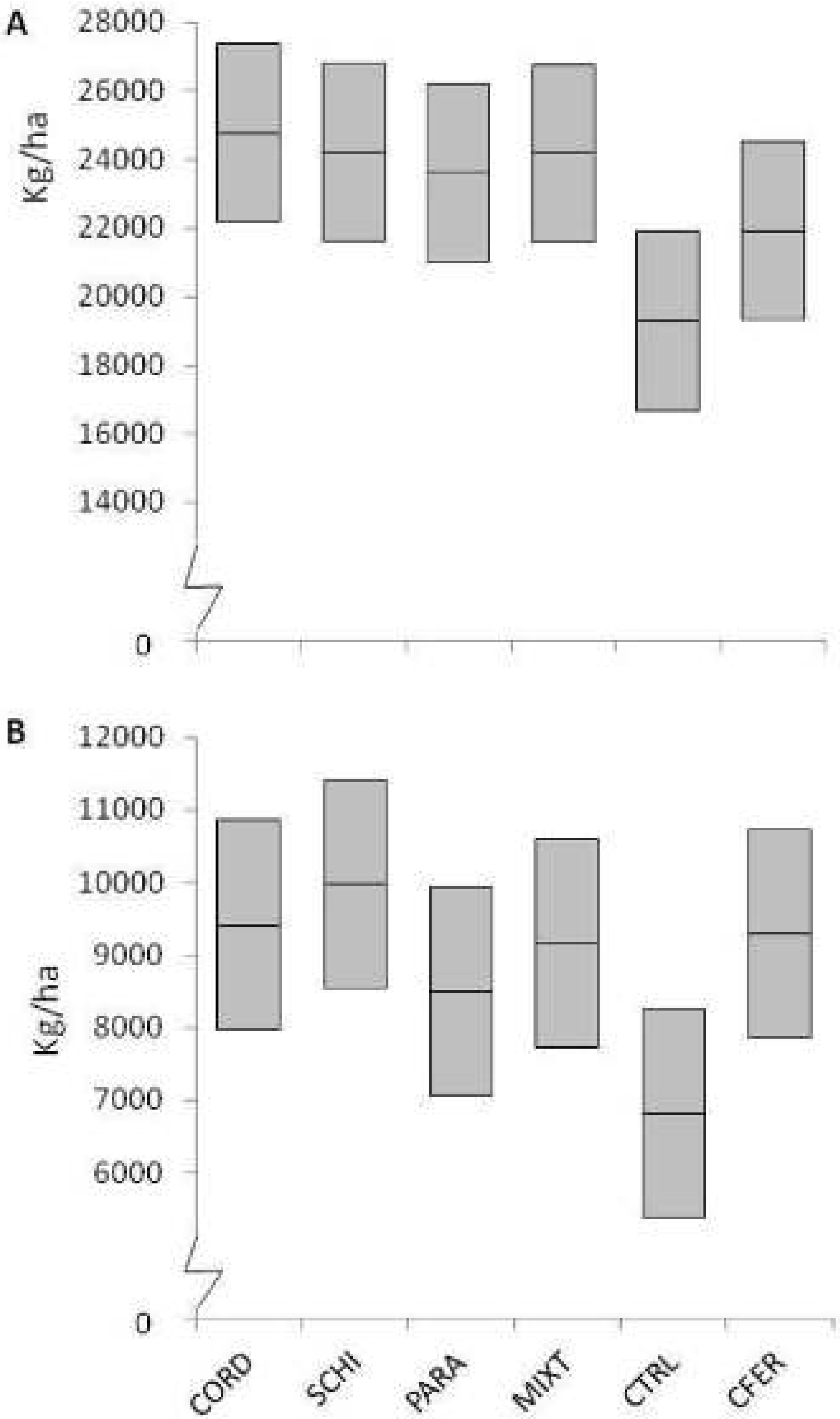

Figure 2: Total aerial biomass of maize plants (A) and ears biomass (B).
Mean values ± HSD; non-overlapping intervals did not differ in the Tukey test ($P<0.05$).

inhibitory effects, which was also observed with maize submitted to prunings of *Gliricidia sepium* (Jaq.) Walp (TIAN; KANG, 1994). Microbiological modification processes (CIPOLLINI et al., 2012) and interactions with mineral components of the soil (INDERJIT; DAKSHINI, 1994) also could promote allelochemical decomposition or interfere with their action.

In general, the mixture of pruning species offered no additional benefits to maize growth or biomass yield. This result is in accordance with the conclusions of Wardle et al. (1997) who did not observe correlation between litter decomposition and mineralization with diversity of species. According to Srivastava et al. (2009) the diversity of detritivores has higher interference on plant residue decomposition than the diversity of plants from which it was originated.

In spite of benefits observed in our study, further investigations are needed in order to verify the occurrence of competition in alley cropping systems with the same species.

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