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Gliricidia sepium intercropping for weed management in immature corn ear production[1]

Consorciação com *Gliricidia sepium* para manejar plantas daninhas visando a produção de espigas imaturas de milho

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ABSTRACT - The goal of the study was to test the effects of combined weeding and gliricidia (*Gliricidia sepium*) intercropping for weed control in baby corn and green corn production. A completely randomized block design was employed, with split-plot and four replicates. Hybrids AG 1051 and BR 205 were subjected to the following treatments: A = two hoeings, 20 and 40 days after sowing (DAS); B = hoeing at 20 DAS + gliricidia intercropping following weeding; C = gliricidia intercropping established at the moment of corn sowing (GICS) + hoeing at 40 DAS; D = GICS; E = no weeding. Gliricidia was broadcast sown with 30 viable seeds m^{-2}. The best treatments follow the order A > B > C as number of ears, fresh mass of ears with husks, fresh and dry masses of ears without husks for baby corn, and number of ears, fresh mass of ears with husks, fresh and dry masses of ears without husks for green corn. The worst results are observed for treatments D and E. Treatment D is only better than treatment E for the number of marketable ears without husks. No differences in the yields of immature ears exist between the hybrids.

Key words: *Zea mays*. *Gliricidia sepium*. Baby corn. Green corn.

RESUMO - O objetivo do trabalho foi verificar os efeitos da combinação de capinas + consorciação com gliricídia no controle de plantas daninhas para produção de minimilho e milho verde. Utilizou-se o delineamento de blocos casualizados com quatro repetições e parcelas subdivididas. Os híbridos AG 1051 e BR 205 foram submetidos aos seguintes tratamentos: A = duas capinas (20 e 40 dias após a semeadura, DAS); B = realização de capina aos 20 DAS + consorciação com gliricídia após a capina; C = consorciação com gliricídia por ocasião da semeadura do milho (CGSM) + realização de capina aos 40 DAS; D = CGSM; E = sem capinas. A gliricídia foi semeada a lanço com 30 sementes viáveis m^{-2}. A ordem dos melhores tratamentos foi A > B > C, quanto ao número de espigas, massas frescas de espigas empalhadas e despalhadas, e massa seca de espigas despalhadas, de minimilho, e quanto aos números e massas totais e de espigas comercializáveis, empalhadas e despalhadas, de milho verde. Os tratamentos D e E foram os piores, sendo o tratamento D superior ao tratamento E apenas quanto ao número de espigas despalhadas comercializáveis. Não existem diferenças entre os híbridos quanto aos rendimentos de espigas imaturas.

Palavras-chave: *Zea mays*. *Gliricidia sepium*. Minimilho. Milho verde.

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INTRODUCTION

Immature corn ears, i.e., ears in which grains have not reached physiological maturity, are consumed in two forms: baby corn and green corn. Baby corn is corn ear without husks, harvested two to three days following the emergence of the style-stigma. Baby corn is consumed as a vegetable, raw or canned, and its production is advantageous because baby corn possesses added value and diversifies the cultivation of corn crops (ALMEIDA *et al*., 2005). Green corn (*Zea mays* L.) ears are ears harvested when the grains exhibit a water content between 70 and 80%. Green corn is highly appreciated by Brazilians, who consume it raw, roasted or boiled, or as an ingredient in various dishes. Green corn garners higher prices than dry corn grain.

The same cultivars and agricultural practices are used for the production of green corn ears and dry grain across the 167 municipalities of the state of Rio Grande do Norte. Weed control consists of at least two hoeings on small farms and applications of herbicides on large farms. Weeding is labor intensive, time consuming, and expensive (MEROTTO JÚNIOR *et al*., 2000). Zárate *et al*. (2009) estimated that the cost of hoeings represents 35% of the labor cost for a corn farm. Herbicides, although efficient for the control of weeds, can be detrimental to the environment (ARIAS-ESTÉVEZ *et al*., 2008).

To avoid the problems associated with hoeings and herbicides, many researchers have searched for alternative methods for weed control. Oliveira *et al*. (2016) observed that green ear yield in corn plots intercropped with gliricidia [*Gliricidia sepium* (Jacq.) Walp.], an exotic leguminous tree, was higher than in non-weeded plots but lower than in plots receiving two hoeings. In that study, gliricidia was broadcast sown between the corn rows at the time of corn sowing. Broadcast sowing of gliricidia is much faster and easier than hoeings. These results indicate the need to test the combination of hoeings together with gliricidia intercropping for weed control on baby corn and green corn productions.

Combinations of various weed control methods have been studied for several crops. For sorghum-peanut intercropping, the combination of low dosages of herbicide with one hoeing exhibited similar results to the treatment with two hoeings and decreased weed infestation more efficiently than higher dosages of herbicides without weeding (MAGANI, 2008). Olorunmaiye and Olorunmaiye (2009) observed that the combination of herbicide application with two hoeings resulted in lower weed biomass and higher corn and cassava yields compared to either the performance of two hoeings or the application of herbicides separately. The combined use of herbicides + hoeing + a leguminous cover crop resulted in a higher economic return from corn-cassava intercropping than either the use of herbicides or a cover crop alone, or the combination of the two (OLORUNMAIYE, 2011). For cassava-corn intercropping, plots managed by weeding or an herbicide application in combination with cover cropping resulted in a higher economic return for cassava but a lower return for corn (CHIKOYE *et al*., 2002).

The goal of the present study was to evaluate the effects of weed control by hoeings combined with gliricidia intercropping on the yields of immature ears of corn cultivars.

MATERIALS AND METHODS

The experiment was carried out from October 2012 to February 2013 at the Rafael Fernandes Experimental Farm, which is part of the Federal Rural University of the Semi-Arid (UFERSA), located in the district of Alagoinha (latitude 5°03’49” S, longitude 37º23’49” W, at an altitude of 80 m), 20 km from the town of Mossoró, in the state of Rio Grande do Norte, Brazil. According to the Köppen classification, the climate in the region is the BSwh’ type, i.e., dry and very hot, with a rainy season from summer to autumn, an average annual temperature of 27.4 ºC, very irregular annual rainfall with an average of 673.9 mm, and a relative humidity of 68.9%. Sunlight increases from March to October, with an average of 241.7 h. The maximum relative humidity reaches 78% in April with a minimum of 60% in September (CARMO FILHO; OLIVEIRA, 1989).

The soil of the experimental area was classified as a Yellow-Red Argisol [Ultisol] (EMBRAPA, 2006) and its chemical characteristics were as follows: pH (water) = 6.46, organic matter = 8.36 g kg^{-1}, P = 6.4 mg dm^{-3}, K^+ = 81.3 mg dm^{-3}, Na^+ = 69.4 mg dm^{-3}, Ca^{2+} = 1.85 $cmol_c$ dm^{-3}, Mg^{2+} = 0.80 $cmol_c$ dm^{-3}, Al^{3+} = 0.00 $cmol_c$ dm^{-3}, H+Al = 0.00 $cmol_c$ dm^{-3}, BS = 3.16 $cmol_c$ dm^{-3}, ESP = 10%.

The soil was prepared by performing harrowing twice. Fertilization was performed at sowing, adding 40 kg N ha^{-1} (ammonium sulfate), 100 kg P_2O_5 ha^{-1} (single superphosphate) and 50 kg K_2O ha^{-1} (potassium chloride). The fertilizers were applied manually in furrows located adjacent to and below the sowing furrows. Top dressings with 40 kg N ha^{-1} (as ammonium sulfate) were performed 20 and 40 days after sowing. Corn sowing was performed manually on 05/21/2012, sowing four seeds per hole, at a spacing of 1.0 m x 0.4 m. Twenty days after sowing, thinning was performed, leaving the two most vigorous plants at each hole, resulting in the planned planting density of 50,000 plants ha^{-1}. Sprayings were performed for the control of fall armyworm (*Spodoptera frugiperda* Smith) at 10, 20, 30, 38, and 45 days after sowing.

Water was applied by sprinkler irrigation. The required daily water depth for corn (5.6 mm) was calculated considering a 0.40 m effective rooting depth. Irrigation time was based on the water retained in the soil at a soil water potential of 0.40 MPa. The irrigation frequency was every two days, with three weekly irrigations. Irrigation was started following planting and stopped 15 days before the harvest of dry corn.

The experimental design was a randomized block design with split plots and four replications. In the plots, the hybrids AG 1051 (a double hybrid developed by Agroceres, with a normal cycle and soft, yellow grains) and BR 205 (a double hybrid produced by Embrapa, with an early cycle and semi-soft, orange-yellow grains) were grown. In the subplots, the following methods of weed control were applied: a) hoeing [20 and 40 days after sowing the corn (DASC)]; b) hoeing at 20 DASC followed by the planting of gliricidia; c) sowing of gliricidia at the time of sowing the corn, followed by hoeing at 40 DASC; d) sowing of gliricidia when sowing the corn; and e) no hoeing. When intercropping, the gliricidia seeds (30 viable seeds m^{-2}) were broadcast and incorporated into the soil with the aid of a rake. The same employee was always assigned to hoe each block.

A subplot consisted of four rows, and each row was 6.0 m long. The usable area was defined as the area occupied by the two central rows, from which the plants from the last hole at each end of the row were discarded when harvested. Of the two central rows, one was used to evaluate the yield of baby corn and the other to assess green ears yield.

Baby corn yield was evaluated at eight harvest times, performed between 52 and 66 days after sowing. Plants were harvested 67 days after sowing for the quantification of biomass. The length, diameter, total number, and fresh and dry masses of ears with husks, fresh and dry masses of ears without husks, and fresh and dry plant masses were measured. Ear length and diameter (measured at the mid-region of the ear) were determined using a ruler and digital caliper, respectively, for ears harvested between the second and sixth harvests. Ears with husks were considered marketable when they were free of damage caused by diseases and pests, and ears without husks were considered marketable when they exhibited good health, a color between pearl white and light yellow, a cylindrical shape, a diameter between 8 mm and 18 mm, and a length between 4 cm and 12 cm (CARVALHO *et al*., 2008). A sample of approximately 300 g was placed in a forced-air oven at 75°C until a constant weight was obtained.

Green corn was harvested when the grains exhibited a water content between 70% and 80%, at 73, 76, and 79 days after sowing. Plants were harvested 80 days after sowing for biomass quantification. The ear length and diameter, total ear number and mass, marketable ear number and mass (with and without husks), and plant fresh and dry masses were quantified. The ear length and diameter were measured as described for baby corn. Green ears with husks were considered marketable when they were free of damage caused by pests or diseases, exhibited no deformities, and had a length equal to or greater than 22 cm. Green ears without husks were considered marketable when they exhibited good health and grain filling and had a length equal to or greater than 17 cm (SILVA *et al*., 2006).

Two corn plants were randomly collected from different holes and cut at ground level for determinations of shoot fresh and dry masses. Following weighing, the plants were ground using a fodder crusher and an approximately 300 g sample of the ground material was placed in a forced-air oven at 75°C until a constant mass was achieved.

The data were subjected to analyses of variance followed by Tukey's tests, at $p<0.05$.

RESULTS AND DISCUSSION

There was no significant interaction of factors (cultivars x weed control methods) on the measured traits. For this reason, only the means of the main effects for the two treatment groups are presented. This interaction has been previously observed to be both insignificant in some studies (SILVA *et al*., 2010) and significant in others (CHIKOYE *et al*., 2008; SILVA *et al*., 2007).

The yield of baby corn, measured as the number and mass of ears with husks and the fresh and dry masses of ears without husks, did not differ significantly between the two tested corn cultivars (Table 1). The highest number of baby corn ears was obtained for the treatment with two hoeings; the lowest number was recorded for intercropping with gliricidia sown at the moment of corn sowing. The remaining treatments exhibited intermediate yields and did not differ significantly from each other. The highest yields in terms of the mass of ears with husks and the fresh and dry masses of ears without husks were observed for the treatment with two hoeings, followed by the treatment combining one hoeing 20 days after corn sowing and intercropping with gliricidia following the weeding. The remaining treatments did not differ significantly from each other, and their yields were lower than those of the two most productive treatments (Table 1).

Hybrid AG 1051 produced longer and thicker (greater diameter) baby corn ears than hybrid BR 205 (Table 2). However, no differences between the two hybrids

Table 1 - Means for the number and weight of ears of baby corn in the corn hybrids as a response to weed control methods

Corn hybrids	Number of ears ha^{-1}	Weight of ears (kg ha^{-1})		
		Unhusked fresh	Husked fresh	Husked dry
AG 1051	72,597 a	5,268 a	1,204 a	138 a
BR 205	76,907 a	5,423 a	1,062 a	119 a
CVplots (%)	21.1	31.0	31.2	30.3
Methods of weed control				
Hoeing 20 and 40 days after sowing the corn (DASC)	88,308 a	7,154 a	1,492 a	169 a
Hoeing at 20 DASC + intercropping with gliricidia after hoeing	73,308 ab	5,637 ab	1,162 ab	132 ab
Intercropping with gliricidia at the time of sowing the corn + hoeing at 40 DASC	77,141 ab	5,177 b	1,096 b	124 b
Intercropping with gliricidia at the time of sowing the corn	62,695 b	3,941 b	888 b	101 b
No hoeing	72,308 ab	4,819 b	1,026 b	117 b
CV Subplots (%)	15.3	22.0	21.5	21.7

[1] For each trait, means followed by the same letter do not differ significantly at 5% probability by Tukey's test.

Table 2 - Means for dimensions of ears of husked baby corn and above-ground biomass of corn hybrids as a response to methods of weed control

Hybrids	Dimensions of ear		Above-ground biomass (kg ha^{-1})	
	Length (cm)	Diameter (mm)	Fresh	Dry
AG 1051	10.9 a	15.1 a	22,626 a	4,826 a
BR 205	10.2 b	14.2 b	22,024 a	4,247 a
CVplots (%)	5.0	4.9	21.8	22.3
Methods of weed control				
Hoeing 20 and 40 days after sowing the corn (DASC)	11.2 a	15.3 a	30,695 a	6,107 a
Hoeing at 20 DASC + intercropping with gliricidia after hoeing	10.9 a	15.1 a	25,956 a	4,997 a
Intercropping with gliricidia at the time of sowing the corn + hoeing at 40 DASC	10.3 bc	14.3 bc	18,706 b	3,685 b
Intercropping with gliricidia at the time of sowing the corn	10.2 c	14.2 c	19,461 b	3,791 b
No hoeing	10.4 bc	13.3 bc	21,805 b	4,101 b
CV Subplots (%)	4.4	3.9	22.3	22.8

[1] For each trait, means followed by the same letter do not differ significantly at 5% probability by Tukey's test

were observed in the shoot fresh and dry masses, measured in plants harvested following the baby corn harvest. The treatment with two hoeings and the treatment with hoeing 20 days after corn sowing followed by establishment of gliricidia intercropping produced the longest and thickest (greatest diameter) baby corn ears and the highest shoot fresh and dry masses of all the treatments (Table 2).

No significant differences between the two tested hybrids were observed for green ear yield, measured as the total numbers and masses of all ears and of marketable ears with and without husks (Table 3). No significant differences in either the total number of ears or the number of marketable ears with husks were observed between the tested weed control methods (Table 3). The highest means of total ear mass, of the masses of marketable ears with and without husks, and of the number of marketable ears without husks were observed for the treatment with two weeding events, while the lowest yield values were recorded for the treatment without weeding and the treatment with gliricidia intercropping established at the time of corn sowing (Table 3). Intermediate values for these parameters were observed for the two treatments combining one hoeing (at 20 or 40 days after corn sowing) with gliricidia intercropping. Intermediate values of the number of marketable ears without husks were also observed for the gliricidia intercropping treatment (Table 3).

Hybrid AG 1051 produced longer and thicker (greater diameter) green ears without husks compared to hybrid BR 205, but the two hybrids did not differ in terms

Table 3 - Means for green ear yield of corn hybrids as a response to methods of weed control

Corn hybrids	Number of ears ha^{-1}		
	Total	Marketable unhusked	Marketable husked
AG 1051	50.068 a	41,005 a	35,294 a
BR 205	50.100 a	38,316 a	33,388 a
CVparcela (%)	4.5	7.4	26.8
Methods of weed control			
Hoeing 20 and 40 days after sowing the corn (DASC)	50.449 a	43,395 a	39,692 a
Hoeing at 20 DASC + intercropping with gliricidia after hoeing	49.531 a	43,066 a	38,594 ab
Intercropping with gliricidia at the time of sowing the corn + hoeing at 40 DASC	49.681 a	39,706 a	35,325 ab
Intercropping with gliricidia at the time of sowing the corn	50.740 a	36,298 a	30,827 ab
No hoeing	50.020 a	35,835 a	27,267 b
CV Subplots (%)	4.5	17.5	22.9

[1] For each trait, means followed by the same letter do not differ significantly at 5% probability by Tukey's test.

of shoot fresh and dry mass yields (Table 4). Green ears without husks had larger dimensions and higher shoot fresh and dry masses when cultivated under the treatment with two hoeings. A longer ear length was observed for the treatment with two hoeings than for the other treatments, which did not differ from each other. The treatment with gliricidia intercropping initiated at the time of corn sowing and hoeing 40 days after corn sowing produced ears with smaller diameters than the treatment with two weeding events but larger diameters than the remaining treatments, which did not differ from each other. Intermediate shoot fresh and dry mass yields were observed for the treatment with weeding 20 days after corn sowing followed by gliricidia intercropping (Table 4). The ear size is important because green ears are often marketed without their husks and consumers prefer larger ears. High fodder yields are also important because the demand for fodder is high, especially during the intercropping period. Frequently, the farmers who produce green corn are more interested in commercializing the corn shoot following the harvest of the green ears.

Of the eighteen parameters measured in the present study, differences between the two tested cultivars were only observed for the ear length and the diameter of baby corn (Table 2) and green corn (Table 5). The lack of differences between cultivars for the majority of the quantified parameters, together with the absence of a significant cultivar x weed control interaction, may indicate that cultivars AG 1051 and BR 205 exhibit similar (or compensatory) tolerance mechanisms and/or weed suppression capabilities. Tolerance is the ability to maintain

Table 4 - Means for green ear yield of corn hybrids as a response to methods of weed control

Corn hibrids	Weight of ears (kg ha^{-1})		
	Total	Marketable unhusked	Marketable husked
AG 1051	13,399 a	11,872 a	6,847 a
BR 205	12,698 a	10,631 a	5,610 a
CVplots (%)	11.3	13.3	31.5
Methods of weed control			
Hoeing 20 and 40 days after sowing the corn (DASC)	15,288 a	13,850 a	8,009 a
Hoeing at 20 DASC + intercropping with gliricidia after hoeing	13,577 ab	12,380 ab	6,830 ab
Intercropping with gliricidia at the time of sowing the corn + hoeing at 40 DASC	12,887 ab	11,090 ab	6,407 ab
Intercropping with gliricidia at the time of sowing the corn	11,755 b	9,644 b	5,264 b
No hoeing	11,734 b	9,293 b	4,633 b
CV Subplots (%)	12.7	21.3	26.4

[1] For each trait, means followed by the same letter do not differ significantly at 5% probability by Tukey's test

Table 5 - Means for dimensions of ears of green corn and above-ground biomass of corn hybrids as a response to methods of weed control

Corn hibrids	Weight of ears (kg ha^{-1})		
	Total	Marketable unhusked	Marketable husked
AG 1051	13,399 a	11,872 a	6,847 a
BR 205	12,698 a	10,631 a	5,610 a
CVplots (%)	11.3	13.3	31.5
Methods of weed control			
Hoeing 20 and 40 days after sowing the corn (DASC)	15,288 a	13,850 a	8,009 a
Hoeing at 20 DASC + intercropping with gliricidia after hoeing	13,577 ab	12,380 ab	6,830 ab
Intercropping with gliricidia at the time of sowing the corn + hoeing at 40 DASC	12,887 ab	11,090 ab	6,407 ab
Intercropping with gliricidia at the time of sowing the corn	11,755 b	9,644 b	5,264 b
No hoeing	11,734 b	9,293 b	4,633 b
CV Subplots (%)	12.7	21.3	26.4

[1] For each trait, means followed by the same letter do not differ significantly at 5% probability by Tukey's test

high yields in the presence of weeds (WORTHINGTON; REBERG-HORTON, 2013). The suppression capability is the joint result of competition and allelopathy. Competition is based on a cultivar's ability to access and use light, water, and nutrients, whereas allelopathy refers to a process by which plants suppress weed growth and reproduction through the exudation of phytotoxins (WORTHINGTON; REBERG-HORTON, 2013).

The tested weed control methods produced varying effects on the baby corn (Tables 1 and 2) and green corn (Tables 3 and 4) yields. These differences could be attributed to at least three causes. First, plants that produce baby corn spend less time competing with weeds than plants that produce green corn. Second, baby corn and green corn are harvested and evaluated differently. Finally, the yields of the two products can be affected by differences in phenology. Reid *et al*. (2014) observed that delaying weed control increased the time interval between the emergence of male and female corn flowers. This increase should not have an effect on the yield of baby corn but may have a negative effect on the yield of green corn because of associated problems with pollination.

Considering the eight parameters measured for baby corn-producing plants (Tables 1 and 2) and the ten parameters measured for green corn-producing plants (Tables 3 and 4), the execution of two hoeings was the best treatment. The second best treatment included weeding 20 days after corn sowing (DAS) followed by gliricidia intercropping (H20 + GI). The third best treatment consisted of gliricidia intercropping established at the time of corn sowing + weeding at 40 DAS (GI + H40). The fact that plants subject to the H20 + GI treatment performed better than those of the GI + H40 treatment may be related to the critical period of weed control (CPWC). The CPWC is the minimum time interval during which the crop should be weed free in order to avoid reductions in biomass accumulation (KOZLOWSKI; KOEHLER; PITELLI, 2009; RODRIGUES *et al*., 2010). The weeding performed 20 DAS must have been more efficient than the gliricidia intercropping for weed control during the critical period.

Corn intercropping with gliricidia at the time of corn sowing without additional weeding was only beneficial in terms of the number of marketable ears without husks (Table 3). This indicates that the gliricidia partially controlled the weeds. This control must have manifested through competition for water, light, nutrients, and space, as well as through allelopathy (OYUN, 2006).

CONCLUSIONS

1. Yields of baby corn and green corn of the two hybrids were similar;
2. The best treatment consisted of two hoeings and should be recommended to the farmer. The second best treatment consisted of hoeing at 20 days after corn sowing (DAS) + intercropping following hoeing. The third best treatment is intercropping at the moment of corn sowing + hoeing at 40 DAS;
3. Gliricidia intercropping and the no-weeding treatment resulted in the lowest yields.

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