CORN CULTIVAR INTERCROPPING WITH ARBOREAL LEGUMES FOR WEED CONTROL[1]

Controle de Plantas Daninhas no Milho via Consorciação com Leguminosas Arbóreas

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ABSTRACT - Gliricidia (*Gliricidia sepium*) seedlings are usually beneficial to corn crops when planted between corn rows. The objective of this work was to assess the effects of corn intercropped with gliricidia and "sabiá" (*Mimosa caesalpiniifolia*), a species native to the Brazilian northeastern region, on weed control and corn green ear and grain yields. The experiment was carried out at Estação Experimental da Universidade Federal Rural do Semi-Árido – UFERSA (Mossoró, State of Rio Grande do Norte, Brazil). The experimental design consisted of randomized complete blocks (multifactorial design) with five replications, arranged in split-plots. The plots consisted of corn cultivars AG1051 and BM 2022; subplot treatments (six) were no-hoeing, twice-hoeing (at 20 and 40 days after sowing) and intercropping with gliricidia and "sabiá", either directly sown or transplanted, simultaneously with corn sowing. The intercropped leguminous plants were spaced 0.40 m from each other, and directly seeded or transplanted (30-day-old seedlings) in between two 1 m-spaced corn rows. Twenty three weed species were identified during the experiment. Gliricidia seedlings were superior to "sabiá" seedlings with regard to plant height and survival rate. The highest corn green ear and grain yields were found for twice-hoed subplots, while the lowest yield was found for no-hoed or intercropped subplots. However, grain yield values in intercropped treatments did not differ from grain yield values in hoed plots. In addition, marketable husked green ear mean weights did not differ between twice-hoed subplots and subplots directly seeded with gliricidia and "sabiá". Such results indicated that corn benefited from the intercropping system, but intercropping with gliricidia and "sabiá" transplanted resulted in lower benefits than with the direct sowing of those species.

Keywords: *Gliricidia sepium, Mimosa caesalpiniifolia, Zea mays*, corn green yield, corn grain yield.

*RESUMO - A gliricídia (**Gliricidia sepium**), plantada entre as fileiras do milho sob a forma de mudas, tem efeito benéfico sobre o milho. O objetivo deste trabalho foi avaliar os efeitos da consorciação do milho com gliricídia ou sabiá (**Mimosa caesalpiniifolia**) sobre o controle de plantas daninhas e sobre os rendimentos de espigas verdes e de grãos do milho. Utilizou-se o delineamento de blocos casualizados (multifatorial) em parcelas subdivididas com cinco repetições. Os cultivares AG 1051 e BM 2022, plantados nas parcelas, foram submetidos a seis tratamentos: sem capinas, duas capinas (aos 20 e 40 dias após a semeadura) e consorciação com a glirícidia e sabiá. Nos consórcios, as leguminosas foram cultivadas no espaçamento de 0,40 m, com semeadura direta ou com transplantio (30 dias após a emergência), entre as fileiras do milho, simultaneamente com a semeadura do milho. Vinte e três espécies de plantas daninhas foram identificadas no experimento. A glirícidia foi superior à sabiá na sobrevivência e altura da planta. Os maiores rendimentos de espigas verdes e de grãos foram obtidos com a realização de duas capinas, e os menores, no milho não capinado ou consorciado. Entretanto, os rendimentos de grãos nos consórcios não diferiram do rendimento de grãos nas*

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parcelas capinadas. Além disso, no peso de espigas verdes despalhadas comercializáveis, não houve diferença entre parcelas capinadas e parcelas consorciadas com gliricídia e sabiá, semeadas diretamente. Esses resultados indicam que a consorciação foi benéfica ao milho e que a consorciação com mudas de gliricídia e sabiá é menos benéfica ao milho que a semeadura direta dessas espécies.

Palavras-chave: *Gliricidia sepium*, *Mimosa caesalpiinifolia*, *Zea mays*, rendimento de milho verde, rendimento de grãos.

INTRODUCTION

Herbicides provide many advantages, including application efficiency and weed control efficiency, cost effectiveness, and selectivity (Deuber, 2006). However, the use of herbicides may contribute to soil and water pollution (Spliid & Koeppen, 1998) and may reduce flora and fauna diversity (Marshall et al., 2003). In addition, the use of herbicides may result in human consumption of residues via contaminated water and foods. Finally, the extensive use of herbicides has resulted in the selection of weed biotypes resistant to these products (Christoffoleti & López-Ovejero, 2003). For these reasons, in many countries an increased interest in physical and cultural weed control methods has been observed in the past two decades, including intercropping (Melander et al., 2005).

Interest in using intercropping as a weed control method is not new, but has received greater attention in recent years, in both corn (*Zea mays*) (Gomes et al., 2007; Aladesanwa & Adigun, 2008) and other crops (Poggio, 2005). Corn intercropping with annual species for weed control purposes is the most common type of corn intercropping (Gomes et al., 2007; Aladesanwa & Adigun, 2008). The idea of using intercropping with perennial plants for weed control in corn has arisen from soil mulching studies. The use of gliricidia (*Gliricidia sepium* (a perennial legume) as soil mulch did not have an allelopathic effect on corn and bean (*Phaseolus vulgaris*), but significantly decreased the population of some weed species (Obando, 1987). Gliricidia branches used as soil mulch reduced weed density and weed biomass (Kamara et al., 2000).

Results found in soil mulching studies with gliricidia branches encouraged some authors to intercrop corn with gliricidia in order to achieve weed control (Silva et al., 2009a). In that particular study, gliricidia was grown between corn rows by transplanting seedlings three to four days after emergence; gliricidia partially controlled the weeds (Silva et al., 2009a).

The above-mentioned study (Silva et al., 2009a) sparked interest in studies where corn would be intercropped with tree legumes in order to test three hypotheses. First, the use of older seedlings could control weeds better. Second, the direct sowing of legume plants would eliminate seedling production costs and labor. Finally, other legume tree species could be tested as intercrops in order to control weeds. In this respect, interest was shown in the assessment of sabiá (*Mimosa caesalpiinifolia*) which, similarly to gliricidia, is a rugged, fast-growing, multi-purpose legume plant (Maia, 2004).

Although attempts to use transplanting as a weed control method may be subject to criticism, it has been successfully tried in corn for the control of *Striga hermonthica*, a species that parasitizes the roots of corn and other grasses (Oswald & Ranson, 2003). In this case, it was observed that corn transplanting was an effective method to improve grain yield and reduce *Striga* infestations (Oswald & Ranson, 2003). Although the production and transplanting of seedlings increase production costs, transplanting methods have been developed for areas under irrigation and intensively mechanized corn cultivation systems (Maranthée, 1991). Similar methods can be potentially developed for other species in which transplanting is advantageous for weed control.

This work aimed to assess the effects of corn intercropped with gliricidia and sabiá grown either by direct sowing or transplanting, on weed control, corn green ear yield, and corn grain yield.

MATERIAL AND METHODS

The studies were conducted at Fazenda Experimental "Rafael Fernandes" (Experimental Farm), Universidade Federal Rural do Semi-Árido – UFERSA, during the period from April to July 2008. The farm is located in the district of Alagoinha, 20 km away from the municipal seat of Mossoró-RN (latitude 5° 11' S, longitude 37° 20' W, and 18 m elevation). According to Gaussen's bioclimatic classification, the climate in the Mossoró region is classified as type 4ath, or distinctly xerothermic, which means tropical hot with a pronounced, long dry season, lasting from seven to eight months and with a xerothermic index between 150 and 200. The mean maximum temperature in the region ranges from 32.1 to 34.5 °C. June and July are the coolest months, and the mean annual rainfall is approximately 825 mm (Carmo Filho & Oliveira, 1989).

The soil in the experiment area is classified as a Red-Yellow Argisol, according to the Brazilian Soil Classification System (Embrapa, 2006), and as a Ferric Lixisol, according to the Soil Map of the World (FAO, 1988). The analysis of a soil sample taken from the experiment area indicated: pH = 6.4; Ca^{2+} = 1.50 $cmol_c\ dm^{-3}$; Mg^{2+} = 0.60 $cmol_c\ dm^{-3}$; K^+ = 0.17 $cmol_c\ dm^{-3}$; Na^+ = 0.04 $cmol_c\ dm^{-3}$; Al^{3+} = 0.00 $cmol_c\ dm^{-3}$; P = 38 mg dm^{-3}; Org. Mat. = 10.0 g kg^{-1}.

The soil was tilled with a tractor by means of two harrowings and was fertilized prior to sowing with 1/3 of total N applied (90 kg ha^{-1}), 60 kg ha^{-1} P_2O_5, and 30 kg ha^{-1} K_2O. The remaining N was applied in equal parts after each hoeing. Ammonium sulfate, single superphosphate, and potassium chloride were used as sources of N, P_2O_5, and K_2O, respectively. Plant rows were spaced 1.0 m apart, and pits in the same row were spaced 0.40 m apart. Seeding was performed manually using four seeds per pit. A thinning operation was conducted 20 days after sowing, leaving the two more developed plants in each pit; the experiment was thus left with a programmed sowing density of 50 thousand plants ha^{-1}.

The fall armyworm (*Spodoptera frugiperda*), the crop's main pest in the region, was controlled with two treatments of 0.0-diethyl-0.3,5.6-trichloro-2-pyridinyl thiophosphate (0.4 a.i. L ha^{-1}), using a backpack sprayer.

The experiment was conducted under dryland conditions, but received sprinkler irrigation as needed, with experimental plots arranged perpendicularly in relation to the row of sprinklers. The water depth required for corn (5.3 mm) was calculated considering an effective depth of the root system of 0.40 m. Irrigation time was based on water retained by the soil at a tension of 0.40 Mpa. Irrigations were performed after sowing, with three irrigations per week, and were stopped five days before harvesting the mature ears.

A randomized complete block experimental design in split-plots (a multifactorial trial in a split-plot design) with five replicates was adopted. Each subplot consisted of four rows; each row had 6.0 m in length. The usable area was the space occupied by the two central rows, from which we eliminated the plants from one of the pits at each end. Cultivars AG 1051 and BM 2202, planted in the plots, were submitted to the six treatments, applied to the subplots: no hoeing, two hoeings (at 20 and 40 days after planting), and intercropped with gliricidia and sabiá, either sown directly or transplanted, simultaneously with corn sowing.

Cultivars AG 1051 and BM 2202 have similar characteristics. Both are double hybrids, medium maturity and present high plant height and ear height. Plant height, leaf development rate, leaf area index, and crown leaf distribution are among the most important characteristics in the competition for light (Sinoquet & Caldwell, 1995). Characteristics such as these can be improved through crop practices, such as changing the spacing or plant density, and/or plant breeding (Lindquist& Mortensen, 1998). These approaches can help maize plants compete better with weeds and help farmers reduce herbicide quantities required to control the weeds, and consequently, reduce environmental damage (Begna et al., 2001).

Weedings were performed with a hoe, and the same employee was assigned to do the service in each block. In the direct sowing treatment, the legume plants were sown using four seeds per pit, and a thinning operation was conducted five days after sowing, leaving one plant per pit. In the transplanting treatment (one seedling per pit), seedlings were taken to the permanent site at 30 days after emergence. The transplanted seedlings were grown in black plastic bags measuring 10 cm in diameter and a 15 cm depth, approximately. Seeding density or seedling density for both legume species was 2.5 plants per square meter.

One of the two rows in the usable area (net plot) of each subplot was selected at random to assess corn green yield, while the other was used to assess mature (dry) corn yield. Green corn yield was assessed based on total ear mass and the masses of unhusked marketable ears and husked marketable ears. The green ears were harvested when the grain had water content between 70% and 80% in the period from 70 to 75 days after sowing. Marketable unhusked ears were considered as those that had an aspect suitable for commercialization, and length equal to or above 22 cm. Marketable husked ears were considered as those that displayed health and grain set suitable for commercialization, and with a length equal to or above 17 cm. These criteria were adopted based on the ears that are commonly marketed in the region where this experiment was conducted. The mature ears were harvested when the grain achieved a water content of about 20%, and were then placed to dry and subsequently threshed out manually.

Mature corn was harvest at 100 days after sowing. After harvesting data were obtained for corn plant height and corn ear height, plant height, and stand for both legume species, weed dry matter of the shoot, and weed floristic composition. Plant height and ear height were measured in all plants of the row that was selected to assess grain yield. The distance from ground level to the point of insertion of the tallest leaf blade was considered as plant height; ear height was measured from ground level to the base of the tallest ear (first ear, in the case of prolific plants). The legume plants present in the area between the two central rows of each experimental unit were counted and measured. Legume plant height was considered as the distance from ground level to the top of each plant. The weeds found in a 1.0 m x 1.0 m area, established at random in the central part of the subplot, were cut even with the ground, identified, and weighed. The occurrence index, defined by the ratio between number of units, where a given species occurred and the total number (60) of experimental units in the experiment, was calculated after the weed species found in each experimental unit were identified.

The data were submitted to the variance homogeneity test prior to the statistical analyses (Bartlett, 1937). Since percentage data tend to follow a binomial distribution, the survival percentage data for the legumes were transformed to arcsine of the square root of the percentage, prior to the statistical analysis (Steel et al., 1997). The analysis of variance was carried out using software developed by the Universidade Federal de Viçosa (Ribeiro Junior, 2001). The means were compared at 5% probability by Tukey's test whenever the F test values from the analysis of variance were significant.

RESULTS AND DISCUSSION

Twenty-three weed species occurred in the experiment area, with *Alternanthera tenella*, *Cucumis anguria*, and *Commelina benghalensis* as the most frequent species (Table 1).

There was no effect of the cultivars x weed control methods interaction on the traits assessed. For this reason, only the means for the main effects of both treatment groups are presented here.

The legume species behaved similarly with regard to survival and plant height (Table 2). For each legume species, there were higher percentages of live plants at the end of the corn cycle in the transplanting growing system than in direct sowing. Because transplanted plants are older, they are certainly more capable of withstanding environmental factors that are harmful for survival - including competition with corn and weeds - than plants resulting from direct sowing. It is, therefore, interesting to point out that corn and - possibly and particularly - weeds are capable of eliminating up to 75% of the intercrop plants, just as the case with sabiá plants grown by direct sowing. The legume

Table 1 - Occurrence index (ratio between the number of experimental units where a given species occurred and the total number of experimental units) of weed species with respective families in experimental plots of corn

Species	Family	Occurrence index (%)
Acanthospermum hispidum	Compositae	6.7
Alternanthera tenella	Amaranthaceae	88.3
Amaranthus viridis	Amaranthaceae	1.7
Blainvillea acmella	Compositae	26.7
Borreria verticillata	Rubiaceae	1.7
Cenchrus echinatus	Gramineae	16.7
Commelina benghalensis	Commelinaceae	53.3
Cucumis anguria	Cucurbitaceae	73.3
Cyperus rotundus.	Ciperaceae	1.7
Dactyloctenium aegyptium	Gramineae	6.7
Desmodium glaglabrum	Leguminosae Faboideae	1.7
Digitaria sanguinalis	Gramineae	18.3
Euphorbia hirta	Euphorbiaceae	1.7
Herissantia crispa	Malvaceae	1.7
Lwdwigia sp.	Onagraceae	1.7
Merremia aegyptia	Convolvulaceae	8.3
Merremia cissoides	Convolvulaceae	3.3
Panicum maximum	Gramineae	1.7
Physalis angulata	Solanaceae	8.3
Phyllanthus amarus	Euphorbiaceae	11.7
Senna sp.	Leguminosae Caesalpinioideae	1.7
Starchytarpheta sp.	Verbenaceae	1.7
Waltheria indica	Sterculiaceae	1.7

plants of the two species that remain in the field after the corn harvest mature have a small growth (Table 2). They are easily eliminated with preparing the soil for subsequent crops. Gliricidia was superior to sabiá in terms of survival and plant height, when a comparison is made between transplanted plants and plants resulting from direct sowing in the field. There are no studies in the literature comparing the behavior of these two legume species for intercropping weed control. No cultivar effect was found for the two traits of the legume plants assessed. Similarly as observed in this work, other authors did not observe corn cultivar effects on gliricidia growth in intercrops (Silva et al., 2009a).

In addition, there was no cultivar effect on weed growth, in agreement with what has been observed by other authors (Gomes et al., 2007). Nevertheless, there are differences among corn cultivars in their competitive ability against weeds (Rossi et al., 1996). Weed dry matter of the shoot was lower in hoed plots and higher in plots where gliricidia was planted by direct sowing or sabiá was transplanted (Table 3).

Corn growth has not been affected by weed control; it was measured by plant height and ear height (Table 3), as was also observed by other authors (Silva et al., 2009b). Due to the fact that weeds compete with the crop for water, light, nutrients, and space, smaller corn plants are expected under no weed control. However, there is a tendency that goes against this. Corn plants would tend to have greater plant heights in the presence of weeds. Plants absorb solar radiation in the red region (R) (wavelengths from 660 to 670 nm) of the spectrum and reflect radiation in the far-red

Table 2 - Survival and plant height of two legume species used for intercropping weed control in two corn cultivars[1/]

Legume plants[2/]	Survival		Plant height (cm)
	Original data (%)	Transformed data	
Gliricidia - transplanted	67.1	55.7 a	88.5 a
Gliricidia - sown	47.9	43.7 b	43.8 b
Sabiá - transplanted	43.6	41.0 bc	28.4 bc
Sabiá - sown	25.0	29.7 c	16.4 c
Cultivars AG 1051 and BM 2202 (mean value)	45.9	42.5	44.3
CV_{plots} (%)	30.5	20.9	45.1
$CV_{subplots}$ (%)	33.1	22.1	41.1

[1/] Means followed by the same letter are not different from one another at 5% probability, by Tukey's test. Survival data were transformed to arcsine of the square root of the percentage. [2/] In the intercrop treatments, legume plants were sown (four seeds pit^{-1}, thinned to one plant pit^{-1} at five days after emergence) or transplanted (seedlings at 30 days after emergence) between corn rows, simultaneously when the corn was seeded.

Table 3 - Dry matter of the shoot of weeds, plant height, and ear height of two corn cultivars under different weed control methods[1/]

Weed control methods[2/]	Dry matter of the shoot of weeds (g m^{-2})	Corn height (cm)	
		Plant	Ear insertion
Two hoeings	218.3 b	197 a	103 a
Intercropped with gliricidia - sown	426.3 a	192 a	94 a
Intercropped with sabiá - sown	364.8 ab	195 a	98 a
Intercropped with gliricidia - transplanted	322.2 ab	195 a	100 a
Intercropped with sabiá - transplanted	396.7 a	195 a	103 a
No hoeing	367.9 ab	195 a	101 a
Cultivars AG 1051 and BM 2202 (mean value)	349.3	194	100
CV_{plots} (%)	36.8	5.8	11.0
$CV_{subplots}$ (%)	34.2	4.4	10.7

[1/] Means followed by the same letter do not differ at 5% probability by Tukey's test. [2/] In the intercrop treatments, legume plants were sown (four seeds pit^{-1}, thinned to one plant pit^{-1} at five days after emergence) or transplanted (seedlings at 30 days after emergence) between corn rows, simultaneously when the corn was seeded.

region (FR) (wavelengths from 730 to 740 nm) of the spectrum. The FR/R ratio plays an important role in the induction of morphological changes in plant architecture, including stem elongation, apical dominance, etc. (Ballaré, 1999). Therefore, the radiation reflected by weeds would result in taller corn plants. Height in corn plants would depend on both tendencies, which would suffer the influences of genotypic and environmental factors. Nevertheless, several researchers (Gomes et al., 2007; Silva et al., 2004a) have observed reductions in corn plant height due to interference (competition and alelopathy) with weeds. The cultivars were not different as to plant height, but cultivar AG 1051 was significantly different from cultivar BM 2202 with respect to ear height (111 cm versus 88 cm) (data not presented).

The highest green ear yield and grain yield values were obtained with two hoeings, while the lowest values were observed for non-hoed corn (Table 4). Intercropping provided intermediate yields, but no significant differences were observed between non-hoed plots and intercropped plots for the three traits used to assess green corn yield and grain yield. In spite of that, grain yield values in intercropped treatments did not differ from grain yield values in hoed plots. In addition, regarding the weight of marketable husked green ears, there were no significant differences between hoed plots and plots intercropped with gliricidia and sabiá sown directly. This means that intercropping was beneficial to corn, especially when conducted via direct sowing.

It can be argued that the beneficial effect of gliricidia and sabiá for corn could have occurred with the transfer of nitrogen by gliricidia or sabiá at intercropping. The absorption of nitrogen by the recipient plant, excreted by the root system of the donor plant, seems to be the mechanism of nitrogen transfer between plants (Hamel et al., 1991). The most important factor influencing this transfer is the extent of contact of plant root systems (Hamel et al., 1991). Therefore, if there was benefit in the use of nitrogen provided by gliricidia or sabiá, it is more likely that this benefit occurred with the weeds, whose roots were in close contact, (than the roots of corn) with the roots of gliricidia or sabiá. This occurred because gliricidia and sabiá were planted between the corn rows, a place of higher incidence of weeds. There are two facts for this possibility. First, the application of nitrogen for corn increased weed biomass, regardless of the type of weed control, including intercropping with gliricidia (Silva et al., 2010). Second, gliricidia was beneficial to corn, although it has not significantly reduced the growth of weeds (Silva et al., 2010). It is important to mention that the transfer of nitrogen fixed by leguminous trees for grasses in rotation can even be zero (Dias et al., 2007).

Results have also indicated that, in intercropped treatments, transplanted gliricidia and sabiá are less beneficial to corn than plants obtained by direct sowing. Gliricidia and sabiá seedlings could have some allelopathic effect on corn plants in early growth stages. It is possible that younger corn plants are more sensitive to the action of allelopathic substances. At least 15 substances were identified in the shoot of gliricidia that could have allelopathic action (Ramamoothy & Paliwal, 1993).

It is interesting to note that the effects of intercropping with gliricidia or sabiá were different with regard to green ear yield and grain yield (Table 4). Two facts can explain this difference. When corn is harvested at the "green stage", competition with weeds is lower than when corn is harvested at the physiological maturation stage. In addition, ears that are unsuitable to be marketed as green corn can be perfectly used for the production of dry grain.

Consistency or parallelism were not always found between treatment effects on weed density and growth and treatment effects on crop yield. That is, some treatments may not reduce weed growth as measured by dry matter of the shoot of the weed plants, but they may be beneficial to crop yield. This has occurred in this study (Tables 3 and 4), but it has also been observed by other authors (Aladesanwa & Adigun, 2008).

Table 4 - Means for green ear yield and grain yield for two corn cultivars under different weed control methods[1/]

Weed control methods[2/]	Yield (kg ha^{-1})			
	Green ears			Grain
	Total	Marketable unhusked	Marketable husked	
Two hoeings	16.108 a	15.690 a	8.730 a	9.209 a
Intercropped with gliricidia - sown	13.484 b	12.631 b	7.061 ab	8.832 ab
Intercropped with sabiá - sown	13.110 b	12.372 b	7.049 ab	7.589 ab
Intercropped with gliricidia - transplanted	13.028 b	12.508 b	6.850 b	7.520 ab
Intercropped with sabiá - transplanted	12.528 b	12.120 b	6.796 b	7.391 ab
No hoeing	12.338 b	11.955 b	6.662 b	7.143 b
Cultivars AG 1051 and BM 2202 (mean value)	13.433	12.879	7.191	7.947
CV_{plots} (%)	10.8	13.5	17.1	14.3
$CV_{subplots}$ (%)	12.5	14.1	18.6	19.4

[1/] Means followed by the same letter do not differ at 5% probability by Tukey's test. [2/] In the intercrop treatments, legume plants were sown (four seeds pit^{-1}, thinned to one plant pit^{-1} at five days after emergence) or transplanted (seedlings at 30 days after emergence) between corn rows, simultaneously when the corn was seeded.

It can be concluded that 23 weed species occurred in this experiment. Gliricidia was superior to sabiá in terms of survival and plant height. The dry matter of the shoot of weeds was lower in hoed plots. The highest green ear yield and grain yield values were obtained with two hoeings, while the lowest values were observed for non-hoed corn and intercropped corn. In spite of that, grain yield values in intercropped treatments did not differ from grain yield values in hoed plots. In addition, with respect to weight of marketable husked green ears, there were no significant differences between hoed plots and plots intercropped with gliricidia and sabiá sown directly. This means that intercropping was beneficial to corn.

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