doi: 10.1590/S0100-83582015000400009

Interference Periods Among Weeds and Soybean RR™ Crops in the Western Center Area of the Brazilian State of Paraná[1]

Períodos de Interferência entre Plantas Daninhas e a Cultura da Soja RR® na Região Centro Ocidental Paranaense

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ABSTRACT - One of the factors that can influence soybeans yield is the interference imposed by weeds. This research has aimed to determine the critical period of weed interference on cv. INT 6100 RR™ soybeans. The experiment was conducted under field conditions at Campo Mourão County, Parana State, in the 2013/2014 harvest, using randomized blocks, arranged in a 2 x 8 factorial, with four replications. In the first factor, the coexistence (period before weed interference) and control (total period of weed interference prevention) periods were assessed. The second factor consisted of management times of weed species (0, 7, 14, 28, 35, 49, 56 and 130 days after emergence – DAE). The evaluations performed were density and shoot dry matter of the weed community, height, number of pods, thousand grain weight and soybean yield. Among the weed species in soybean crops, there was predominance of eudicotyledonous ones (82%). The yield results allowed establishing, for cv. INT 6100 RR™ soybeans at Campo Mourão County, Parana State, a critical period for preventing interference between 24-38 DAE.

Keywords: coexistence, weed control, competition, *Glycine max*.

RESUMO - Um dos fatores que podem influenciar a produtividade da cultura da soja é a interferência imposta pelas plantas daninhas. A pesquisa teve como objetivo determinar o período crítico de prevenção à interferência das plantas daninhas sobre a cultura da soja cv. INT 6100 RR®. O experimento foi conduzido em campo no município de Campo Mourão, PR, na safra 2013/2014, em delineamento experimental de blocos casualizados, em esquema fatorial 2 x 8, com quatro repetições. No primeiro fator, avaliaram-se os períodos de convivência e controle das plantas daninhas, representados pelo período anterior à interferência – PAI e período total de prevenção à interferência – PTPI, respectivamente. O segundo fator consistiu das épocas de controle das espécies daninhas: 0, 7, 14, 28, 35, 49, 56 e 130 (ciclo todo) dias após a emergência – DAE. Foram avaliados densidade e massa seca da parte aérea da comunidade infestante, altura, número de vagens, massa de mil grãos e produtividade da cultura da soja. Entre as espécies infestantes da cultura da soja, verificou-se predominância de eudicotiledôneas (82%). Os resultados de produtividade permitiram estabelecer para a soja cv. INT 6100 RR® um período crítico de prevenção à interferência entre 24 e 38 DAE.

Palavras-chave: convivência, controle, competição, *Glycine max*.

INTRODUCTION

Soybean (*Glycine max*) cultivation undoubtedly stands out among oilseeds grown in the world and is one of the largest segments of Brazilian agriculture, being cultivated in various biomes of the country. This importance grows due to demands from domestic and foreign markets for protein and high quality oil (Brandão et al., 2006). In the Brazilian state of Paraná, the western center area stands out as the main producer of

[1] Recebido para publicação em 6.7.2015 e aprovado em 6.10.2015.
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soybeans of the state, with an acreage of 610,000 ha and production of 2,013,000 tons of grains (DERAL, 2014).

In Paraná's northern and western regions there is a predominance of soybean (first crop) and maize (second crop) cultivation succession. This cultivation system makes farmers prioritize the cultivation of shorter cycle soybean genotypes, such as early and very early. However, these genotypes have some disadvantages, such as being more sensitive to variations in sowing and adverse conditions, and demanding that cultivation practices be carried out at the right time (Crotser &Witt, 2000; Heiffig et al., 2006).

In this context, it is known that soybeans have sensitivity to weeds interference during their development cycle (Pittelkow et al., 2009). Scholten et al. (2011) have reported that the interference caused by weeds can reduce soybeans productivity between 15 and 80%, mainly due to competition for resources that are essential to plant growth and development. This fact was confirmed by Procópio et al. (2004), who have found that *Bidens pilosa* and *Euphorbia heterophylla*, species of high occurrence in soybean crops, have greater efficiency in the use of nitrogen absorbed in the soil when compared to soybean plants.

Weeds interference relationships in agricultural crops depend on factors related to weeds (species, density and distribution) and their own culture (cultivar, spacing, planting timing and seeding density), plus the environment and period in which interference takes place (Duarte, 2009). Studies about interference between crops and weeds are intended to identify critical periods of interference and thus set the best time for weed control, aiming to avoid losses in crop yield (Vidal et al., 2010).

The periods considered in the evaluation of weed interference to crops are: the period before interference (PBI), total period of interference prevention (TPIP) and critical period of interference prevention (CPIP) (Silva et al., 2014). At the beginning of the cycle, the culture can coexist with weeds for a certain period of time without the occurrence of yield loss, and this phase is called the period before interference (PBI), wherein the environment is capable of providing growth resources necessary for the culture and the weeds (Smitchger et al., 2012). According to Meschede et al. (2004), PBI is the period of greatest importance in the crop cycle, as it is from where yield loss begins. According to Silva et al. (2014), TPIP is the period from the emergence, in which the crop is expected to grow free from the presence of weeds so that productivity is not changed. After that time, weeds that are present will not compete so that they reduce crop yield because it already has the capacity to suppress competing plants.

CPIP is the phase when control practices must be effectively adopted to prevent losses in productivity, being characterized by the difference between PBI and TPIP (Salvador et al., 2006). Thus, knowledge of the interference periods serves as a tool to identify the moment when the control measures should be adopted so that the crop express its full productive potential.

Given the above, it is clear that the determination of interference periods in regionalized conditions is of paramount importance for the optimization of times and duration of control strategies. Despite its importance for soybean production, western center region of Parana State is still lacking in research in this area. Thus, the aim of the present study was to determine the critical period of weed interference on cv. INT 6100 RR™ soybean in western center region of Parana State.

MATERIAL AND METHODS

The experiment was conducted in the field in the period from October 28, 2013 to March 8, 2014, in an experimental area located in the Brazilian city of Campo Mourão, PR (23º59'25,23" south latitude, 52º21'36,86" west longitude and 528 m altitude). The soil of the area was identified as dystrophic red latosol (Embrapa, 2013). The physicochemical analysis of the soil showed pH in water of 6.02, content of $H + Al^{+3}$ of 5.11 $cmol_c$ dm^{-3}, Ca^{+2} of 3.47 $cmol_c$ dm^{-3}, Mg^{+2} of 1.46 $cmol_c$ dm^{-3}, K^+ of 0.46 $cmol_c$ dm^{-3}, P of 5.79 mg dm^{-3}, C of 13.2 g dm^{-3}, clay of 740 g kg^{-1}, silt of 110 g kg^{-1} and total sand of 150 g kg^{-1}. The area climate is classified, according to Köppen, as Cfa, characterized by a subtropical climate (Iapar, 2000).

In relation to rainfall and temperature index in the experiment performance period, the total of accumulated rainfall during the soybeans crop cycle of 616 mm and minimum of 12.5 °C and maximum of 36.9 °C temperatures (Figure 1) were observed.

Weed management desiccation in the area was held two weeks before soybean sowing, with the application combination of herbicides glyphosate + 2,4-dichlorophenoxyacetic acid (3.0 + 1.5 L p.c. ha^{-1}). Fertilization was based on soil analysis and followed the recommendations for soybean crops proposed by Sfredo (2008). The fertilization and seeding joint operation was mechanically held on 11/11/2014, using early cultivar INT 6100 RRTM, at the density of 15 seeds per linear meter and spacing between rows of 0.50 m, previously inoculated with *Bradyrhizobium japonicum*. Cultivar INT 6100 RRTM presents early cycle, with maturity group 6.1 and indeterminate growth habit; its seeding in the region of Campo Mourão, PR between 10/10 and 11/30 is recommended.

The experimental design was in randomized blocks in a 2 x 8 factorial arrangement, with four replications. In the first factor, the periods of weed coexistence and control were assessed, represented by PBI e TPIP, respectively, and the second factor consisted in control times of the weed community during periods of 0, 7, 14, 28, 35, 49, 56 days after emergence (DAE) and the entire crop cycle (130 DAE). Each experimental unit consisted of a 12 m² (3 x 4 m) area, considering as the floor area in the evaluations the inside of the plot, ignoring the two side rows and 0.5 m from the end of each row.

At the end of each coexistence period (PBI), the plots began to be weeded weekly until harvest. In the treatments with control periods (TPIP), the culture was weeded weekly until every predetermined period; subsequently, weeds control methods were not adopted. The only control method used was the mechanical one by means of inter-rows weeding and thinning the crop sowing rows.

Aiming diseases management, two fungicides applications in stages R1 and R5.1 of the soybean crop were performed

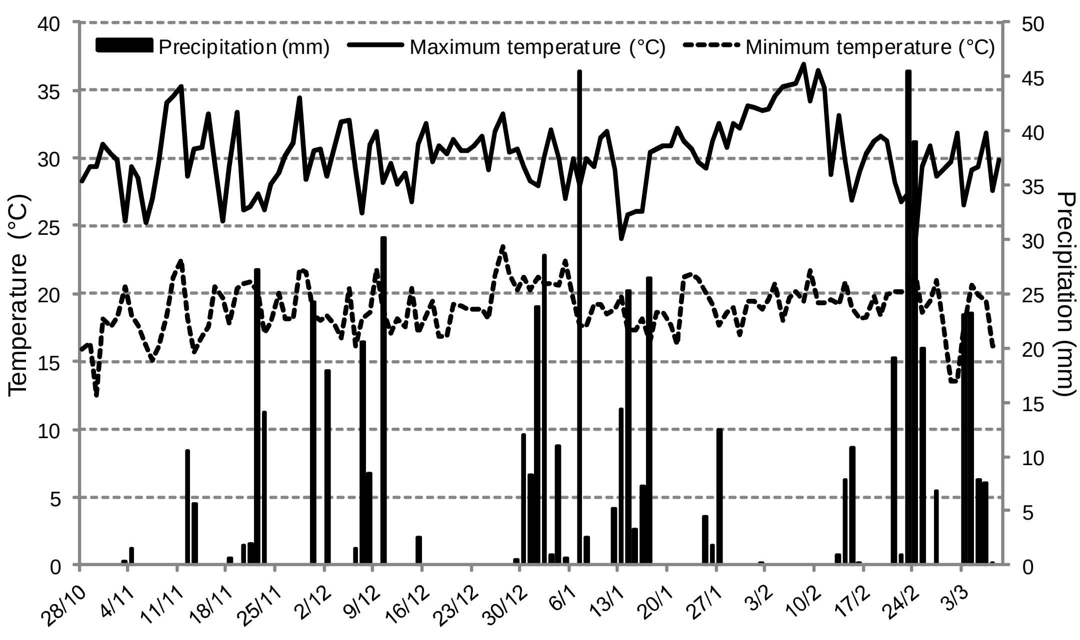

Figure 1 - Rainfall (mm) and minimum and maximum temperatures (°C) during the 2013/2014 period from October 28 to March 8. Campo Mourão, PR, 20013/2014.

using 1.5 L p.c. ha^{-1} of Locker™ (carbendazim + tebuconazol + kresoxim-methyl) and 0.6 L p.c. ha^{-1} of Opera™ (piraclostrobina + epoxiconazol), respectively. For pest control, two insecticide applications in stages V5 and R3 were also held, using 0.05 L p.c. ha^{-1} of Premio™ (clorantraniliprole) and 0.07 L p.c. ha^{-1} of Belt™ (flubendiamide), respectively. All applications were done with an application volume of 200 L ha^{-1} by means of a pull type sprayer.

At the end of each coexistence period, weeds density identification and determination were done, as well as weeds shoots dry matter quantification (MSPD). This procedure was carried out using a square-shaped metallic jig with 0.25 m² area and four random entries were done per plot. Weeds shoots were collected and separated into monocotyledons and eudicotyledons. The samples were dried in an air forced circulation stove at 60 °C until constant weight, and then weighed on a precision balance.

Soybean plants height was assessed in stage R6 with the aid of a graduated ruler, randomly selecting ten plants present in the floor area of each plot. In stage R7, counting the number of pods per plant was performed by randomly collecting ten plants per plot. At the end of the crop cycle, manual harvest of two central rows of the plot was done, totaling an area of 2 m² to determine grain yield. For standardization, grain moisture was adjusted to 13%. Thousand grain weight was determined by weighing four repetitions with thousand grains each on a precision scale.

The results were submitted to analysis of variance by the F-test and regression analysis, both at 5% probability. The chosen mathematical models were quadratic and sigmoidal (three and four parameters) because they better explain the biological behavior of the evaluated phenomenon. The models description is below.

$$y = a + bx + cx^2$$

where y = dependent variable; x = independent variable; a = intercept; b = linear coefficient; and c = quadratic coefficient.

$$y = \frac{a}{1 + e^{-\left[\frac{x - x0}{b}\right]}}$$

where y = dependent variable; x = independent variable; a = maximum value of y; and b and $x0$ are constant of the sigmoidal model.

$$y = y0 + \frac{a}{1 + e^{-\left[\frac{x - x0}{b}\right]}}$$

where y = dependent variable; x = independent variable; $y0$ = lower value of y; a = difference between the higher and lower values of y; and b and $x0$ are constant of the sigmoidal model.

The determination of the period before interference (PBI) and the total period of interference prevention (TPIP) was done by estimating losses of 5% compared to the yield obtained by plants that have developed free of the presence of weeds, using adjusted regression models. Mathematical models were obtained with the help of statistical software SigmaPlot 10.0™, and regression curves generated in the Microsoft Excel™ spreadsheet.

RESULTS AND DISCUSSION

The weed community present in the culture during the experiment was mainly composed of nine species: plantain signalgrass (*Urochloa plantaginea*), jamaican crabgrass (*Digitaria horizontalis*), littlebell (*Ipomoea triloba*), milkweed (*Euphorbia heterophylla*), perennial pigweed (*Amaranthus deflexus*), benghal dayflower (*Commelina benghalensis*), tropical mexican clover (*Richardia brasiliensis*), beggarticks (*Bidens pilosa*) and wild radish (*Raphanus raphanistrum*).

For the results of weeds density (Figure 2), it was observed that the largest infestations occurred from 7 DAE, extending to 35 DAE, with a predominance of eudicotyledonous species (82%) compared to monocotyledons (18%). However, it was at 14 DAE that the highest densities were reached, and, as the soybean crop was developing, there was a reduction of the weed population. Similar results were obtained by Silva et al. (2009), who found a reduction of weed density at 33 and 28 DAE for soybeans grown in medium and high infestation, respectively. According to Tavares et al. (2012), this is due to the closing of the soybean canopy, which restricted the emergence of new weeds through shading, thereby exerting crop control.

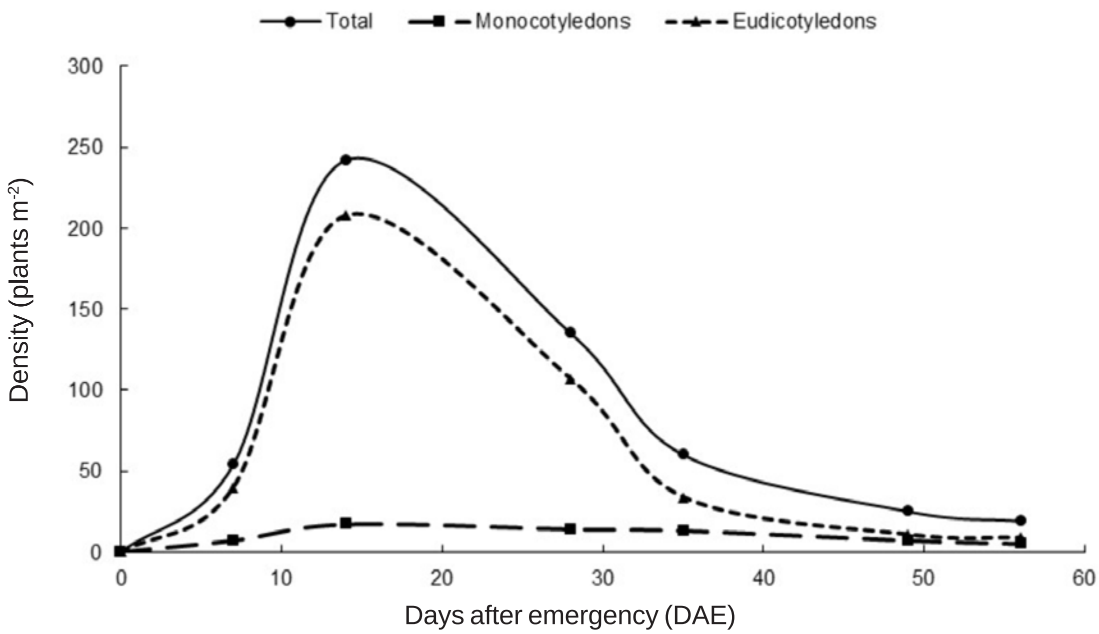

Figure 2 - Weeds density (plants m^{-2}) after different periods of coexistence with soybean crops. Campo Mourão, PR, 2013/2014.

The higher incidence of eudicotyledonous species in the weed community enhances the interference for the soybean crop since, according to Vasconcelos et al. (2012), the competition between weeds and crop may be even greater if they are morphologically and physiologically similar, because they may have similar requirements.

The weeds dry matter accumulation remained low for an initial period and after 20 DAE of the crop it showed a significant increase throughout the assessment period (Figure 3). Similar results were found by Silva et al. (2008) evaluating weed densities and control periods on soybean yield components. According to Meschede et al. (2004), the accumulated dry matter proves to be more important than the weeds density in relation to the degree of interference imposed on soybeans, and displays an inverse correlation to the yield components of this culture. This is because, as weeds increase their density and develop, especially those which germinate and emerge at the beginning of the cycle, they are more vigorous and thus become dominant, while the smaller ones are suppressed or die, a fact justified by the reduction in plants density with increased dry matter (Afifi & Swanton, 2011).

For the coexistence period, it was observed that the weeds affected the cv. INT 6100 RR™ soybean crop height from the second week after emergence (Figure 4), and this characteristic is related to the fact that the interference was intense. As for the control period, it was observed that up to about 35 DAE, the soybean plants growth decreased. For Jannink et al. (2000), early soybean cultivars have a stronger initial growth and increased competitiveness in this development stage. Silva et al. (2009) have mentioned that the culture, while in competition for light, tends to increase its height (shading), in order to improve the capture of radiation and shade weeds. This is the first symptom of the competition and, according to Vidal (2010), it occurs primarily not by shading, but by light reflected (wavelength – red) by the weeds.

The number of pods per soybean plant was directly affected by the interference imposed by weeds, and in the longer periods of coexistence smaller numbers of pods per plant were verified (Figure 5). These results corroborate those found by Silva et al. (2008) and Pittelkow et al. (2009), who have also observed a reduction of pods in soybean plants as they increased the intensity of interference imposed by the weed community to the culture. However, for the thousand grain weight, differences were not observed between the coexistence and control periods (Figure 6), corroborating the results by Duarte (2009), which conclude that this characteristic has greater individual control and is intrinsically related to the cultivar sown, with low variation amplitude by environmental stimuli.

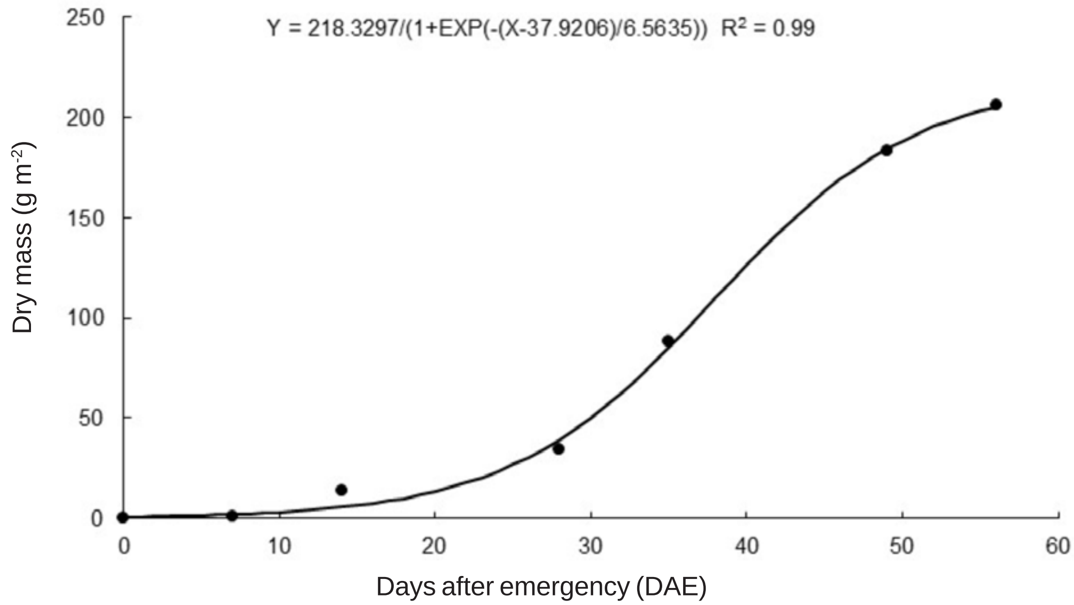

Figure 3 **-** Weeds dry weight (g m^{-2}) after different periods of coexistence with soybean crops. Campo Mourão, PR, 2013/2014.

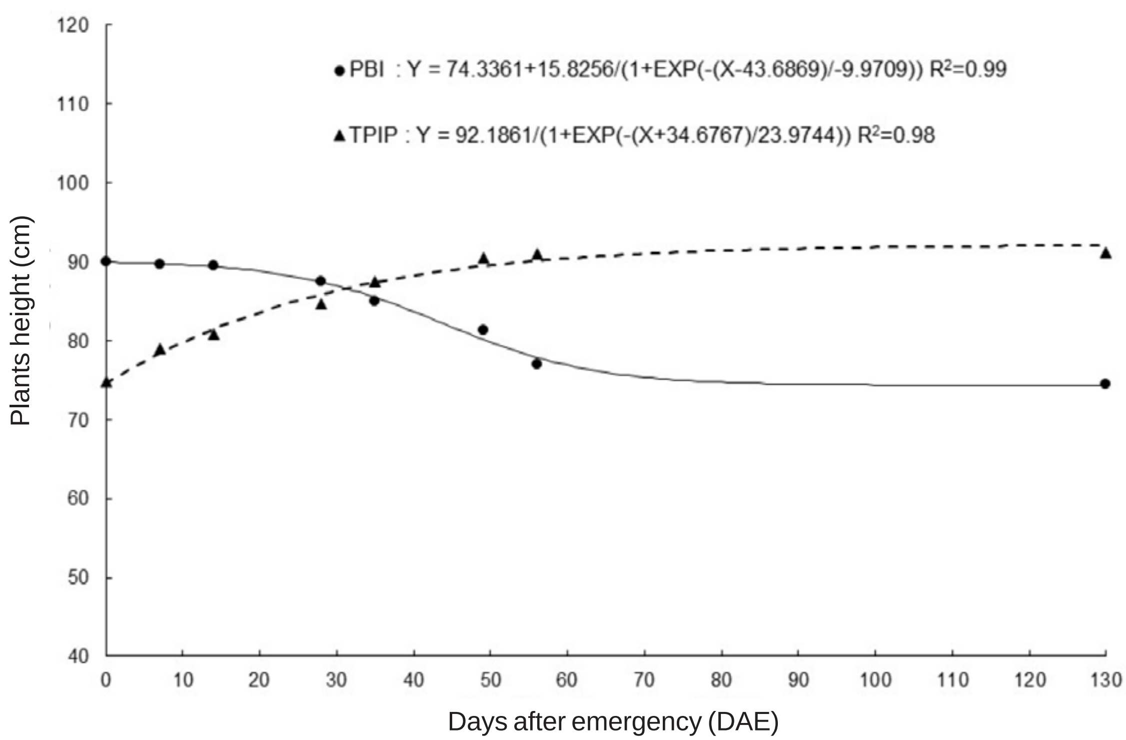

Figure 4 **-** Soybean plants height (cm) after different periods of weed coexistence and control. Campo Mourão, PR, 2013/2014.

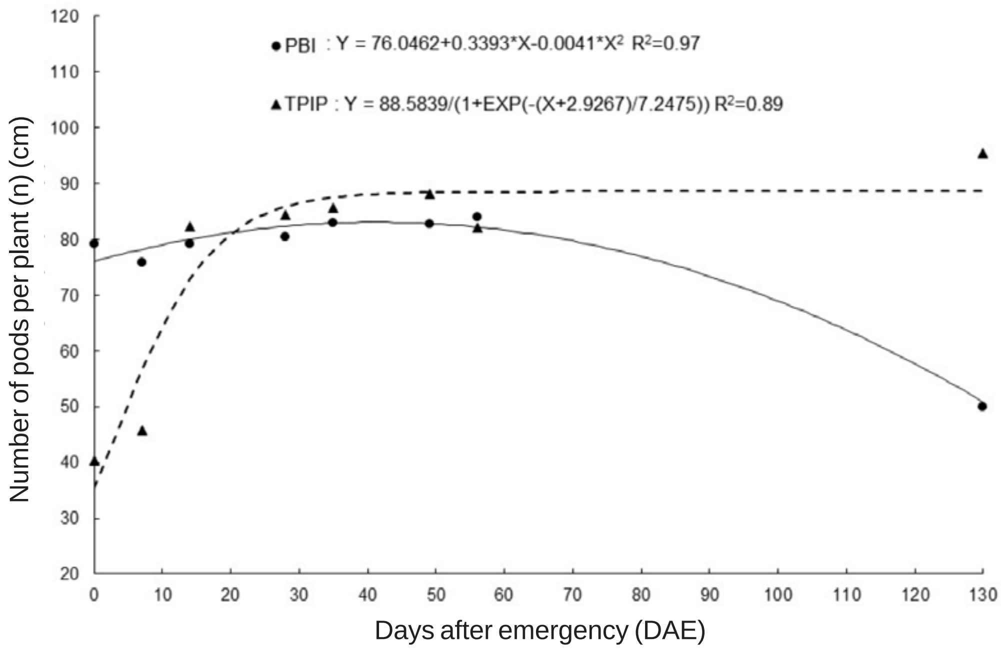

Figure 5 **-** Number of pods per soybean plant after different periods of weed coexistence and control. Campo Mourão, PR, 2013/2014.

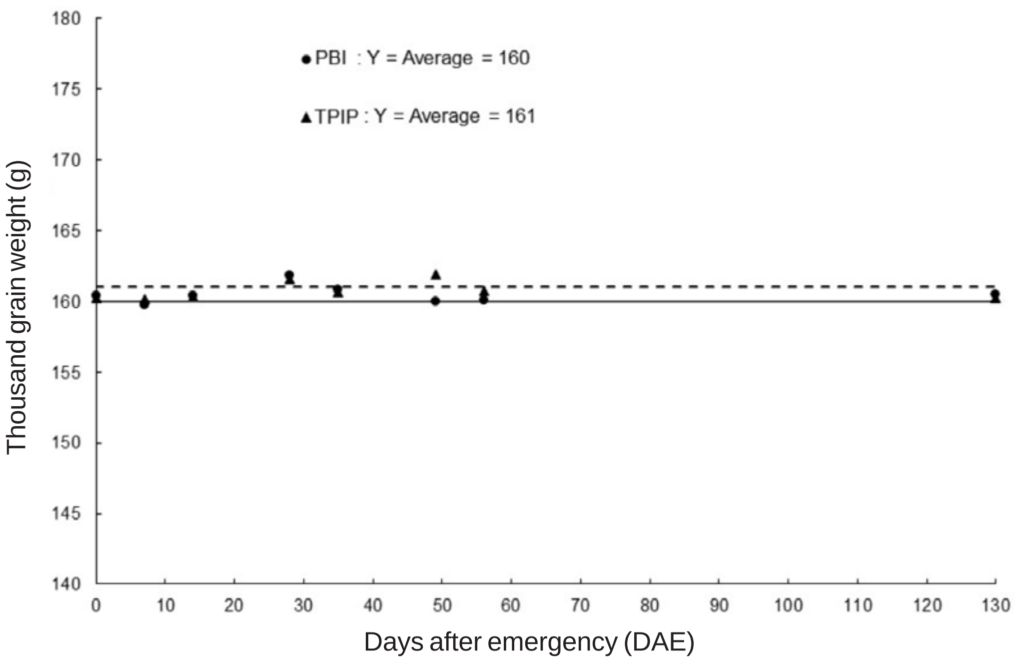

Figure 6 **-** Soybeans thousand grain weight (g) after different periods of weed coexistence and control. Campo Mourão, PR, 2013/2014.

For INT 6100 RR™ soybean cultivar, sown at Campo Mourão County, Parana State, in the 2013/2014 harvest, it was found that the coexistence of weeds throughout the crop cycle (130 days) resulted in 52% yield losses in relation to plants that have developed throughout the whole cycle in the absence of coexistence with the infestation (Figure 7).

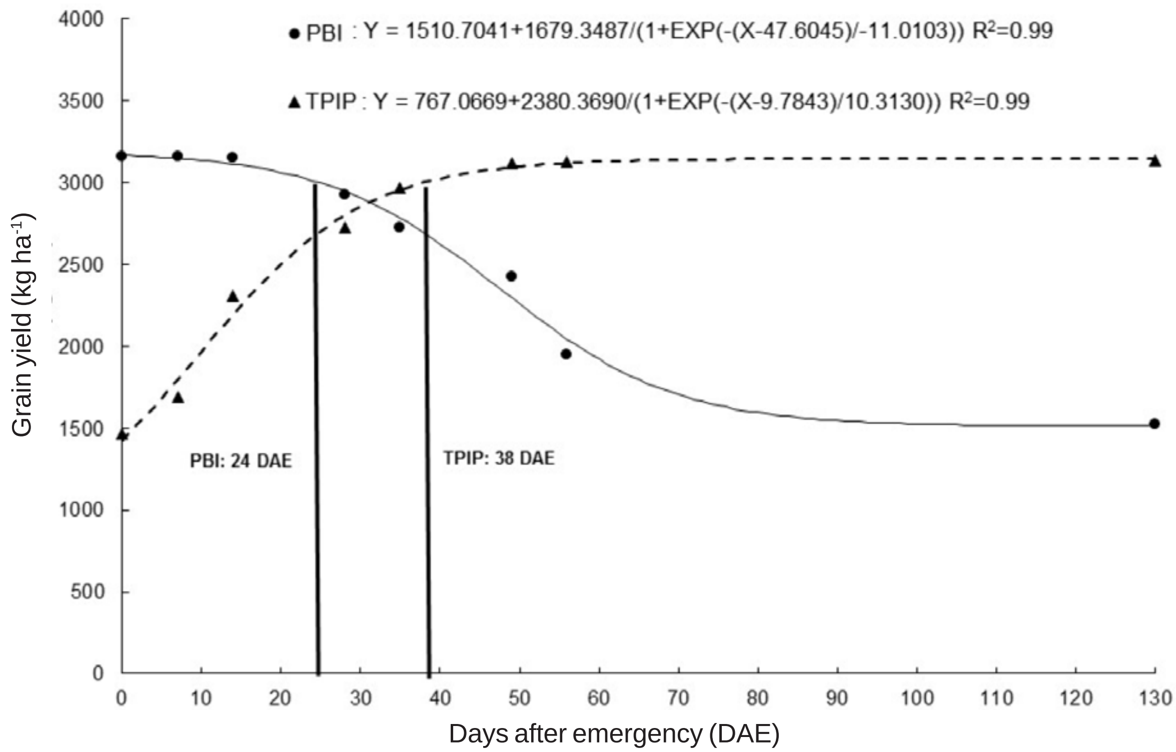

Figure 7 **-** Soybean grains yield (kg ha^{-1}) after different periods of weed coexistence and control. Campo Mourão, PR, 2013/2014.

In this sense, considering 5% tolerance in grain yield reduction, it was established that the PBI and TPIP periods took place at 24 and 38 DAE of INT 6100 RR™ soybean, respectively, characterizing the CPIP interval between 24 and 38 DAE. Therefore, so that there are no significant losses in soybean yield in the edaphoclimatic environment in which the experiment was conducted, it is necessary that in this period the culture be free of weed interference.

From 24 DAE, progressive increase in weeds dry matter accumulation was verified and the resources available in the environment became insufficient to meet the crop and weeds demands. Thus, the process of competition for these resources was intensified and there was a reduction in crop yield. However, from 38 DAE the soybean crop was more competitive than weeds so that it promoted culture control without the need to perform other control measures anymore. Santos et al. (2003), comparing the accumulation and utilization of solar radiation by soybeans and common beans and weeds *B. pilosa*, *E. heterophylla* and *Desmodium tortuosum*, have found that soybeans had the highest dry biomass production rate over its cycle and also the largest leaf area index, indicating its greater ability to capture light and shade the weeds.

As for weeds chemical control under experimental conditions, the culture was in the V3-V4 stage at 24 DAE, which is the appropriate time to achieve the application of postemergence herbicides. However, postemergence application must be done before that period because chemical management does not eliminate competition immediately after application. For herbicides with effect in preemergence, used in direct seeding desiccation or even soon after crop implementation in a conventional system, it would be necessary for them to show residual activity up to 38 DAE. Otherwise, the postemergence herbicides applications should be performed in every new emergence flow of weeds until 38 DAE of the soybeans. The adoption of these measures is to ensure crop yield.

Experiments aimed at determining the weeds interference periods in soybeans crops are designed to direct the best time of weed management for different producing regions. Nepomuceno et al. (2007), evaluating weed interference in direct seeding systems (cv. CD 201™) and conventional seeding (cv. M-SOY-6101™) at Jaboticabal County, São Paulo State, have reached PBI values equivalent to 33 and 34 DAE and TPIP of 66 and 76 DAE, respectively. Silva et al. (2009) have determined only PBI under low, medium and high weed infestation conditions for soybeans cultivar BRS 243-RR™ at Coimbra County, Minas Gerais State, observing periods of 17 DAE in low infestation and 11 DAE in medium and high infestation. As for Pittelkow et al. (2009), they have observed, in the Brazilian state of Rondônia, PBI of 22 and 33 DAE for cultivar TMG106RR™, using high and medium weed infestation, respectively. Meschede et al. (2004) have obtained PBI of 11 DAE for BRS-133™ soybeans cultivated with low seeding rate at Quarto Centenario County, Parana State.

Therefore, the degree of weeds interference in crop plants can be influenced by several factors such as culture, weed community, environment and management. Thus, the search results are also shown quite varied and it is important to carry out regional studies in different seasons in order to establish, for a given condition, when control measures should be adopted. In the case at Campo Mourão County, Parana State, the critical period of weeds interference prevention (CPIP) for soybeans cultivar INT 6100 RR™ was established between 24 and 38 DAE.

LITERATURE CITED

AFIFI, M.; SWANTON, C. J. Maize seed and stem roots differ in response to neighbouring weeds. **Weed Res.**, v. 51, n. 5, p. 442-450, 2011.

BRANDÃO, A. S. P.; REZENDE, G. C.; MARQUES, R. W. C. Crescimento agrícola no período de 199/2004: a explosão da soja e da pecuária bovina e seu impacto sobre o ambiente. **Econ. Aplicada**, v. 10, n. 2, p. 249-266, 2006.

CROTSER, M. P.; WITT, W. W. Effect of *Glycine max* canopy characteristics, *G. max* interference, and weed-free period on *Solanum ptycanthum* growth. **Weed Sci.**, v. 48, n. 1, p. 20-26, 2000.

Departamento de Economia Rural – DERAL. **Soja** – análise da conjuntura agropecuária. Curitiba, 2013. Disponível em: <p://www.agricultura.pr.gov.br/arquivos/File/deral/Prognosticos/Soja__2014_15.pdf>. Acesso em: 3 ago. 2015.

DUARTE, D. J. **Interferência da comunidade infestante na cultura da soja tolerante ao glyphosate**. 2009. 109 f. Dissertação (Mestrado em Agronomia) – Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal, 2009.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – EMBRAPA. **Sistema Brasileiro de Classificação de Solos**. 3.ed. Brasília, DF: 2013. 353 p.

HEIFFIG, L. S. et al. Fechamento e índice de área foliar da cultura da soja em diferentes arranjos espaciais. **Bragantia**, v. 65, n. 2, p. 285-295, 2006.

INSTITUTO AGRONÔMICO DO PARANÁ – IAPAR. **Cartas climáticas do Estado do Paraná**. Londrina: 2000. p. 9-11.

JANNINK, J. L. et al. Index selection for weed suppressive ability in soybean. **Crop Sci.**, v. 40, n. 4, p. 1087-1094, 2000.

MESCHEDE, D. K. et al. Período anterior à interferência de plantas daninhas em soja: estudo de caso com baixo estande e testemunhas duplas. **Planta Daninha**, v. 22, n. 2, p. 239-246, 2004.

NEPOMUCENO, M. et al. Período de interferência das plantas daninhas na cultura da soja nos sistemas de semeadura direta e convencional. **Planta Daninha**, v. 25, n. 1, p. 43-50, 2007.

PITTELKOW, F. K. et al. Interferência de plantas daninhas na cultura da soja transgênica. **Global Sci. Technol.**, v. 2, n. 3, p. 38-48, 2009.

PROCÓPIO, S.O. et al. Absorção e utilização do nitrogênio pelas culturas da soja e do feijão e por plantas daninhas. **Planta Daninha**, v. 22, n. 3, p. 365-374, 2004.

SALVADOR, F. L. Manejo e interferência das plantas daninhas em soja: uma revisão. **R. Fac. Zootc. Veter. Agron.**, v. 13, n. 2, p. 58-75, 2006.

SANTOS, J. B. et al. Captação e aproveitamento da radiação solar pelas culturas da soja e do feijão e por plantas daninhas. **Bragantia**, v. 62, n. 1, p. 147-153, 2003.

SFREDO, G. J. **Soja no Brasil:** calagem, adubação e nutrição mineral. Londrina: Embrapa Soja; 2008. 148 p. (Documentos, 305)

SCHOLTEN, R. et al. Período anterior à interferência das plantas daninhas para a cultivar de feijoeiro 'Rubi' em função do espaçamento e da densidade de semeadura. **Acta Sci. Agron.**, v. 33, n. 2, p. 313-320, 2011.

SILVA, C. et al. Interferência de plantas daninhas na cultura do sorgo sacarino. **Bragantia**, v. 73, n. 4, p. 438-445, 2014.

SILVA, A. F. et al. Período anterior à interferência na cultura da soja-RR em condições de baixa, média e alta infestação. **Planta Daninha**, v. 27, n. 1, p. 57-66, 2009.

SILVA, A. F. et al. Densidades de plantas daninhas e épocas de controle sobre os componentes de produção da soja. **Planta Daninha**, v. 26, n. 1, p. 65-71, 2008.

SMITCHGER, J. A.; BURKE, I. C.; YENISH, J. P. The critical period of weed control in lentil (*Lens culinaris*) in the Pacific Northwest. **Weed Sci.**, v. 60, n. 1, p. 81-85, 2012.

TAVARES, C. J. et al. Interferência de plantas daninhas em dois cultivares de soja. **R. Agr.**, v. 5, n. 17, p. 223-235, 2012.

VASCONCELOS, M. C. C.; SILVA, A. F. A.; LIMA, R. S. Interferência de plantas daninhas sobre plantas cultivadas. **Agropec. Cient. Semi-Árido**, v. 8, n. 1, p. 1-6, 2012.

VIDAL, R. A.; KALSING, A.; GHEREKHLOO, J. Interferência e nível de dano econômico de *Brachiaria plantaginea* e *Ipomoea nil* na cultura do feijão comum. **Ci. Rural**, v. 40, n. 8, p. 1675-1681, 2010.

VIDAL, R. A. **Interação negativa entre plantas:** inicialismo, alelopatia e competição. Porto Alegre: Evangraf, 2010. 130 p.