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Chemical Control of White Clover in Soybean Crops[1]

Controle Químico do Trevo-Branco na Cultura da Soja

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ABSTRACT - White clover is tolerant to many herbicides, making difficult a chemical control of this species during soybean crop establishments. The objective of this research was to select herbicides applied postemergence to control white clover in soybean and know the effects of this control on soybean yield. Seven herbicides were assessed, applied postemergence, with or without sequential application of glyphosate, and two control treatments (no control and total control of white clover). Glyphosate (with two sequential applications), fomesafen (with a sequential application of glyphosate), chlorimuron-ethyl and lactofen have shown a satisfactory control of white clover (above 80%). The lower control efficiency has resulted in lower production of soybeans.

Keywords: herbicide, Integrated Crop-Livestock System, interference, *Trifolium repens*, *Glycine max*.

RESUMO - O trevo-branco apresenta tolerância a diversos herbicidas, o que torna difícil o controle químico dessa espécie durante o estabelecimento da cultura da soja. Os objetivos desta pesquisa foram selecionar herbicidas utilizados em pós-emergência que controlam o trevo-branco na cultura da soja e conhecer os efeitos desse controle na produtividade da soja. Foram avaliados sete herbicidas aplicados em pós-emergência, com ou sem aplicação sequencial de glyphosate, e dois tratamentos testemunhas (sem controle e controle total do trevo-branco). Os herbicidas glyphosate (com duas aplicações sequenciais), fomesafen (com aplicação sequencial de glyphosate), chlorimuron-ethyl e lactofen apresentaram controle satisfatório do trevo-branco (acima de 80%). A menor eficiência de controle resultou em menor produção da cultura da soja.

Palavras-chave: herbicida, Sistema Integrado de Produção Agropecuária, interferência, *Trifolium repens*, *Glycine max*.

INTRODUCTION

The need to increase agricultural yield in a sustainable way signals the adoption of production systems in an integrated and balanced manner (Gilbert, 2009). In this context, it is necessary to search for strategies to concurrently achieve increased agricultural yield and environmental quality (Lemaire et al., 2014).

In response to society new demands, the Integrated Crop-Livestock System (ICLS) has emerged in order to diversify and integrate the various production systems, thus promoting more efficient use of inputs and nutrients cycling (Carvalho, 2010) and the activation of agro-ecosystems potential (Lemaire et al., 2014).

In subtropical climates, the use of ICLS with animal grazing in winter and grain

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production in summer is widespread as an important agricultural model (Moraes et al., 2014), and the winter poaceae are the main forage used (Lustosa et al., 2011). Their intercropping with white clover (*Trifolium repens*), constitutes an alternative for increasing the nutritional quality of pasture, as well as biological nitrogen fixation contribution (Phelan et al., 2013; Cougnon et al., 2014).

When using white clover (WC) in the composition of winter pastures, one should take into account that it is a perennial legume. Thus, if unchecked after use, it remains in the area, becoming a competing plant with the subsequent grains crop. An aggravating factor is that this crop is tolerant to several herbicides used to control broad-leaf plants (Machado et al., 2013; Mccurdy et al., 2013), which can hamper the chemical control of WC.

Among the grains produced in a subtropical climate during the summer, soybeans stand out as one of the most important due to their international representation. The lack of weed control in crops can lead to productivity losses up to 73% (Fickett et al., 2013). Their cultivation in areas with production systems integrated with WC becomes difficult due to the lack of information about which active ingredients applied postemergence can be used for WC tillage in soybeans crop.

The objectives of this research were to select herbicides for use in efficient postemergence in white clover control in soybeans crop and to quantify the effect of this control on soybeans production.

MATERIALS AND METHODS

The experiment was conducted in an experimental field located at 25°23’36 “S and 51°27’19" W, in a typical and very clayey-textured aluminic oxisol bruno (Embrapa, 2006). The local climate is Cfb (mesothermal humid subtropical), with no dry season, with cool summers and mild winters, according to the Köppen-Geiger classification. The average annual rainfall is 1,944 mm, the average annual minimum temperatures are 12.7 °C and the maximum are 23.5 °C.

The experimental design was a randomized complete block design with three replications in a 7 x 2 + 2 factorial arrangement, with seven herbicide applications in postemergence combined or not with a sequential application of glyphosate (720 g ha^{-1}) and two additional controls (without control and with total control of WC), totaling 16 treatments. The herbicides used were bentazon (600 g ha^{-1}), chlorimuron-ethyl (250 g ha^{-1}), imazethapyr (100 g ha^{-1}), fomesafen (250 g ha^{-1}), lactofen (240 g ha^{-1}) and imazamox + bentazon (600 + 28 g ha^{-1}). Each experimental plot had five soybean rows spaced 0.40 m by 8 m long.

The implementation of WC occurred in April 2012 with cultivar Zapicán inoculated with *Rhizobium leguminosarum* bv. *trifolli* (10 mL kg^{-1}). Sowing was done in furrows spaced 0.18 m, depth of 0.05 m and density of 8 kg ha^{-1}, with a base fertilization of 120 kg ha^{-1} of P_2O_5, 60 kg ha^{-1} of K_2O and 1.2 kg ha^{-1} of B.

Desiccation of the area containing WC and spontaneous winter forage was carried out with an application of glyphosate (720 g ha^{-1}) in November. Sowing of soybean BMX Apolo® RR occurred eight days later, following technical recommendations for crops.

When soybeans reached the V2 stage (14 DAE), treatments were applied in postemergence for control of the WC remaining from the application of glyphosate in desiccation, which presented 96.02 ± 8.8 g m^{-2} of DM at that time.

A sprayer pressurized with CO_2 and constant pressure of 50 lb $inch^{-2}$ was used, equipped with a fan-type four-tips bar with 110:0.2 air induction, spaced 0.50 m and spray volume of 190 L ha^{-1}. At the time of application, the plant surface was dry, relative humidity was 73.6% and temperature 21.3 °C.

WC and other weeds were collected at 0, 7, 21, 35 and 70 days after application (DAA) in postemergence, cutting at ground level was held, using a square of 0.16 m^2 to determine the dry matter (DM). Subsequently, to quantify the DM reduction speed of WC by the treatments, a linear regression was adjusted (y = ax + b), which intercepted the point of dry matter before application of treatments.

The control efficacy of WC by the treatments was determined using the obtained control percentage, calculated by the following mathematical expression (Barros et al., 2007):

$$Ef = 100 - \left(\frac{C2 - d}{C1} * 100 \right)$$

where: *Ef* is the treatment efficiency (%); *C1* is the dry matter of WC per square meter collected prior to application of the treatments; *C2* is the dry matter of WC per square meter collected 10 weeks after application of the treatment in soybean in R2; and *d* is the difference between the dry matter of white clover per square meter between the first and second assessments in the treatment without the application of the herbicide. Thus, this mathematical expression includes as control not only the reduction in DM, but also its amount that WC stopped growing, being more suitable for perennial species, as maintaining them without growth also characterizes control.

Soybean plants were harvested at the R8 stage in 2 linear meters in the three central rows of each plot. The grain moisture was adjusted to 13% to determine productivity.

Coefficient *a* of dry matter reduction regression of WC underwent – along with the variables efficiency of control of WC, DM of WC, DM of other weeds and soybeans yield – analysis of variance and the averages were compared by Duncan test ($p < 0.01$).

RESULTS AND DISCUSSION

Chemical control of WC provided by the herbicides applied postemergence in soybeans crops shows that bentazon, imazethapyr, fomesafen e imazamox+bentazon do not present a satisfactory performance (< 50% of control) (Table 1). Glyphosate applied postemergence again presented WC control of 63.64% and chlorimuron-ethyl and lactofen showed a satisfactory performance (> 80% of control) (Table 1). Still, the sequential application of glyphosate after the application of fomesafen and glyphosate treatments resulted in a satisfactory control (Table 1).

Regarding DM of WC, at 70 DAA of the herbicides, treatments with lactofen and chlorimuron-ethyl had the lowest averages, with 20.54 and 19.94 g m^{-2}, respectively (Table 1). The sequential application of glyphosate had a positive effect on these treatments, but the DM of WC did not differ for chlorimuron-ethyl. The WC control coefficient

Table 1 - Dry matter (g m^{-2}), control efficiency (%) and white clover control angular coefficient (g m^{-2} day^{-1}) at 70 days after application (R2 stage of soybean crop), depending on the herbicide applied postemergence

Herbicide postemergence	Dry matter (g m^{-2}) of white clover		Control efficiency of white clover (%)		White clover control angular coefficient (g m^{-2} day^{-1})	
	Glyphosate (720 g ha^{-1})					
	without	with	without	with	without	with
Bentazon	94.71 cA[1/]	53.58 bB	22.55 fA	60.20 eB	0.359 cA	- 0.269 bB
Imazethapyr	100.89 bA	43.29 cB	16.25 gA	70.34 dB	0.508 bA	- 0.570 cB
Fomesafen	79.64 dA	29.54 dB	34.35 eA	83.77 cB	- 0.047 dA	- 1.055 dB
Imazamox + Bentazon	74.06 eA	52.62 bB	40.91 dA	61.37 eB	- 0.051 dA	- 0.516 cB
Glyphosate	49.39 fA	20.68 eB	63.64 cA	92.26 bB	- 0.600 eA	- 0.944 cB
Chlorimuron-ethyl	20.54 gA	20.19 eA	92.09 bA	92.60 bA	- 1.012 fA	- 1.169 eB
Lactofen	19.94 gA	14.64 eB	92.67 bA	97.82 abA	- 1.051 fA	- 1.404 eB
Without control	147.81 a	147.81 a	–	–	0.966 a	0.966 a
Total control (weeded)	0.00 h	0.00 f	–	–	–	–
CV (%)	4.01	5.52	37.81	18.06	15.62	12.37

[1/] For each variable, means followed by the same letters, lowercase in the columns and uppercase in the rows, do not differ by Duncan test in $p < 0.01$.

increased from a reduction in DM of -1.012 e -1,051 to -1.169 and -1,404 g m^{-2} day^{-1} for lactofen and chlorimuron-ethyl, respectively, with the sequential application of glyphosate (Table 1).

Of the herbicides of application in postemergence that did not show a satisfactory control of WC (< 50% control), bentazon and imazethapyr resulted in the growth of WC after its application, and this is of 0.359 and 0.508 g m^{-2} day^{-1}, respectively (Table 1). Mc Curdy et al. (2013) and Machado et al., (2013), studying herbicides selective to WC crop, have identified bentazon and imazethapyr as selective to crops, agreeing with the results obtained in this study (Table 1).

The highest yield was obtained in the control with full control of WC with 3.72 Mg ha^{-1}, followed by lactofen treatment with a sequential application of glyphosate, with a productivity of 3.50 Mg ha^{-1} (Table 2). The lower yields were encountered in the unsprayed controls and in the treatment with an isolated application of chlorimuron-ethyl, this being of 0.39 and 0.98 Mg ha^{-1}, respectively (Table 2).

It is noteworthy that the herbicides used, though selective to crops, cause an effect that is phytotoxic to soybeans. However, works such as the one by Souza et al. (2002) reveal that at 20 DAA of the herbicides these effects disappear, not significantly changing the soybean crop production.

Further, for yield (Table 2), the greater the control of WC, the higher the productivity per area, except for two treatments, being the ones with an application of chlorimuron-ethyl and lactofen. These treatments have shown the higher amounts of DM of other weeds, with 35.19 and 49.16 g m^{-2}, respectively (Table 2).

For latifolicide treatments without a sequential glyphosate application, it is possible to see that the greater the control of WC, the higher the occurrence of other weeds (Table 2), since, with the exception of glyphosate, all other treatments have not shown action control over narrow-leaf species. The reduction in the expression of the seed bank by the presence of WC is linked to the fact that the forage, when established, promotes the soil cover, preventing the emergence of other weeds (Den Hollander et al., 2007a, b; Wortman et al., 2013). Thus, the greater the control of WC, the greater the expression of the soil seed bank of other weeds.

It should be noted that, for a satisfactory control of WC only with glyphosate, it is required, in addition to the application to the drying area, two more postemergence applications, resulting in an amount of 2,160 g ha^{-1}. Considering the issue of increasing weed resistance to glyphosate and

Table 2 - Dry matter of other weeds (g m^{-2}) and soybean yield (Mg ha^{-1}), depending on the herbicide applied postemergence

Herbicide postemergence	Dry matter (g m^{-2}) of other weeds		Soybean yield (Mg ha^{-1})	
	Glyphosate (720 g ha^{-1})			
	without	with	without	with
Bentazon	05.19 dA[1/]	0.60 eB	1.54 eA	1.75 fB
Imazethapyr	05.32 fA	0.47 fB	1.60 dA	2.91 dB
Fomesafen	14.95 eA	3.01 aB	1.61 dA	2.93 dB
Imazamox + Bentazon	27.16 cA	0.87 dB	1.67 dA	2.79 eB
Glyphosate	05.58 dA	0.52 eB	2.43 bA	3.24 cB
Chlorimuron-ethyl	35.19 bA	1.43 bB	0.98 fA	3.17 cB
Lactofen	49.16 aA	1.27 cB	1.83 cA	3.50 bB
Without control	2.40 fA	2.40 bA	0.39 gA	0.39 gA
Total control (weeded)	0.00 gA	0.00 fA	3.72 aA	3.72 aA
CV (%)	7.45	12.3	17.2	13.3

[1/] For each variable, means followed by the same letters, lowercase in the columns and uppercase in the rows, do not differ by Duncan test in $p < 0.01$.

the intensification in the use of glyphosate being a factor in their selection (Beckie, 2011), preference should be given to the rotation of molecules for the control of WC.

Given the results, it is concluded that the presence of WC reduces soybean production, characterizing the need for its control. Among the tested herbicides applied in postemergence, glyphosate (with two sequential applications), fomesafen (with a sequential application of glyphosate), chlorimuron-ethyl and lactofen have shown a satisfactory control of WC (> 80%). Treatment with lactofen plus another sequential application of glyphosate has provided the highest soybean production.

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