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Glyphosate-resistant hairy fleabane competition in RR® soybean

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Abstract

Weed competition in the soybean causes changes in morphological and physiological characteristics that reduce the competitive ability of the crop. The objective of this study was to determine the control periods and coexistence of glyphosate-resistant hairy fleabane and its interference in morphological and photosynthetic variables and RR soybean yield. A field experiment was conducted during the 2011/2012 growing season, the treatments consisted of weed interference and weed free periods of the glyphosate-resistant hairy fleabane with soybean (BRS Estância RR). The periods were 0, 7, 14, 21, 28, 35, 42 and 154 days after the soybean emergence. The results sugested no differences between the control periods for the variables evaluated. The increase interference period of the weed reduced growth, development and the photosynthetic variables in the soybean. There are positive correlations between morphological and photosynthetic variables of soybean during the weed interference. The period before the glyphosate-resistant hairy fleabane interference in the soybean crop is 24 days for plants established before the crop sowing.

Key words: *Glycine max*, weed interference, photosynthesis.

Competição de buva resistente a glifosato em soja RR®

Resumo

A convivência de plantas daninhas à soja altera características morfofisiológicas que comprometem a habilidade competitiva dessa cultura. O objetivo deste estudo foi determinar os períodos de controle e de convivência de buva resistente ao herbicida glifosato e sua interferência em variáveis morfológicas e fotossintéticas e produtividade da cultura da soja RR. Experimento a campo foi conduzido no ano agrícola 2011/2012, no qual foram testados períodos de controle e de convivência da buva resistente ao glifosato com a cultura da soja (BRS Estância RR). Os períodos de controle e convivência foram 0, 7, 14, 21, 28, 35, 42 e 154 dias após a emergência da cultura. Os resultados demonstraram que não houve diferenças entre os períodos de controle para as variáveis avaliadas. O aumento do período de convivência da planta daninha prejudicou o crescimento, desenvolvimento e as variáveis fotossintéticas da cultura. As variáveis morfológicas da soja correlacionam-se positivamente com as variáveis fotossintéticas mensuradas durante o período de convivência da buva com a soja. O período anterior à interferência da buva resistente ao glifosato na cultura da soja é de 24 dias para plantas estabelecidas antes da semeadura da cultura.

Palavras-chave: *Glycine max*, convivência, fotossíntese.

1. INTRODUCTION

Rio Grande do Sul (RS) is a important producer of soybean in Brazil, with 4.9 million ha (CONAB, 2014). In the last decade, the area planted with the oilseed has grown over 40% in the state, which is mainly due to the introduction of glyphosate-resistant soybeans (RR). The rapid adoption of the herbicide-resistant soybean is due to the weed management flexibility, the broader spectrum of control and low risk of injuries to the cultivar, regardless of the stage of development.

RR soybean growing has provided considerable increase in the glyphosate use, which began to be used in two to three applications in crop growth cycle. The repeated use of a single molecule in soybeans has increased the selection pressure on weeds. In growing season 2004/2005 soybean it was observed an unsatisfactory control for *Conyza bonariensis* (hairy fleabane) in several Rio Grande do Sul State farms , however when these plants are controlled in burndown even in advanced stages of development the control is satisfactory (Vargas et al., 2007).

Many soybean crops have high infestations of *Conyza* sp. species with the resistance evolution, due the lack control, especially in areas that autumnal management was not performed, making these plants the main weeds in soybean crop. The wind dispersal and reproductive ability are the main characteristics of the species which can produce over 700,000 seeds per plant, giving to the weed high efficiency in the infestation on crops (Shrestha et al., 2010). Moreover, hairy fleabane has great ability to reduce the yield of soybeans depends on the weed population (Trezzi et al., 2013).

The soybean performance in competition depends of the species and weed population, such as environmental conditions like temperature, solar radiation, water and nutrient availability. Soybean is less efficient in extracting water from the soil than some weeds; furthermore, the weed population is generally higher than the soybean density, making it a more competitive weed for environmental resources (Procópio et al., 2005).

The soybean crop is able to resist the early weeds competition, without losses yield (Jannink et al., 2001). However, management practices as a choice of cultivar, spacing, density, season sowing and cultivation system affect the time of weed interference (Silva et al., 2007). In general, weeds must be controlled from 10 days after the emergence (DAE) of soybean until 76 DAE (Constantin et al., 2007; Nepomuceno et al., 2007).

The period in which the crop can be in the presence of weeds, without losses yield, is known as the period prior to interference (PPI) (Pittelkow et al., 2009). The total period of interference prevention (TPIP) refers to the time from the cultivar emergence in which one must be free from the presence of competitive plants so that its yield is not affected (Brighenti et al., 2004). In turn, critical period of interference (CPI) is located among the maximum limits of both periods mentioned previously; it is the phase in which the control practices should be effectively adopted to prevent losses in the crop yield (Evans et al., 2003).

Most studies of competition between crops and weeds assess the morphological effects and crop yield, without taking into account the physiological characteristics that are modified. The physiological factors are related to morphological responses in plants competition and, for example, the photosynthetic rate plants correlate with the morphological changes due to competition. The photosynthetic rate of *Atriplex prostrata* when in low populations was twice as high compared with high populations (Wang et al., 2005).

Knowledge of the critical period for weed control is useful for taking decisions on the necessity and timing of weed control, positioning the best weed management in the crops. The objective of this study was to determine the critical period weed removal glyphosate-resistant hairy fleabane and the effects of this specie in morphological, photosynthetic variables and RR soybean yield.

2. MATERIAL AND METHODS

An experiment was conducted in the crop season 2011/2012, at the Experimental Station of Embrapa Trigo, Passo Fundo (RS). The soil used were Oxisol. The experimental design was a randomized complete block with four replicates. Plots were five rows (2.25 × 5 m), with 0.45 m row spacing. The soybean cultivar used in the sowing was BRS Estância RR, was performed with a density of 21 seeds m^{-2}.

The experiment consisted in two factors: weed-free and weed-intereference periods of the hairy fleabane with soybean. In the weed-free period, plots remained without weed competition during 0, 7, 14, 21, 28, 35, 42 and 154 days after soybean emergence (DAE); after which, hairy fleabane were allowed to reinfest the plots and compete with the soybean plants. In the weed interference period, hairy fleabane were allowed to emerge at planting and compete 0, 7, 14, 21, 28, 35, 42 and 154 DAE, and then, plots were kept weed free for the remainder of the soybean crop cycle. The hairy fleabane removal was performed by manual control.

The population of glyphosate-resistant hairy fleabane in the experiment area, from natural occurrence, and the management before the soybean seeding was done with two application of glyphosate (1080 g e.a. ha^{-1}) and one clethodim (120 g i.a. ha^{-1}). The aplication was done at 85 and 20 days before the soybean seeding, for grass and broadleaf control, leaving at the experiment area glyphosate-resistant hairy fleabane in the average population of 37 plants m^{-2}. At the soybean emergence, the hairy fleabane plants had a height of up to 15 cm. After soybean emergence were performed two applications of glyphosate (720 g e. a. ha^{-1}), at 14 and 28 DAE for control of the other weeds species.

Were performed evaluation in soybeans free and in competition with hairy fleabane at soybean flowering stage (80 DAE); a) morphological evaluation: number of trifoliates, leaf area, dry mass of leaves, dry mass of stem, dry mass total; b) physiological evaluation: net photosynthesis (A), stomatal conductance (gs) and transpiration rate (E).

Were collected plants in 0.225 m^2 of the plot to morphological variables evalutions. After counting the number of trifoliate leaves, the leaves were removed from plants, the petioles taken out and was measured the leaf area by leaf area determiner (LICOR 3100). For the variables dry mass of leaves and dry mass of stem, the leaves and stems were separated and the samples were dried in a dry oven at 60 °C for 72 hours. The photosynthetic variables were assessed using infrared gas analyzer (IRGA, model LI-6400 XT), and the evalutions were carried out during the morning taking for the assessment the last leaf totally expanded of the plant.

At pre- harvest was measured plant height of soybean from the soil surface to the highest free-standing point of six random selected plants in each plot. Middle rows (5 rows) were harvest each plot to determined the soybean yield. The soybean yield from each plot was performed from harvest machine and, after weighed, the values were corrected to 13% of moisture and expressed in kg ha^{-1}.

ANOVA was performed by F test (p>0.05) and to compare the means for the weed interference and weed free periods, when significant, using the Tukey test (p>0.05). The photosynthetic variables were subjected to regression analysis by the exponential model, using the equation $y = yo + a^*e^{(-b^*x)}$. The comparison between days was performed by the least significant difference test (LSD) (p>0.05). For soybean yield, the data were subjected to regression analysis by the logistic model, using equation $y = yo + a/(1 + (x/xo)^b$.

The critical period of hairy fleabane interference was determined based on the regression equation for soybean yield, subtracting 5% of the yield, and this value was considered the cost of control. The yield loss curve was segmented into linear equations to obtain the slope of each segment of the line, and to determine the number of points in each segmentation the highest coefficient of determination was considered. Pearson correlation matrices were prepared for morphological and photosynthetic variables.

3. RESULTS AND DISCUSSION

Interaction among weed interference and weed free periods for all morphological variables evaluated were verified. For the plant height, number of trifoliate and leaf area, it was found that in the weed free period there were no differences. However, the results to weed interference period indicate that the permanence of the weed for a period over 35 DAE results in a decrease in the plant height, number of trifoliate and leaf area (Table 1). In the comparison among the periods, from the 28 DAE of the soybeans, the coexistence with weed has caused reductions in plant height and leaf area of the soybean, while for the number of trifoliate differences were verified only for a period over 42 DAE.

Usually, in weed competition, the crop tends to increase the height, to obtain an advantage in light competition as observed for the interference of *Lolium multiflorum* and *Raphanus sativus* with wheat (Agostinetto et al., 2008) and soybean in competition with *Bidens* spp., *Sida rhombifolia* and *Raphanus sativus* (Bianchi et al., 2006). However, this behavior can not be observed in soybean competition with hairy fleabane, because the increasing time interference decreased the soybean height. Changes in quality and light intensity, especially on red and far red wavelengths ratio incident on plants, affect the development of soybean cultivar (Ballaré et al., 1990).

Soybean plants having greater leaf area shadowed more intensely the competing plants, resulting in impaired growth and development of weed (Bianchi et al., 2006). The leaves formation defines the ability of the canopy to intercept the photosynthetically active radiation, being considered a determinant factor in dry matter accumulation by plants (Silva et al., 2004).

The dry mass of leaves, dry mass of stem and dry mass total of soybean were not changed due to the weed free period. However, dry mass of stem and dry mass total of soybean were reduced by 35 days of weed interference, differing from weed-free soybean (Table 2). Reductions in dry mass of leaves were observed in crop that remained all cycle in hairy fleabane presence. In the average, the dry mass of leaves, dry mass of stem and and dry mass total of soybean, it was noted that the coexistence throughout the whole period with the weed reduced in approximately 70% the growth of the soybean plants.

Even in plants under non-limiting conditions for growth, the light reflected by a neighboring plant causes reductions in the leaf area and biomass accumulation in soybean plants (Green-Tracewicz et al., 2012). In comparing the periods, it is possible to see that from the 35 DAE were noticed reductions in the weed interference periods regarding the weed free period (Table 2).

The plants growth, development and phenological stage can influence photosynthesis, causing increases in the photosynthetic activity, and altering the response to variation in environmental factors (Ribeiro et al., 2004). The soybean net photosynthesis (A), stomatal conductance

Table 1. Effects of glyphosate-resistant hairy fleabane weed interference and weed free periods in soybean plant height, trifoliates and leaf area

Time (days)	Plant height (cm)		Trifoliates (nº $plant^{-1}$)		Leaf area (cm^2 $plant^{-1}$)	
	Weed free	Weed interference	Weed free	Weed interference	Weed free	Weed interference
0	69.7aA[1]	69.9 aA	89.3 aA	105.3aA	6754 aA	7021 aA
7	66.3aA	70.0 aA	86.5 aA	88.7abA	6352 aA	6862 aA
14	66.2aA	64.2 abA	86.8 aA	82.8abA	6134 aA	4933 abA
21	70.4aA	64.9 abA	88.3 aA	84.5abA	6449 aA	4850 abA
28	72.9aA	62.3 abB	95.3 aA	84.8abA	6532 aA	4839 abB
35	70.4aA	56.9 bcB	90.3 aA	68.0bcA	6618 aA	3884 bcB
42	67.2aA	46.8 cB	100.3 aA	68.5bcB	6371 aA	3908 bcB
154	71.3aA	50.1 cB	112.5 aA	44.5cB	7159 aA	2064 cB

[1]Means followed by the same letter, lowercase on the column and uppercase on the line, do not differ by Tukey test at 5% probability.

(gs), and transpiration rate (E) were reduced by the weed interference with hairy fleabane, while for weed free period, the exponential model did not fit the data (Figure 1). Reductions in A, gs and E were noticed from 14 days of coexistence of the hairy fleabane.

The competition effects among plants have influence about stomatal opening, particularly in regard to the wavelengths perceived by the plants, once the far red wavelengths induce the closure of the stomata (Sharkey and Raschke, 1981). The water stress is another factor that contributes to stomatal closure, which results in reduced leaf conductance, photosynthesis and respiration inhibition (Attridge, 1990).

The plants detect that they are being shaded when red and far red wavelengths ratio is reduced due to the increase of light reflected by the neighboring plants. The perception of changes in the light quality occurs through phytochrome. The phytochromes detect changes in the radiation quality and appropriately redirect growth and development according light quality (Smith, 1995).

The effects of hairy fleabane competition on soybean transpiration may be related to opening and closing stomata,

Table 2. Effects of glyphosate-resistant hairy fleabane weed interference and weed free periods in soybean dry mass of leave, dry mass of stem and dry mass total

Time (days)	Dry mass of leave (g plant^{-1})		Dry mass of stem (g plant^{-1})		Dry mass total (g plant^{-1})	
	Weed free	Weed interference	Weed free	Weed interference	Weed free	Weed interference
0	22.43 aA[1]	26.50 aA	26.46 aA	30.51 aA	48.89 aA	57.01 aA
7	22.91 aA	22.89 aA	27.20 aA	26.86 abA	50.12 aA	49.76 abA
14	21.15 aA	19.88 aA	23.79 aA	22.65 abA	44.95 aA	42.54 abA
21	21.49 aA	16.93 abA	27.54 aA	22.43 abA	49.02 aA	39.37 abcA
28	22.08 aA	17.26 abA	25.67 aA	19.94 abcA	47.75 aA	37.20 abcA
35	24.08 aA	16.04 abB	27.46 aA	15.50 bcB	51.54 aA	31.55 bcB
42	24.11 aA	15.77 abB	27.12 aA	17.27 bcB	51.23 aA	33.04 bcB
154	27.83 aA	8.06 bB	28.29 aA	9.07 cB	56.12 aA	17.14 cB

[1]Means followed by the same letter, lowercase on the column and uppercase on the line, do not differ by Tukey test at 5% probability.

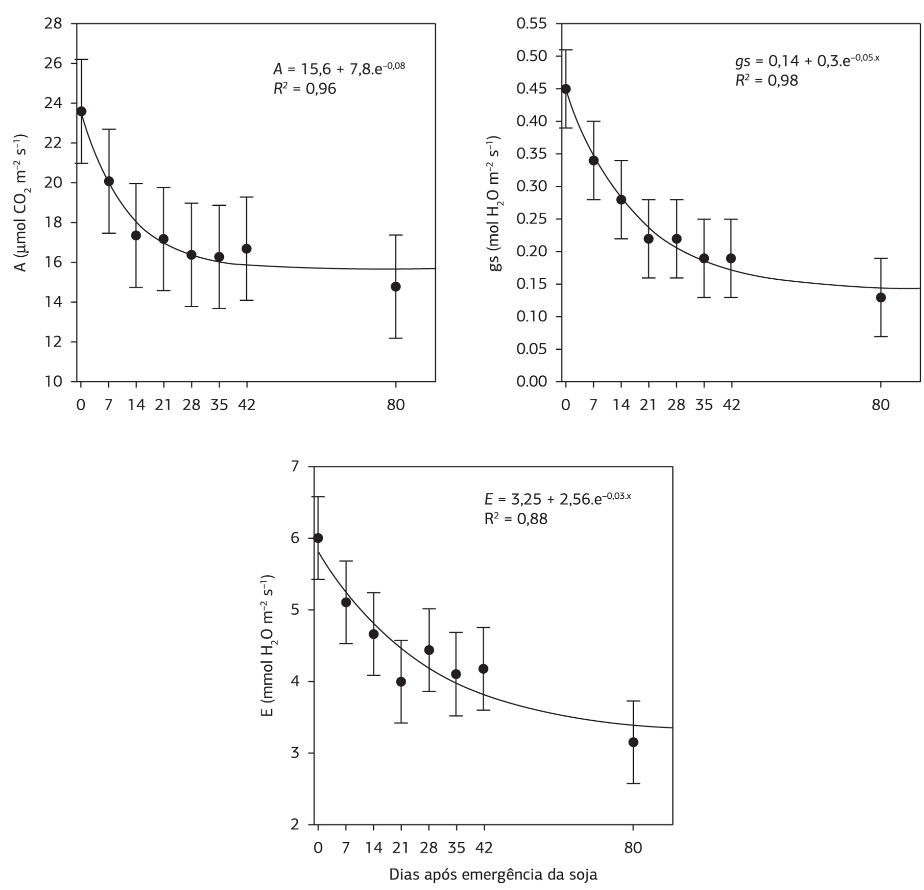

Figure 1. Effects of glyphosate-resistant hairy fleabane interference periods on photosynthesis rate (A), stomatal conductance (gs), and transpiration rate (E) of soybean. The bars represent least significant difference (LSD).

regulated by changes in light quality, as the plants in competition sense changes through a greater relationship between red and far red wavelengths ratio, indicating the presence of neighbors, and low water availability, close their stomata to prevent water losses. As adjustment mechanism, when the brightness is reduced, or even when under drought stress, plants tend to close the stomata, thus implying lower transpiration that is directly related to the gain of dry matter (Cochard et al., 2002; Concenço et al., 2007).

In the Pearson correlations among the morphological and photosynthetic variables, there are positive responses in the interaction for most variables, indicating that the effects of hairy fleabane competition in soybean in the morphological variables are reflected in the physiological responses (Table 3). Positive correlations were observed between the leaf area and dry mass total with A or gs, indicating that both photosynthetic variables respond to the increase of the leaf area and dry matter. Thus, high leaf area and dry mass total increase the photoassimilation capability, the largest ability to intercept light and therefore increases in A and gs can be observed.

The period before interference is a period that crop growth cycle when weed control must be initiated to keep potential yield, or, the maximum amount of time early weed competition that can be tolerated by the crop without losses yield. The weed interference period allowed determining the time of weed coexistence with soybean, with tolerated period without significant crop yield loss (less than 5 percent), being of the 24 DAE of crop (Figure 2). The end of the coexistence period is when the weed control should be started to avoid a yield loss. The interval weed-free requirement it was not possible to determine because after removal of hairy fleabane there was not new hairy fleabane reinfestation.

Segmentation, for linear models, of the logistic model resulted in two lines, the first segment consisting in the hairy fleabane competition from the soybean emergence until 21 DAE, while the second consisted between 21 DAE and 42 DAE (Figure 2). These segmentations provides losses yield by hairy fleabane competition by day of coexistence. Thus, during the first 21 days of competition it has been found that the yield loss for each day of competition was of 4.2 kg ha^{-1}, while that weed competiton between 21 to 42 DAE the yield losses were of 20.7 kg ha^{-1} day^{-1}.

In this study it was observed that until 24 days, the hairy fleabane causes tolerable interference in soybean, and management practices should be taken when hairy fleabane has become more vulnerable to any intervention in order to control it. The herbicide use for control of hairy fleabane in soybean crop must take into account time that the herbicide takes to control or make it physiologically unable of competing with the crop. However, this period depends, among some factors, on the efficiency of the herbicide to reach the site of action and of the physiological conditions of the weed.

Table 3. Pearson Correlation between morfological and photosynthetic variables of soybean

Morfological variables	Photosynthetic variables		
	A	gs	E
Leaf area	0.86*	0.97*	0.90*
Dry mass total	0.87*	0.95*	0.88*

* or [ns] significances interactions or not significance at 5% probability, respectively. A = net photosynthesis; gs = stomatal conductance; E = transpirations rate.

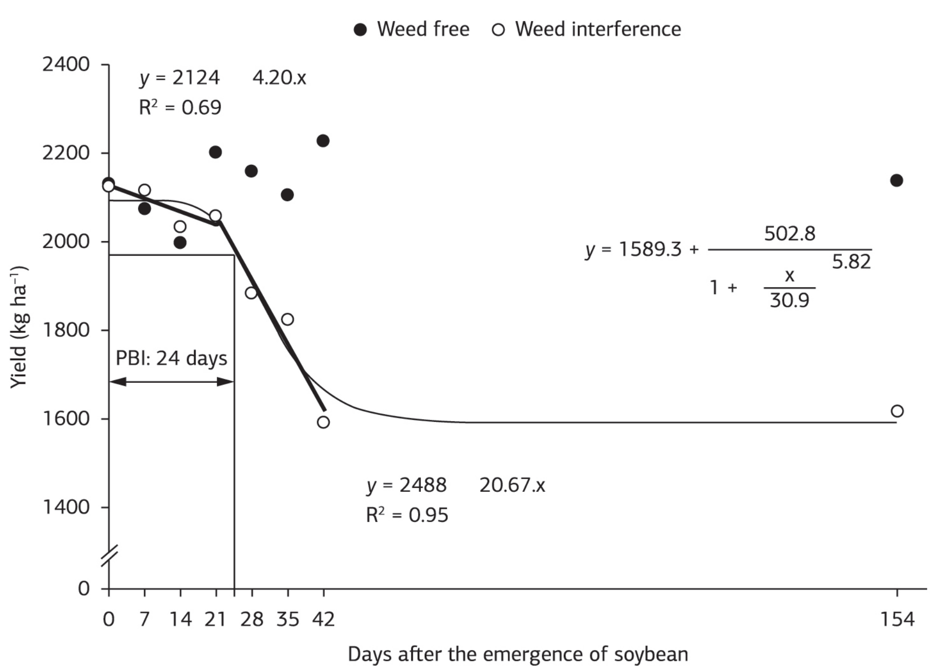

Figure 2. Response of yield soybean by increase periods of glyphosate-resistant hairy fleabane interference. PBI, period before interference.

4. CONCLUSION

The growth and development of soybean, cultivar BRS Estância RR, quantified by morphological and physiological variables, are negatively affected by the coexistence with glyphosate-resistence hairy fleabane. The morphological variables of the soybean correlate positively with the photosynthetic variables measured during the hairy fleabane competition periods with soybean. The period before interference in the soybean is 24 days after the crop emergence for hairy fleabane population of 37 plants m^{-2}, established before crop sowing.

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