CORN AND ALEXANDERGRASS INTERCROPPING SYSTEM: INFLUENCES OF HERBICIDE MANAGEMENT ON GRAIN AND FORAGE YIELD

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ABSTRACT

In Southern Brazil, intercropping system between corn and *Urochloa* is an interesting way to improve soil cover and animal feed after corn harvesting. This study was carried out with the objective to evaluate the effect of herbicides and its doses on corn and Alexandergrass (*Urochloa plantaginea*) yield, in an intercropped system. The experiment was arranged in a randomized block design, with four replications in a factorial scheme. First factor was composed of four herbicide associations: (1) Atrazine + Oil; (2) Atrazine + Simazine + Oil; (3) Atrazine + Nicosulfuron + Oil; and (4) Atrazine + Mesotrione + Oil. The second factor was composed of three doses of these herbicide combinations: 100%, 75% and 50% of the recommended dose to control Alexandergrass. A control treatment, without herbicide spraying, was evaluated. Corn crop was sowed in no-till system and Alexandergrass established by self-seeding. Herbicide management in corn with Alexandergrass intercropping system is primordial to obtain good grain yields, once corn was highly affected by the forage. Herbicides and doses influenced Alexandergrass forage yield, although, all the managements allow forage availability after corn harvest. The better corn yields in the intercropping, with adequate Alexandergrass forage production, were obtained with 75% of the recommended dose of Mesotrione and Nicosulfuron associations.

Key words: interspecific competition; natural reseeding; *Urochloa plantaginea.*

SISTEMA CONSORCIADO DE MILHO E PAPUÃ: INFLUÊNCIA DO MANEJO COM HERBICIDAS NO RENDIMENTO DE GRÃOS E FORRAGEM

RESUMO

No Sul do Brasil, o sistema consorciado de milho e papuã é uma alternativa interessante para aumentar a oferta de forragem aos animais e prover cobertura do solo após a colheita do milho. Objetivou-se com este estudo avaliar o efeito de herbicidas em diferentes doses sobre o rendimento de grãos de milho e de forragem de papuã (*Urochloa plantaginea),* num sistema consorciado. O experimento foi conduzido em blocos ao acaso, em esquema fatorial com quatro repetições. O primeiro fator foi composto por quatro associações de herbicidas: (1) Atrazina + Óleo; (2) Atrazina + Simazina + Óleo; (3) Atrazina + Nicusulfuron + Óleo; e (4) Atrazina + Mesotrione + Óleo. O segundo fator foi composto por três doses das combinações de herbicidas: 100%, 75% e 50% da dose recomendada para o controle total do papuã. Também foi avaliada uma testemunha sem a aplicação de herbicidas. A cultura do milho foi semeada em sistema de plantio direto e o papuã estabelecido por ressemeadura natural. O manejo de herbicidas é primordial para obter bons rendimento no consórcio de milho e papuã, uma vez que o milho é fortemente afetado pela pastagem em crescimento livre. As combinações e doses de herbicidas influenciaram a produção de forragem, todavia todos os manejos apresentaram forragem disponível após a colheita do milho. Os melhores rendimentos de milho, com produção satisfatória de forragem, foram obtidos com 75% da dose das associações com Mesotrione e Nicosulfuron.

Palavras-chave: competição interespecífica; ressemeadura natural; *Urochloa plantaginea.*

INTRODUCTION

Crop-livestock systems in Southern Brazil are mainly performed with grain crops in the summer and dairy/beef production on winter forages (BALBINOT JR. et al., 2009; SILVA et al., 2016). In these systems there is a gap of forage availability between summer crop harvest and winter pasture establishment, in which corn and grass intercropping could be an interesting alternative to supply forage.

In the Brazilian Cerrado, intercropping with *Urochloa* forages has being highlighted due its easy establishment, adaptation to soil characteristics, high production and efficiency in minimize occurrence of weed species (SILVA et al., 2016). In Southern Brazil, however, there are no studies with this system, besides it could be even easier adopt because of the presence of Alexandergrass (*Urochloa Plantaginea*).

Alexandergrass present high rates of growth and good ability to compete for light, water and nutrients, what makes it be considered by farmers and technicians as a weed (CARVALHO et al., 2011). These aggressive characteristics may affect the development of corn (JAKELAITIS et al., 2006a; VIDAL et al., 2004) and, thus, according to the objective of the system, the plant could be desirable or not. It is important to consider that weed interference may be a problem even in the intercrop (PARAWADA; MUDIMU, 2011). Thus, the application of sub-lethal doses of herbicide may be considered (JAKELAITIS et al., 2005; BORGHI et al., 2006). The aim of his practice is to cause a temporarily stress to the forage, enabling corn plants to reach the capacity of suppression by shading.

The objective of this study was to evaluate the effect of herbicides and its doses on corn grain yield and Alexandergrass forage production, in an intercropped system.

MATERIAL AND METHODS

The trial was carried out at Agronomic Institute of Paraná – IAPAR, Pato Branco, Paraná State, Brazil, from October 2011 to March 2012. Experimental area is located at 26º07' S, 52º39' W and 730 m above sea level. The climate of the region is subtropical humid with mild summers, a Cfa type according to the Köppen classification (MAACK, 1968). Soil at the experimental site is classified as Oxisol (EMBRAPA, 2006). The experiment was arranged in a complete randomized block design, with four replications in a factorial scheme. The first factor was composed by four herbicide + adjuvant combinations (1 - Atrazine + Mineral Oil; 2 - Atrazine + Simazine + Mineral Oil; 3 - Atrazine + Nicosulfuron + Mineral Oil; and 4 - Atrazine + Mesotrione + Mineral Oil). The second factor was represented by three doses of these herbicide associations with 100, 75 and 50% of the recommended dose to control Alexandergrass, as well as a control treatment, without herbicide spraying. The recommended dose of herbicide, isolated or in association, in g of active ingredient per hectare, were: 3000g of atrazine; 1500 g atrazine + 1500 simazine; 2000 atrazine + 16 g nicosulfuron; and 2000 g atrazine + 96 g mesotrione. In all treatments with herbicides, 600 g ha^{-1} of mineral oil was added.

Experimental area was used in no-till system for 15 years before the implantation of the trial, with winter grasses as cover crops and corn and soybean as summer crops. Each plot measured 3.5m width (five rows of corn spaced in 0.70m) x 5m long. Corn plants samples were taken from the three central rows of each plot, not considering the asides rows and 0.5m from the both edges, aiming to avoid surround effect. Alexandergrass was established by natural self-seeding, from soil seed bank. Corn was sown in 10/04/2011, with 70,000 seeds per hectare, and harvested in 03/06/2012.

Some soil chemical attributes at 0 to 20-cm layer were: 4.6 of pH ($CaCl_2$); 10.2mg dm^{-3} of extractable P; 0.25cmol dm^{-3} of exchangeable K^+; 5.5g kg^{-1} of organic matter, 4.5cmol dm^{-3} of exchangeable Ca^{+2}; 45.3% of base saturation; and 14.2cmol dm^{-3} of Cation Exchange Capacity. 300kg ha^{-1} of fertilize 08-20-20 (N-P_2O_5-K_2O) was applied at corn sowing. The urea was applied in side dress at the four expanded leaves stage of corn, performing 150kg ha^{-1} of N. Insecticide Tiametoxan + Lambda-cialotrina (Engeo Pleno®) was sprayed at a dose of 250mL ha^{-1} of commercial formula at phenological stage of V_3 of corn, to control *Spodoptera frugiperda.* Herbicide treatments were sprayed on October 18, 2011, when the corn was at the V_3 Stage (two expanded leaves) and Alexandergrass was at the stage of the first two true leaves, code 11 of General BBCH Scale for monocotyledons (MEIER, 2001), using a CO_2 pressurized back pack sprayer with Teejet TTJ02-11002 nozzles, delivering 200L ha^{-1}. The environmental conditions at herbicides spraying event presented air relative humidity of 40%, wind speed of 3.0 km h^{-1}, air temperature of 25.9°C, and soil surface temperature of 30.2°C.

To determine corn yield, three central rows of the plots were harvested, threshed and grain weighed, adjusting the values to the standard of 13% moisture content. Forage production was assessed after corn harvest by cutting the forage mass in a random 0.25m^2 square area at 15cm of sward canopy height. Samples were placed in Kraft paper bags, dried in a forced-air oven at 60^{o}C and then weighed. After sampling, pasture at the plots was mowed uniformly at 15cm of height. Analysis of variance was performed and Duncan test was used for multiple comparisons among means (P<0.05). Polynomial regression was performed for quantitative factor. The control treatment means were compared with groups of treatments according to the model proposed by Genes statistical program (CRUZ, 2006), which compares the treatments by contrasts.

RESULTS AND DISCUSSION

Herbicide management at corn and Alexandergrass intercropping presented consistent weed control, regardless the treatment. This agree with several studies which relates the same behavior in these systems (FREITAS et al., 2008; BORGHI et al., 2008). Corn production was affected by water stress that occurred at the most critical phenological period (tasseling and grain filling), since rainfall mean was 32% below local average at November, 78% at December and 15% at January.

There was no significant interaction between the factors, besides corn yield was significantly affected by the treatments (P<0.05, Table 1). Herbicide treatments with Mesotrione and Nicosulfuron associations showed similar results and better performance. Simazine and Atrazine associations presented lower efficiency, as Alexandergrass suppression was not enough to avoid interference on corn. Thus, interspecific competition promoted corn yield decrease (Table 2).

Table 1. Influences of herbicide spraying on corn grain yield (CGY, kg ha^{-1}) and Alexandergrass dry mass (ADM, kg ha^{-1}), in intercropping system. Pato Branco, Brazil, 2011/12.

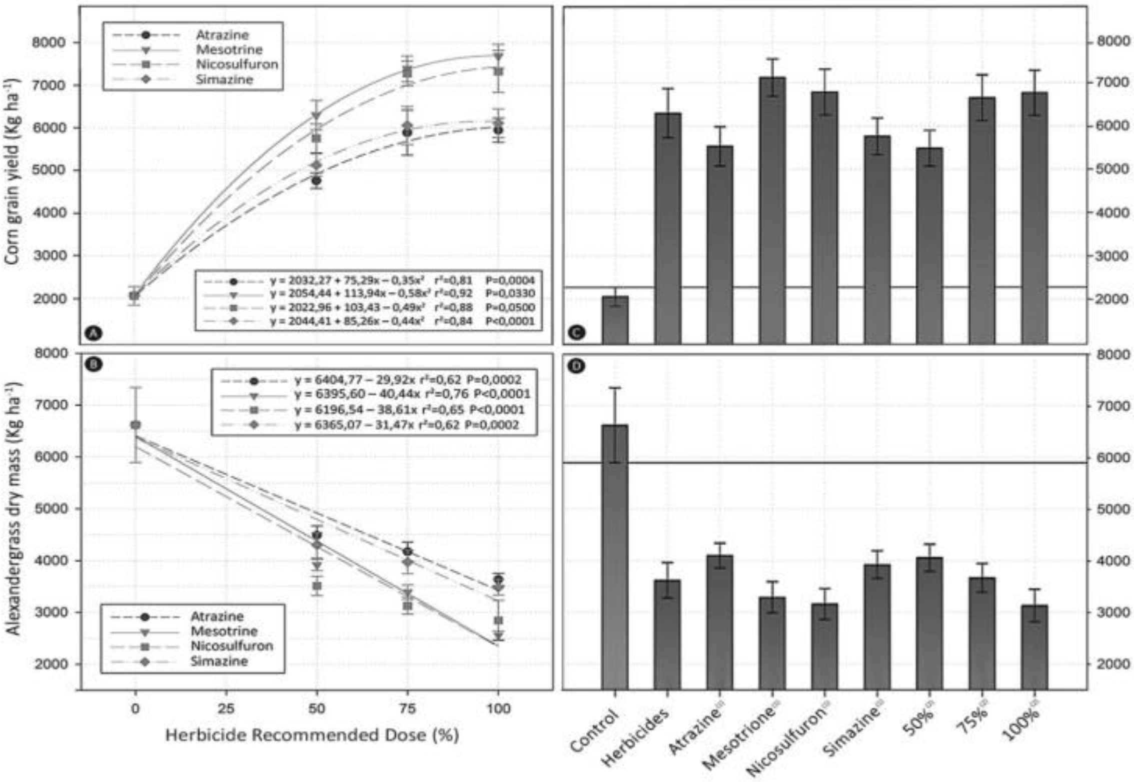
Herbicides + Oil	Dose (g.a.i.ha^{-1})(1)							
	100% RD(2)		75% RD		50% RD		Mean	
	CGY(3)	ADM(4)	CGY	ADM	CGY	ADM	CGY(5)	ADM(5)
Atrazine + Nicosulfuron	7322	3487	7275	3972	5753	4303	6784 A	3160 C
Atrazine + Mesotrione	7682	3636	7384	4172	6295	4488	7120 A	3289 BC
Atrazine + Simazine	6108	2559	6053	3393	5124	3915	5762 B	3921 AB
Atrazine	5944	2843	5886	3127	4761	3511	5531B	4099 A
Mean	6763	3131	6649	4054	5483	3617	6299	3617

(1) Grams of active ingredient per hectare.
(2) Recommended Dose.
(3) CGY – Corn Grain Yield (kg ha^{-1}), C.V.= 10.2%;
(4) ADM – Alexandergrass Dry Mass (kg ha^{-1}), C.V.= 12.3%;
(5) Means in the same column followed by different letters differ by Duncan Test (*P*<0.05)

Highest corn yields were achieved when Alexandergrass first emergence flux was totally controlled with Nicosulfuron and Mesotrione associations. The grass was further established from a second flux, after the corn critical period of competition (second half of November), when corn phenological stage was V7 (KOZLOWSKI, 2002). In this case the corn showed self-capacity to suppress the forage development.

High efficiency of Nicosulfuron and Mesotrione associations to control Alexandergrass is in accordance with reports of Adegas et al. (2011), Jakelaitis et al. (2004), Jakelaitis et al. (2005) and Petter et al. (2011). Control treatment, with no herbicide spraying, differed from other treatment groups showing 67.3% of corn yield decrease, when contrasted with the herbicides group (Figure 1C; P<0.05). Adegas et al. (2011) observed similar result using *Urochloa ruziziensis* instead of Alexandergrass. Thus, it is possible to infer that it is difficult to achieve high corn yields without herbicide use when the soil seed stock of the weed/pasture is high. Even in treatments which the lowest efficiency of control (Atrazine), corn yield was 62% higher than the treatment without any herbicide spraying (Figure 1C; P<0.05). Grain yield reductions in intercrops with *Urochloa* was also reported by Portes et al. (2000) and Jakelaitis et al. (2005).

Figure 1. Corn grain yield and Alexandergrass (*Urochloa plantaginea*) forage production in an intercropped system, under the influence herbicide spraying. Pato Branco, Brazil, 2011/12. (A) Influences of herbicide dose in the Corn grain yield (B) Influences of herbicide dose in Alexandergrass dry mass production. (C) Corn Yield contrast among control treatment (no herbicide spraying) and herbicide treatment groups. (D) Alexandergrass dry mass contrast among control treatment (no herbicide spraying) and herbicide treatment groups. [(1)]Average of 3 doses; [(2)]Average of 4 herbicides.



Assessment of Alexandergrass dry matter (DM) occurred on the same day for all treatments, after corn harvest at March, 2012. The sward reached the minimum height recommended for cutting (30cm) even at the treatments with higher herbicide injury (Mesotrione and Nicossulfuron associations). There was no significant interaction among herbicides associations to the DM yield, but there were influences of the treatments (P<0.05; Table 1).

The Alexandergrass DM production was negatively correlated with corn yield (r=-0.45; P=0.0011; Figure 1). Among the herbicides evaluated, single Atrazine showed the lower effect on Alexandergrass (Table 1), being in accordance with Adegas et al. (2011) and Jakelaitis et al. (2006b). Still, Atrazine and Simazine associations presented similar results, allowing higher Alexandergrass DM than the other herbicide treatments (Table 1; P>0.05). These results are explained by the same reason mentioned to explain the corn yield behavior, e.g. Mesotrione and Nicosulfuron associations controlled the first flux of Alexandergrass emergence and, in these treatments, seedlings emerged just from a second flux, beginning the development on limiting conditions when the crop was shading the sub-sward. The use of Nicosulfuron provide high Alexandergrass control. Martins et al. (2007) found that Nicosulfuron provided the highest levels of injury on *Urochloa brizantha,* finding DM yield reductions in the order of 83%. Jakelaitis et al. (2005), studying Alexandergrass, observed 76% of DM reduction, in comparison to the treatment with Atrazine alone.

It was observed significant differences among Alexandergrass DM production between control treatment and the contrasted groups (Figure 1D; P<0.05). Better results mirrored the development free from herbicides injuries, once in this case Alexandergrass presented overdone growth and lodged, forming a thick layer of straw close to the ground. Besides the high production, this condition reduces the forage quality and the availability to animal graze. If the intent is just to provide soil cover, there are no problems about that.

Doses of herbicides better adjusted for the polynomial quadratic model for Corn grain yield, and polynomial linear model for Alexandergrass Dry Mass Production (Figure 1A; 1B). Major toxicity for the forage was observed as the dose were increased, which is a common result as higher the dose, higher the amount of herbicide active ingredient delivered. The same behavior was observed by Jakelaitis et al. (2006b) and Marchesan (2011).

Even the treatments with full dose do not keep the crop free from the Alexandergrass until the grain harvest. It is important to point out, however, that based in the findings of Kozlowski (2002), especially in the higher herbicide levels (75% and 100%), Nicosulfuron and Mesotrione associations protected corn from competition influences. This author relates that the critical competition period for corn is until stage V_7 (seven expanded leaves) and, as stated, Nicosulfuron and Mesotrione associations allowed the development of Alexandergrass just after that.

A treatment that promotes concomitant living of crop and forage with no yield reduction was not achieved. On the other hand, the treatment of Mesotrione and Nicosulfuron associations reached the better results of corn yield (Table 1; Figure 1A;1C). In systems that intent to prioritize animal production, high forage could be achieved with Atrazine and Simazine associations, at the costs, however, of considerable decay on grain yield. This last case needs a prudent economic analysis if looking to maximize income of the intercropping.

Regardless the herbicide treatment, it was noticed the Alexandergrass has high capacity of self-reseeding. At the corn harvesting period, forage plants had inflorescences at various stages of development, which is interesting when seeking pasture subsequent establishment through the soil seed bank. Moreover, this behavior before corn harvest allows forage seeds to reach physiological maturity and shatter prior to removal of the inflorescences by grazing. It is also noteworthy that when Martins et al. (2007) evaluated *Urochloa decumbens,* it was observed that the use of Nicosulfuron induced seed dormancy and also that Atrazine increased the percentage of dead seeds, which may be similar to other tropical forage seeds as Alexandergrass.

CONCLUSIONS

Herbicide management in corn and Alexandergrass intercropping system is primordial to obtain good grain yields, once corn was highly affected by the forage in free growth or with some herbicides.

Types and doses of herbicide influenced Alexandergrass forage yield, although all the managements allow forage availability after corn harvest.

Around 75% of the recommended dose of Atrazine + Mesotrione + Mineral oil and Atrazine + Nicosulfuron + Mineral oil promoted the better corn yields in the intercropping with adequate Alexandergrass forage production in association.

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