

ATRAZINE REDUCES THE CRITICAL PERIOD OF WEED INTERFERENCE ON NARROW ROW CORN¹

Atrazine Reduz o Período Crítico de Interferência de Plantas Daninhas em Milho Adensado

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ABSTRACT - The objective was to determine whether a change occurs in the critical period of weed interference prevention in narrow row corn with the use of atrazine and whether there is influence of the herbicide on crop yield components. The treatments consisted of periods without or with an initial weed control (0, 21, 35, 49, 63, 77, and 91 days after emergence), with or without application of atrazine in spikely post-emergence. The experiment was carried out in a 2 x 7 randomized blocks design (with and without weed control and seven periods with three replications). The use or not of atrazine was arranged in a split plot design. The most important weed species were *Senecio brasiliensis*, *Urochloa plantaginea*, *Conyza bonariensis*, *Sida rhombifolia*, and *Solanum* spp. Corn yield reduced by 15% and 18% with and without application of atrazine, respectively. The number of grains per spike and corn yield were negatively influenced by coexistence with weeds, while the number of rows per spike, the diameter and length of spike were not affected. Corn yield components were not affected by the use of atrazine. The critical period of weed interference prevention was 35 days without atrazine and 23 days with application of atrazine. There is a reduction of the critical period of weed interference prevention on narrow row corn by using atrazine, with no influence of the herbicide on crop yield.

Keywords: herbicide, period of coexistence, *Zea mays*.

RESUMO - O objetivo deste estudo foi verificar se ocorre alteração no período crítico de prevenção à interferência de plantas daninhas em milho adensado com o uso de atrazine e se há influência do herbicida sobre componentes de rendimento da cultura. Os tratamentos consistiram em períodos sem ou com controle inicial de plantas daninhas (0, 21, 35, 49, 63, 77 e 91 dias após a emergência), com ou sem aplicação de atrazine em pós-emergência inicial. O experimento foi conduzido em delineamento de blocos casualizados 2x7 (sem e com controle e sete períodos com três repetições). A aplicação ou não de atrazine ocorreu em parcelas subdivididas. As espécies mais importantes de plantas daninhas foram **Senecio brasiliensis**, **Urochloa plantaginea**, **Conyza bonariensis**, **Sida rhombifolia** e **Solanum** spp. A redução de produtividade de milho foi de 15% e 18% com e sem a aplicação de atrazine, respectivamente, para convivência com a infestação durante todo o ciclo. Apenas o número de grãos por espiga e a produtividade de milho foram influenciados negativamente pela convivência com as plantas daninhas, enquanto o número de fileiras por espiga, o diâmetro e o comprimento da espiga não foram influenciados. Os componentes de rendimento de milho não foram afetados pelo uso de atrazine. O período crítico de prevenção à interferência no milho adensado foi reduzido de 35 para 23 dias com a aplicação de atrazine, sem alterar a produtividade final da cultura.

Palavras-chave: herbicida, período de convivência, *Zea mays*.

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INTRODUCTION

Corn (*Zea mays*) crop is sensitive to weed interference, particularly during the early stages of establishment (Kumar et al., 2002). Yield losses caused by this interference can often be over 30% (Chikoy and Ekeleme, 2003; Hassan et al., 2010) if a satisfactory control of the weed community is not achieved. Weed interference is especially due to competition for environmental resources (such as water, light and nutrients). However, the intensity of such interference depends on factors related to the weed species, crop, management, coexistence period, and soil and weather conditions (Galon et al., 2008). Because these factors are interrelated, the influence of one of them has effects on the others.

Among the factors that affect the degree of interference, the coexistence period is considered one of the most important (Carvalho et al., 2008). As a function of the duration of the coexistence period, the interference periods can be estimated: PBI (period before interference), TPIP (total period of interference prevention) and CPIP (critical period of interference prevention), according to Pitelli and Durigan (1984). The duration of these periods is dependent on management conditions, such as fertilization (Bressanin et al., 2013), irrigation (Adigun, 2005), seeding date (Barroso et al., 2010), crop system (Horta et al., 2004), etc. Application of residual herbicides (such as atrazine) can also affect the CPIP, mainly by altering the local weed community. The hypothesis of this study is that application of atrazine at the early post-emergence of corn planted in narrow rows may reduce the duration of CPIP without a negative effect on crop yield components.

The aim was to determine whether there is: (i) a change in CPIP in narrow row corn with application of atrazine, and (ii) influence of this herbicide on crop yield components.

MATERIAL AND METHODS

A field experiment was conducted from November 2013 to March 2014 in an experimental area (latitude 27°47'18" S, longitude 50°18'09" WGr and altitude 823 m), in an Argillaceous Aluminous Humic

Cambisol soil having the following characteristics: 54% clay; 3.8% MO; pH (water) = 5.1; SMP = 5.0; P, Na, K contents 2.9, 10 and 80 mg dm⁻³, respectively; Ca, Mg, Al, H+Al and effective CEC 4.63, 3.49, 1.36, 13.0 and 9.68 cmol_c dm⁻³, respectively; and Al saturation and bases 14.05 and 37.80%, respectively. Correction of soil acidity and fertilization were performed as recommended by the Brazilian Society of Soil Science (SBCS, 2004).

Hybrid corn seeds P30F53YHR were sown in 50-cm rows width, with an estimated population of 90,000 plants per hectare. The experimental units (subplots) corresponded to four lines with 5 m in length, totaling 10 m². For the assessment, the two central lines were considered, disregarding 0.5 m of each end. The useful area for assessment was 4 m². To maintain the corn phytosanitary conditions, clorantraniliprole + lambda-cyhalothrin (Ampligo, Syngenta, 15 + 7,5 g a.i. ha⁻¹) insecticides and epoxiconazol + pyraclostrobin fungicides were applied (Opera, Basf, 50 + 133 g a.i. ha⁻¹).

The treatments studied were represented by two groups, namely: (i) initial periods without weed control, from emergence to harvest; (ii) initial periods with weeds control, from emergence to harvest. The periods corresponded to 0, 21, 35, 49, 63, 77 and 91 days after emergence (DAE). In the first group, at the end of each period, the weeds were removed by hoeing. In the second group, weeds hoeing started at emergence and lasted until the end of the period. In each of the groups described, atrazine herbicide was applied in post-emergence, when the corn plant was at stage V3, and the same treatments were performed without herbicide application. Therefore, the experimental design consisted of randomized blocks with 14 treatments (periods with and without weeds control and seven experimental periods) and three replications. Application or non-application of atrazine was allocated to split plots for each treatment.

Atrazine (Primóleo, 400 g e.a. L⁻¹; Syngenta) was applied in the morning of December 4, when wind speed was under 3 km h⁻¹ and temperature was 18 °C. Five liters ha⁻¹ (2 kg a.i. ha⁻¹) of the herbicide was applied with

a CO₂ pressurized backpack sprayer equipped with flat-fan tips model 8002VS (TeeJet), calibrated to a spray volume of 200 L ha⁻¹ and 200 kPa pressure.

The weed community was assessed at the end of each initial period without control and at 91 DAE for all initial periods with control, by collecting two samples of plants emerged in an 0.25 m² area using a 0.5 x 0.5 m sampling quadrat thrown at random in the useful area of the subplots. In these periods, the weed species were identified, quantified and collected and then dried in a forced-air oven at 65 °C for one week to determine the dry weight in a 0.01 g precision scale. Data related to the weeds occurrence frequency, number of individuals and dry weight were used to calculate the phytosociological indices of Relative Constancy (RCo), Relative Density (RDe), Relative Dominance (RDo) and Relative Importance (RI) of each species following the methodology proposed by Müller-Dombois and Ellenberg (1974).

At the end of the experimental period, corn spikes were harvested manually at the two central lines of the subplots. The number of grain rows per spike (GRS), number of grains per spike (NGS), spike diameter (SD), spike length (SL) and grain yield (GY) were determined, adjusted to 13% moisture and converted to kg ha⁻¹.

Data of crop yield components were analyzed through the F Test (ANOVA) and Tukey's test (means comparison) at 5% probability level. Additionally, Pearson's correlation test was used for the characteristics assessed, at 5% probability level. The Statistica® software (version 8.0) was used to perform the tests described.

The periods of interference described by Pitelli and Durigan (1984) were determined through nonlinear regression analysis of the grain yield data using the SigmaPlot® (version 10.0) software. PBI (period before interference) and TPIP (total period of interference prevention) were estimated by means of adjusted curves, considering 5% of acceptable yield losses; CPIP (critical period of interference prevention) was estimated at the beginning and end of the PBI and at the end of the TPIP.

RESULTS AND DISCUSSION

Among the species present during the experiment assessment, the most common were *Senecio brasiliensis*, *Urochloa plantaginea*, *Conyza bonariensis*, *Sida rhombifolia* and *Solanum* spp. The *S. brasiliensis* species exhibited the highest values for constancy and relative density indices. Regarding the relative dominance, *U. plantaginea* was the species that exhibited the highest accumulation of biomass per individual (Figure 1). This weed community represents the species most commonly found in corn crops, especially in southern Brazil (Kozłowski, 2002; Martin et al., 2011).

A high density of *S. brasiliensis* plants was found, with high relative importance in the community. The second species in decreasing order of importance, *U. plantaginea*, belongs to the family Poaceae, the same of corn. Belonging to the same family of the crop maximizes the interference effect of the weed species (Page et al., 2012). In general, interference of plants of the family Poaceae has a greater negative effect on the corn plant development, which explains the drop of corn yields found in the experiment (Faria et al., 2014).

Application of the atrazine herbicide did not change corn yields when the crop was free from the interference of weeds (hoed plots), indicating that it did not cause poisoning of the culture (Table 1). The interference levels of the present community were different as to the herbicide application. By coexisting with weeds for 91 days, the corn crop had its final yield reduced by 15% and 18% with and without atrazine application, respectively (Table 1 and Figure 2). These values are low if compared to the majority of studies conducted with narrow row corn crops, in which interference exceeds 70% of reduction of grain yield (Kozłowski, 2002; Massing et al., 2003; Mahmoodi and Rahimi, 2009).

U. plantaginea exhibited a fast initial increase in allocating resources to its root system, improving the plant attachment to the ground and facilitating competition for water and nutrients, which explains the RI found even at low density in the infesting



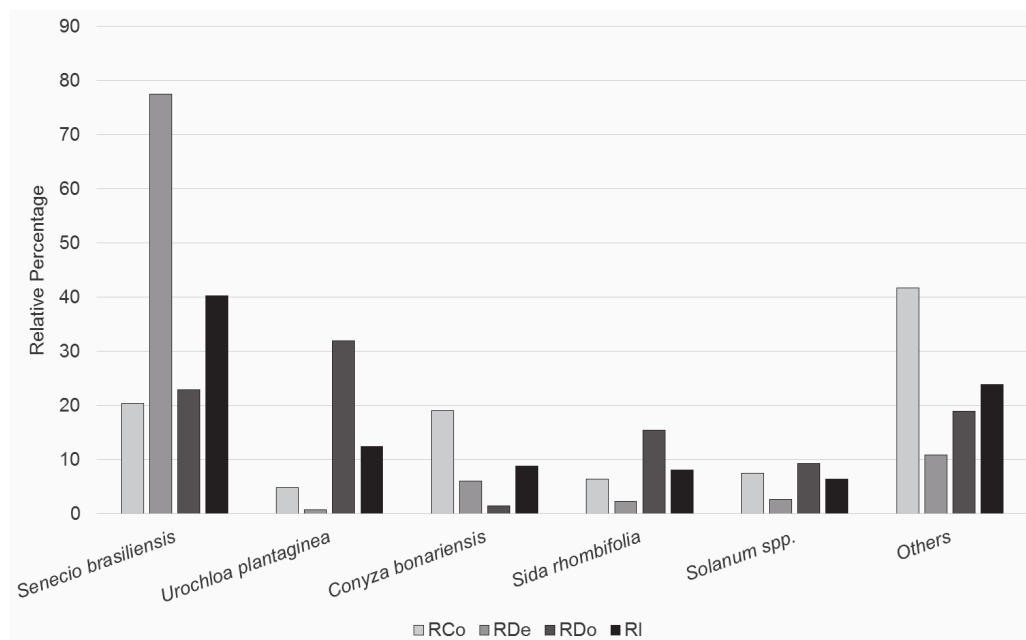


Figure 1 - Phytosociological indices of relative constancy (RCo), relative density (RDe) relative dominance (RDo) and relative importance (RI) of the weed species mostly found in the experiment periods.

community. In addition, this species exhibits greater accumulation of nitrogen, potassium, magnesium and sulfur per biomass unit than corn (Carvalho et al., 2007). However, even with such fast development, low densities of *U. plantaginea* seemed not to affect greatly the final corn yields, as observed in this and other studies, as the one conducted by Spader and Vidal (2000).

The number of rows per spike, spike diameter and spike length did not change as a result of the different periods of coexistence and weeds control, as well as with or without atrazine application (Table 1). The number of grains per spike decreased as the period of coexistence with weeds increased, reaching values higher than 30%. Characteristics such as the spike diameter and spike length in general are not affected when corn plants and weeds coexist, corroborating the data found in this study. Other studies report a harmful effect of the weeds community on the number of spikes produced per plant and a significant correlation between such reduction and yield decline (Galon et al., 2008; Faria et al., 2014). With longer periods of control of the weeds community, the number of seeds per spike was greater. Atrazine application did not cause an effect on the variables observed.

The final corn yield indicated positive correlations with the number of grains per spike, spike diameter and spike length. The number of rows per spike did not show a correlation with the final crop yield (Table 2). These results differ from those observed when the corn plant coexisted with *U. plantaginea* in conventional rows spacing, where all characteristics were negatively affected by the coexistence of species, indicating that narrow row planting favored the development of the corn plants compared with the weeds community (Galon et al., 2008).

Application of atrazine delayed the start of the weeds interference with the corn culture. The periods observed prior to the weeds interference (PBI) were 22 and 32 days, with and without atrazine, respectively 2). Application of atrazine also delayed the germination and/or development of the weed species so that the culture gained ten days without weeds interference. The total periods of weeds interference prevention were 57 and 55 days with and without atrazine, respectively, and in the increasing periods of control no significant differences were found (Figure 2).

The critical period of interference prevention (CPIP) of weeds on corn – period in

Table 1 - Number of grain rows per spike (NRS), number of grains per spike (NGS), spike diameter (SD), spike length (SL) and grain yield (GY) of corn grown with and without atrazine application as a function of increasing coexistence periods and weeds control

Period (Days)	Atrazine	NRS (unit)	NGS ^L (unit)	SD (mm)	SL (mm)	GY ^L (kg ha ⁻¹)
Coexistence periods						
0	YES	17	446 ab	50.4	166.8	12339 a
	NO	16	468 a	50.3	162.1	12182 a
21	YES	16	430 bc	49.6	154.6	11830 ab
	NO	17	443 b	50.0	152.5	11820 ab
35	YES	17	403 cd	49.5	154.3	11716 ab
	NO	16	403 cd	49.3	149.3	10778 cd
49	YES	17	378 def	49.1	148.1	11243 bc
	NO	16	390 de	49.3	146.9	10764 cd
63	YES	16	364 def	48.5	146.9	10782 cd
	NO	17	362 ef	48.6	142.5	10166 def
77	YES	16	356 ef	48.1	146.3	10647 cde
	NO	16	352 ef	47.8	138.8	9495 f
91	YES	16	349 f	47.0	136.1	10482 cde
	NO	16	339 f	47.8	135.7	9975 ef
VC%		8	21	12	16	18
Control periods						
0	YES	17	371 ef	47.2	138.7	10106 fg
	NO	16	360 f	49.2	135.0	10138 fg
21	YES	16	378 def	48.2	143.2	9660 g
	NO	17	375 def	49.7	135.9	10065 fg
35	YES	17	399 cde	48.8	145.4	10372 efg
	NO	16	383 def	49.8	142.5	10186 fg
49	YES	17	400 cd	48.9	145.5	11200 cd
	NO	17	388 def	49.9	144.2	10678 def
63	YES	16	403 cd	49.6	148.7	11505 bc
	NO	16	419 bc	50.5	147.6	11062 cde
77	YES	16	445 ab	50.7	149.9	12295 a
	NO	16	420 bc	51.2	152.5	11337 bcd
91	YES	17	445 ab	51.2	153.1	11914 ab
	NO	17	467 a	51.3	160.5	11478 bc
VC%		6	18	12	15	17

Means followed by different letter in each column are not significantly different by the Tukey's test at 5%

which the infesting community interfered negatively with the crop – was 35 days without the use of atrazine and 23 days with application of the herbicide. This period corresponds to the control period, starting on the third or fifth week after emergence of the culture and lasting until the eighth week. These initial control values (PBI) are higher than those found in literature, because of the narrow row condition. Studying these periods of corn crops coexisting exclusively with

U. plantaginea plants, the CPIP found was 16 days (Galon et al., 2008). In general, this control period starts early, in the first weeks of cultivation (Ferrero et al., 1996; Kozłowski, 2002; Dogan et al., 2004).

These results show that even with the low development of the interfering plants present, such as *S. brasiliensis* and *C. bonariensis*, and the low levels of interference of these weeds in the culture (around 15%), the critical



Table 2 - Correlation between the number of grain rows per spike (NRS) number of grains per spike (NGS), spike diameter (SD), spike length (SL), and grain yield (GY) of corn grown without atrazine application (above diagonal) and with atrazine application (below diagonal) as a function of increasing coexistence periods and weeds control

Variable	NRS	NGS	SD	SL	GY
	Coexistence periods				
NRS	-	0.107 ^{ns}	0.160 ^{ns}	0.017 ^{ns}	0.240 ^{ns}
NGS	0.042 ^{ns}	-	0.882**	0.968**	0.915**
SD	0.098 ^{ns}	0.801**	-	0.906**	0.916**
SL	0.019 ^{ns}	0.816**	0.904**	-	0.864**
GY	0.131 ^{ns}	0.955**	0.885**	0.858**	-
Control periods					
NRS	-	0.187 ^{ns}	0.199 ^{ns}	0.186 ^{ns}	0.193 ^{ns}
NGS	0.189 ^{ns}	-	0.849**	0.933**	0.815**
SD	0.142 ^{ns}	0.931**	-	0.874**	0.848**
SL	0.136 ^{ns}	0.818**	0.963**	-	0.867**
GY	0.128 ^{ns}	0.788*	0.752**	0.652*	-

** e * Significant at 1% and 5% probability, respectively, by Pspikeson's correlation test.

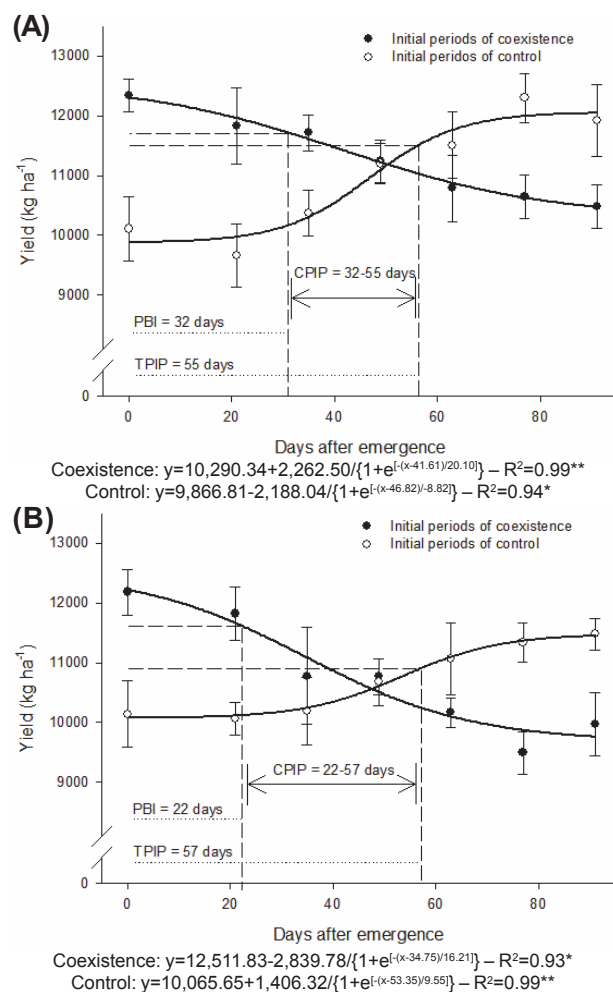


Figure 2 - Relation of corn yields with atrazine application (A) and without atrazine application (B) at early post-emergence, with an increase in the initial periods without weed control (A) and with control.

period diminished by almost two weeks with application of atrazine. Still, the control of plants such as *C. bonariensis* with atrazine is one of the alternatives, but not the only one, in the management of the weeds resistance to herbicides such as glyphosate. However, constant use of atrazine is not recommended due to the harmful effects to the environment; therefore, herbicides rotation with different mechanisms of action is always recommended (Ying et al., 2005). Narrow row corn enhances the potential competition of this culture with the infesting community through the management of this culture. The use of various methods of control is vitally important in the long-term management of weeds, as already reported in literature (Swanton and Weise, 1991).

The conclusions of this study are that there was a decreased CPIP in high density corn crops when the atrazine herbicide was applied at the early stages of post-emergence of the culture and that there was no influence of this herbicide on the corn yield components.

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