Modeling of Weeds Interference Periods in Bean[1]

Determinação de Períodos de Interferência das Plantas Daninhas na Cultura do Feijão

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ABSTRACT - The research objective was to determine the effects of spacing and seeding density of common bean to the period prior to weed interference (PPI) and weed period prior to economic loss (WEEPPEL). The treatments consisted of periods of coexistence between culture and the weeds, with 0 to 10, 0 to 20, 0 to 30, 0 to 40, 0 to 50, 0 to 60, 0 to 70, and 0 to 80 days and a control maintained without weeds. In addition to the periods of coexistence, there were still studies with an inter-row of 0.45 and 0.60 m, 10 and 15 plants m^{-1}. The experimental delineation used was randomized blocks with four repetitions per treatment. The grain productivity of the culture had a reduction of 63, 50, 42 and 57% when the coexistence with the weed plants was during the entire cycle of the culture for a row spacing of 0.45 m and a seeding density of 10 and 15 plants per meter; and a row spacing of 0.60m and a seeding density of 10 and 15 plants per meter, respectively. The PPI occurred in 23, 27, 13, and 19 days after crop emergence and WEEPPEL in 10, 9, 8, and 8 days, respectively.

Keywords: *Phaseolus vulgaris*, competition, PPI, WEEPPEL

RESUMO - Objetivou-se com este trabalho determinar o período de convivência anterior à interferência das plantas daninhas (PAI) e o período anterior ao dano no rendimento econômico (PADRE) na cultura do feijão, em diferentes espaçamentos (0,45 e 0,60 m) e densidade de plantas (10 e 15 plantas m⁻¹). Os tratamentos foram constituídos de períodos de convivência entre a cultura e as plantas daninhas (0 a 10, 0 a 20, 0 a 30, 0 a 40, 0 a 50, 0 a 60, 0 a 70 e 0 a 80 dias), mais uma testemunha sem convívio com as plantas daninhas. Adotou-se o delineamento experimental de blocos casualizados, com quatro repetições. Os períodos anteriores à interferência (PAI) da cultura foram de 23, 27, 13 e 19 dias após emergência, e os períodos anteriores ao dano no rendimento econômico (PADRE), de 10, 9, 8 e 8 dias, para os tratamentos com espaçamento de 0,45 m e densidades de semeadura de 10 e 15 plantas m⁻¹ e para aqueles com espaçamento de 0,60 m e densidades de semeadura de 10 e 15 plantas m⁻¹, respectivamente, o que reduziu a produtividade de grãos em 63, 50, 42 e 57%, respectivamente, com a presença das plantas daninhas durante todo o ciclo do feijoeiro.

Palavras-chave: *Phaseolus vulgaris,* competição, PAI, PADRE.

INTRODUCTION

Beans are one of the most important crops in Brazil, which is the largest world producer, with 3.64 million tons (CONAB, 2012). However, this value can be reduced by the presence of some biotic factors, including those caused by the weeds that will interfere with growth, development, and plant productivity. This effect is called interference (Pitelli, 1985) and, in bean, can cause reductions of 15 to 80% in grain productivity (Salgado et al., 2007; Barroso et al., 2010; Parreira et al., 2011).

Studies about weed interference are aimed at determining the critical periods of interaction between culture and the weed community. For this, we created models, as the model K&S, proposed by Knak & Slife (1965) and adapted in Brazil by Blanco (1973) and Pitelli & Durigan (1984). This model defines weeds interferences in three periods; the period prior to weed interference (PPI), the total period of prevention of weed interference (TPPWI), and the critical period of weed interference prevention (CPWIP).

For Pitelli & Durigan (1984), the period prior to weed interference (PPI) is a period that starts with sowing or emergence, when the culture can live with the weed community without negative effects on crop productivity. The higher the period of coexistence is of crop and weeds competing for the environmental resources, the bigger the degree of the interference, thereby significantly damaging crop production (Pitelli, 1985). The duration of the competition between the species cultured and weeds can cause losses in growth, development and, consequently, of productivity (Karam & Cruz, 2004). This model has been used in recent decades to support the decision to perform weed management. However, these models present some difficulties, such as defining what level of loss of crop yield is acceptable (Vidal et al., 2005).

Therefore, these values cannot be fixed, but can vary according to the cost controlling weeds and the value of culture. To remedy these limitations, Vidal et al. (2005) proposed that the cost of control should be the criterion for defining the acceptable amount of damage in the crop, and the weed period prior to economic loss (WEEPPEL). The weed period prior to economic loss represents the days from germination or emergence that culture can live with the weed community without the occurrence of economic damage, considering the cost of herbicide application and the value of production.

This study aimed to compare the prior period to weed interference (PPI) and the weed period prior to economic loss (WEEPPEL) as well as the implication of different densities and spacings of beans in each one of them, for the producer to ensure a greater economic return in weed control.

MATERIAL AND METHODS

The experiment was conducted in the field, in a soil classified as a Dark Red Latossoil of clayey texture, with the chemical characteristics shown in Table 1. The culture system used was conventional, with one plowing and two harrowing.

The treatments consisted of eight periods of the culture of coexistence with the weeds: with 0 to 10, 0 to 20, 0 to 30, 0 to 40, 0 to 50, 0 to 60, 0 to 70, and 0 to 80 days and one control maintained without weeds. The coexistence periods were established at two spacings: 0.45 and 0.60 m; and two plant densities: 10 and 15 plants m^{-1}. Each plot was five meters. The bean seeds of the Carioca group, variety Rubi, were used. Were adopted the experimental design of randomized blocks with four replications.

The treatments were coded in 10-0.45 (10 plants m^{-1} and 0.45 m of spacing), 15-0.45 (15 plants m^{-1} and 0.45 m of spacing), 10-0.60 (10 plants m^{-1} and 0.60 m of spacing), and 15-0.60 (15 plants m^{-1} and 0.60 m of spacing) to facilitate the discussion of the results.

At the end of each coexistence period, the weeds present in two random sample areas of 0.25 m^{-2} were removed, identified, separated by species, counted, and dried for dry weight determination. After the expiration of the respective coexistence periods, the

Table 1 - Chemical characteristics in soil on the experiment. Jaboticabal-SP (2007)

pH	M.O.	P resina	K	Ca	Mg	H+ Al	SB	T	V
(CaCl$_2$)	(g dm^{-3})		(mmol dm^{-3})						(%)
5.4	25	6.3	2.7	33	13	31	48.7	79.7	61

experimental plots were kept weeded until the harvest. This was performed for evaluating the effect of weed interference. Density and dry weight data production were related to evaluating the effect of weed interference.

For the determination of the WEEPPEL, the proposal of Vidal et al. (2005) was followed, in which the loss of income tolerated in culture (CT) is equivalent to the weed control cost (CC). The cost of weed control is the same cost of the herbicide used (HC) in the area plus the cost of application (CA). The loss of income is found by the daily percentage loss (DL) multiplied by the grain price (GP) and then multiplied by the number of days of coexistence of the weeds after crop emergence (DC).

$$DC = WEEPPEL = (HC + CA)/(DL * GP).$$

The daily loss percentage is (DC) established by the liner regression, with the division of "b" (slop coefficient) by "a" (interception in the x axis).

To parameterize the model, the market values of 2010 were used. The weed control post-emergence per hectare resulted in a cost of R$ 125.80 (fluazifop-p-butyl + fomesafen), considering, besides the price of the herbicide (PH), the cost of application (CA), involving fixed and variable costs. The variation can be great, but the average price of R$ 5.10 per hectare sprayed was used (Lamego et al., 2002). The cost of weed control per hectare was, therefore, set at R$ 130.90 (herbicide price R$ 125.80 and application cost R$ 5.10). The crop yield was established in each experimental unit, always comparing with the control (maintained without weeds - free from coexistence throughout the experimental period). The value of the bean seed was fixed in R$ 1.34 kg^{-1} (CONAB, 2010), concerning the minimum price (R$ 80.00) in the region which the experiment was conducted (São Paulo). In the regression analysis, the software Statística was used.

RESULTS AND DISCUSSION

Among the populations found in the area, the highest densities were represented by *Cenchrus echinatus*, with 194 plants m^{-2} (10-0.45) at 40 days after emergence (DAE); *C. echinatus* with 174 plants m^{-2} (15-0.45) at 50 DAE; (*Arachis hypogea*), with 118 plants m^{-2} (10-0.60) at

50 DAE and *Raphanus raphanistrum* with 58 plants m^{-2} (15 0.60) at 20 DAE (Figure 1).

Based on the dry weight analysis of the three most frequent species in this experiment (Figure 2), it was found that up until 30 DAE, the weeds dry weight was almost insignificant. The greatest dry weight accumulation was observed 80 DAE to *R. raphanistrum* in this experiment, with the most representative species to dry weight among the three most common species found in the weed community (4.690, 4.497, 4.569, and 3.442 g m^{-2} to 10-0.45; 15-0.45; 10-0.60; and 15-0.60, respectively) (Figure 2). About the weeds dry weight values, the *R. raphanistrum* represents 94, 95, 88, and 95% of the total of dry weight from 10-0.45; 15-0.45; 10-0.60 and 15-0.60, in that order.

The bean production was reduced in 63, 50, 42, and 57% comparing the total production obtained in the treatment with weed control (1.293, 1.374, 1.484 and 1.771 kg ha^{-1}) and the production obtained in the presence of the weeds throughout the crop cycle (474, 680, 866 e 753 kg ha^{-1}), respectively, for 10-0.45; 15-0.45; 10-0.60 and 15-0.60 (Table 2).

Lunkes (1997) observed, in the bean crop, losses ranging from 15 to 97%, variable with the cultivar, the sowing date and the composition and density of weed community. However, when the culture was handled in accordance with technical recommendations for the bean crop, it was more competitive with some weeds. Paes et al. (1999) found reductions of 27 and 34% in the productivity of common beans (cultivars "Ouro" and "Ouro Negro", respectively). Fontes et al. (2001) measured a 73% reduction in bean productivity.

The PPI was extended until 23, 27, 13, and 19 DAE, respectively, for treatments 10-0.45; 15-0.45; 10-0.60 and 15-0.60 (Figure 3). For the two spacings between the lines, it was observed that the increase in the populations of plants resulted in the elevation of PPI, and this was 15 and 32%, respectively, for 0.45 and 0.60 m. It was also observed that, independent of the population, 0.60 m between the lines resulted in a lower PPI, since this treatment provided better conditions for the development of the weeds, that start earlier with the interference. Similar results were obtained by Parreira et al. (2011) on that the spacing of
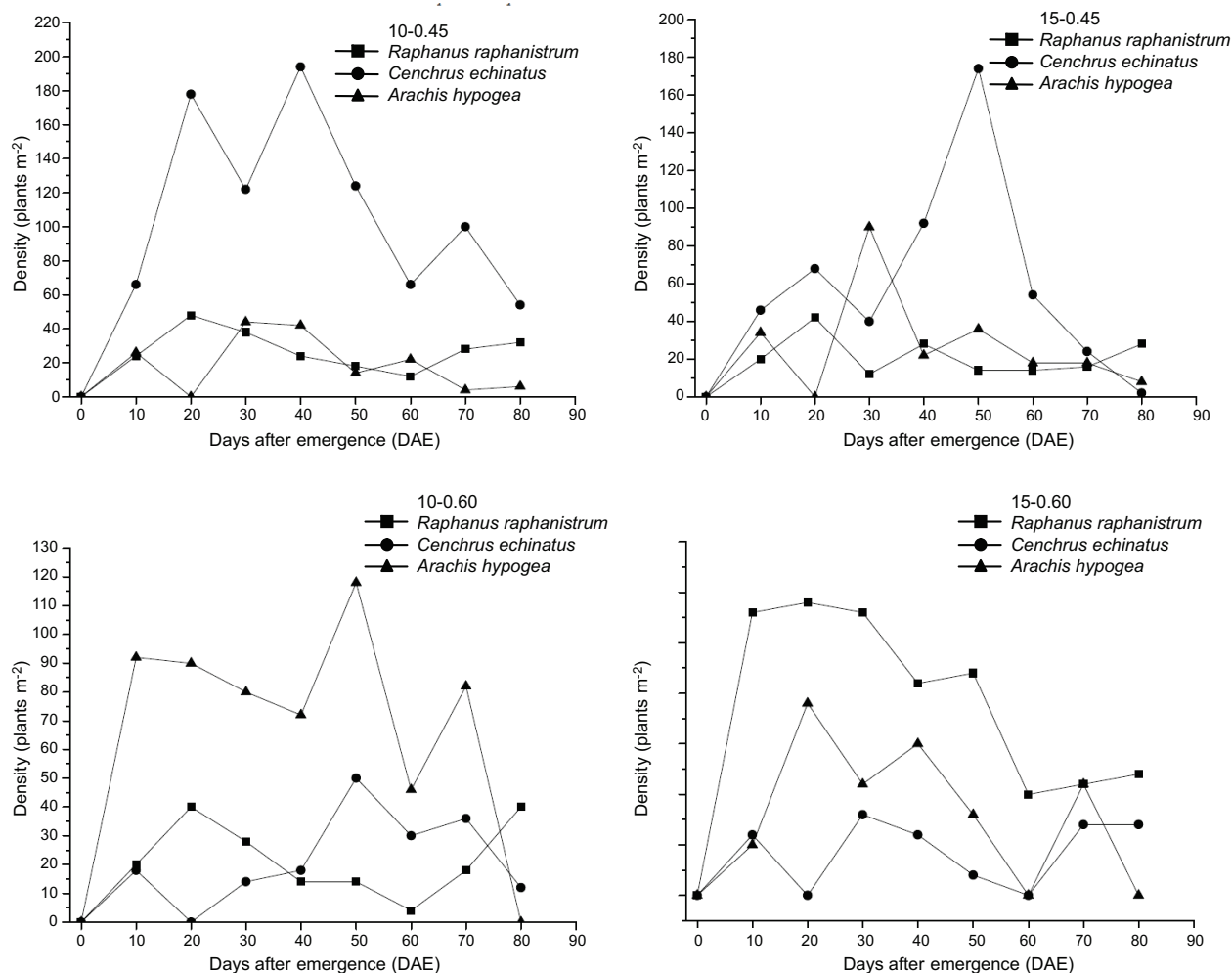
Figure 1 - Density of the main weeds (plants m⁻²) price of the herbicide was R$ 125.80 and the application cost was R$ 5.10, resulting in a cost control of R$ 130.90. on the experiment according the period of coexistence with bean: 10-0.45; 15-0.45; 10-0.60 and 15-0.60 Jaboticabal-SP (2007).

0.60 m had a lower PPI. For some authors, for the bean crop, the PPI was between the first and second weeks after sowing or emergence of the crop (Agundis et al., 1963; Rodriguez & Faiguenbaum, 1985; Chagas & Araújo, 1988).

The higher productivity of bean was obtained in the spacing 0.60 m and in the density of 15 plants m⁻¹ (15-0.60), when free from weeds infestation (1.771 kg ha⁻¹). The productivity had a linear increase with the increasing of the spacing and with the seeding density, even with a smaller population per hectare, and this increase was 6% when comparing 10-0.45 with 15-0.45; and was 16% to 10-0.60 compared with 15-0.60, thereby

suggesting a better use of available resources in the area. Researching the effect of spacing and population in the bean crop, Moura et al. (1977) found that the spacing affects the height of bean plants, while Cunha & Oliveira (1978) found no effect in the population density. However, the largest populations of plants had higher productions in that experiment. According to Teixeira et al. (2000) the increase in density planting reduced weed infestation.

The daily loss percentage in the production of bean crop, determined by linear regression, were established at 0.74%, 0.83%, 0.85%, and 0.67% to 10-0.45; 15-0.45; 10-0.60 and 15-0.60, respectively (Figures 4 and 5).
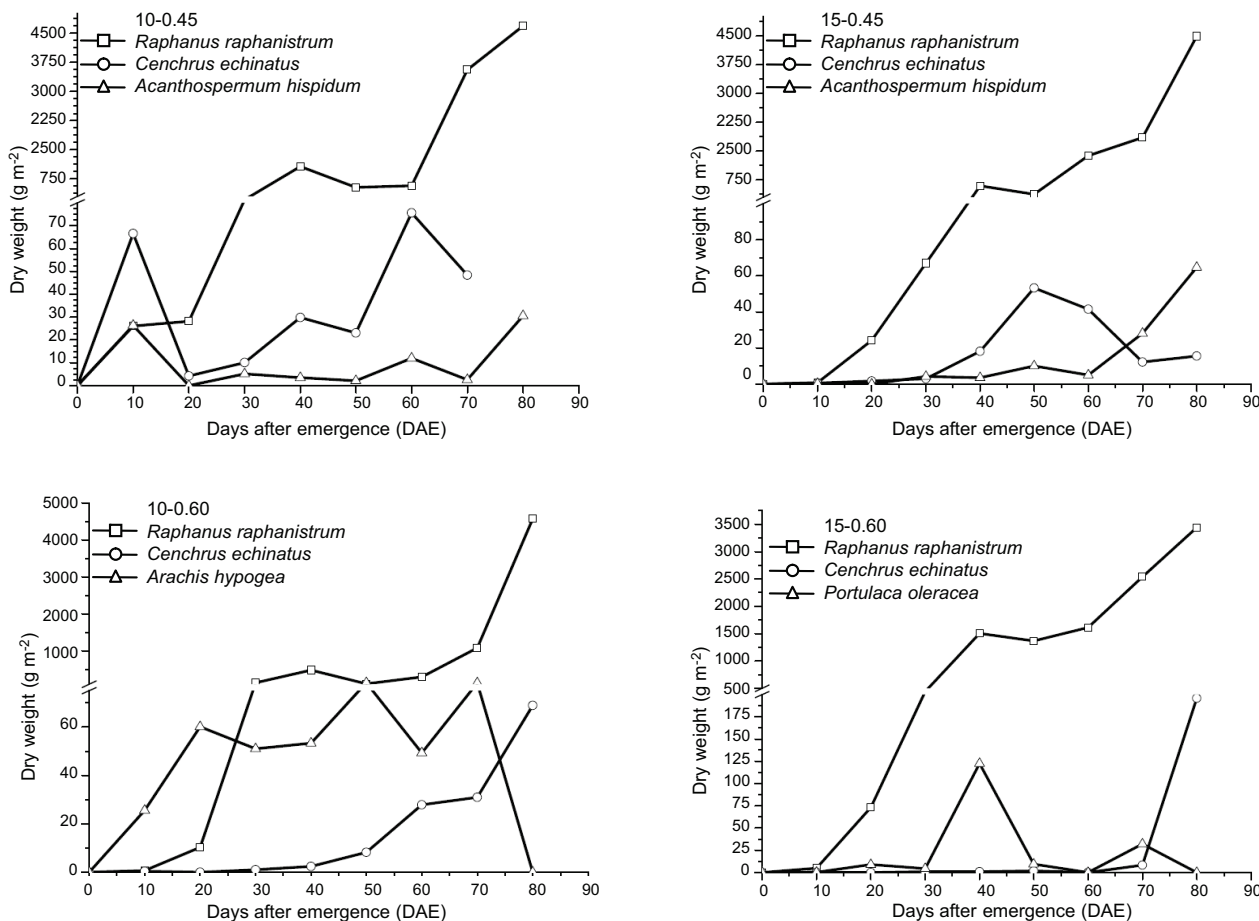
Figure 2 - Dry weight of the main weeds (g m⁻²) on the experiment according the period of coexistence with bean. 10-0.45; 15-0.45; 10-0.60 and 15-0.60. Jaboticabal-SP (2007).

Table 2 - Bean production with and without the interaction of weeds throughout the crop cycle, and reduction crop productivity, Jaboticabal-SP (2007)

Bean crop production	10 plantas m⁻¹ 0.45 m	15 plantas m⁻¹ 0.45 m	10 plantas m⁻¹ 0.60 m	15 plantas m⁻¹ 0.60 m
With interaction (kg ha⁻¹)	474	680	866	753
Without interaction (kg ha⁻¹)	1293	1374	1484	1771
Reduction (%)	63	50	42	57

The values of daily percentage loss of production were higher than the value obtained by Vidal et al. (2005). It can be explained by the methodology used, which considered the effect of the whole weed community. The more competitive the weed community was in relation to the crop, the greater the value of percentage daily loss. In the situation of a lower daily loss, the only weed that accumulated dry weight was the *C. echinatus*, but the *R. raphanistrum* and *Portulaca oleracea* had their development suppressed (Figure 2), thereby leading to the higher productivity of the bean crop.
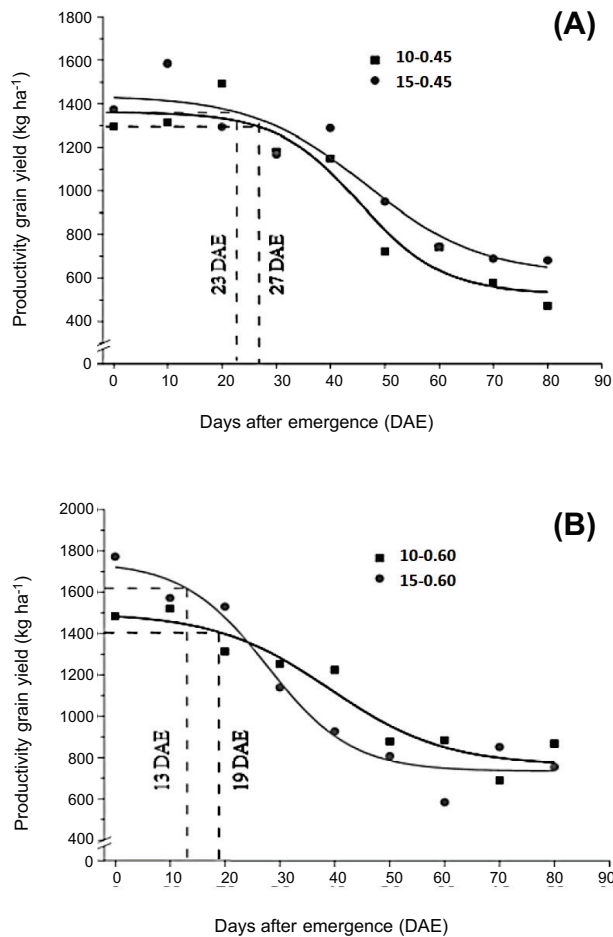
Figure 3 - Grain yield of bean (kg ha⁻¹), 10-0.45 e 15-0.45 (A) e 10-0.60 and 15-0.60 (B), in response to periods of coexistence with weeds, considering the loss of productivity. Jaboticabal-SP (2007).

PPI. Differently of the WEEPPEL, the increase of density in the spacing of 0.45 m had no significant results, as well as the spacing of 0.60 m (1 and 0 days, respectively). In the density of 10 plants per linear meter, the increase of the spacing led to a decrease in the WEEPPEL in 2 days, indicating a need for early control. In a density of 15 plants m⁻¹, changes made to the spacing do not result in changes of the WEEPPEL.

A higher yield resulted in a lower WEEPPEL, because the lower the lost production, the
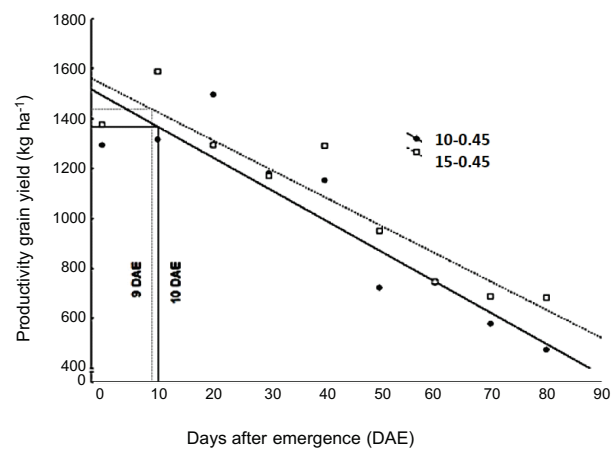

Figure 4 - Grain yield of bean (kg ha⁻¹), 10-0.45 and 15-0.45 in response to periods of coexistence with the weeds, and the weed period prior to economic loss (WEEPPEL) representation. Jaboticabal-SP (2007).
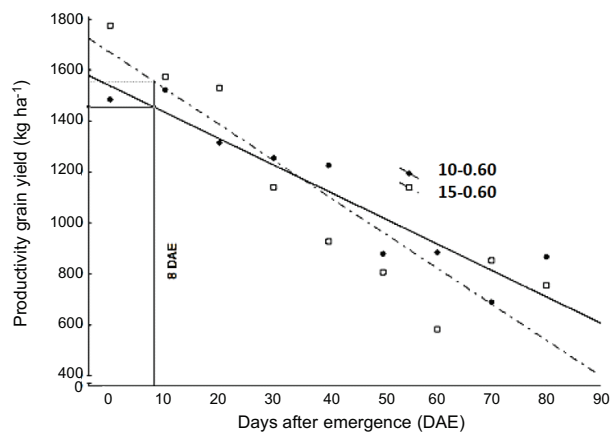
As mentioned above, the increase of planting density and the reducing of spacing between the lines provide a reduction in weed interference. However, the treatment 10-0.45 and 15-0.60 suffered a greater per cent daily loss. This fact can be explained by a probable intraspecific competition suffered by the bean. According to Stone & Silveira (2008), the population limit to a higher production of beans was set at 240,000 plants ha⁻¹, whereas on a treatment of 10-0.45 the density was 333,333 plants ha⁻¹.

The previous periods to economic damage were seen at 10, 9, 8, and 8 days to 10-0.45; 15-0.45; 10-0.60, and 15-0.60, respectively. In all situations, the WEEPPEL was less to the

Figure 5 - Grain yield of bean (kg ha⁻¹), 10-0.60 and 15-0.60 in response to periods of coexistence with the weeds – linear regression. Jaboticabal-SP (2007).

greater the return on the sale of grain is, and the higher production achieved between treatments in 15-0.60, leading to a WEEPPEL of 8 days.

For a WEEPPEL to 10 days, with a spacing of 0.45 m and density of 10 plants m[1], the loss of production would be 121.45 kg and 98.29 kg to a density of 15 plants m[-1]. In other words, considering the costs, the acceptable losses would be 8.14 and 6.39% of the maximum production obtained in the witness. The loss of production adopting a WEEPPEL with 8 days, to a spacing of 0.60 m would be 86.39 kg and 117.05 kg, for 10 and 15 plants per meter, respectively, representing 5.62 and 7.02% of the maximum production obtained in the control free of weeds. With this, adopting a fixed loss, as in the PPI, for example, 5% is not ideal in all conditions.

Considering the price of the bean R$ 1.34 kg^{-1}, the acceptable losses adopting the WEEPPEL, amounted to a loss of R$ 87.00; R$ 92.00; R$ 99.00 and R$ 119.00 ha^{-1}, to 10-0.45; 15-0.45; 10-0.60 and 15-0.60, respectively. If the producer adopts the WEEPPEL, in each case, it would return R$ 164.00, R$ 275.00, R$ 84.00 and R$ 175.00 ha^{-1} in the above order and, in most of the cases, the price of a new application in post-emergence (R$ 139.90).

Under the conditions and time of the experiment was carried out, the bean crop lived with the weeds *Acanthospermum hispidum, A. hypogaea, C. echinatus, P. oleracea* and *R. raphanistrum* for 27, 23, 19, and 13 days after crop emergence to the PPI model and up to 10, 9, 8, and 8 days for the WEEPPEL model in population densities of 10, 15, 10, and 15 plants m[-1], in the spacing between the lines of 0.45, 0.45, 0.60, and 0.60, respectively.

Comparing the model WEEPPEL with the model PPI, it appears that the use of economic information in the model of interference is very important, as it ensures a higher return for producers.

LITERATURE CITED

AGUNDIS, O. et al. Periodos críticos de competencia entre frijol y malezas. **Agric. Técnica México**, v. 2, n. 1, p. 87-90, 1962/1963.

BLANCO, H. G. et al. Observações sobre o período em que as plantas daninhas competem com a soja (*Glycine max* L. Merr.). **O Biológico**, v. 39, n. 2, p. 31-35, 1973.

BARROSO, A. A. M. et al. Efeito da espécie, da cultivar e das condições climáticas nas relações de interferência entre as plantas daninhas e o feijoeiro. **Bragantia**, v. 69, n. 3, p. 609-616, 2010.

CHAGAS, J. M.; ARAÚJO, G. A. A. Feijão. **Inf. Agropec.**, v. 13, n. 152, p. 46-48, 1988.

COMPANHIA NACIONAL DE ABASTECIMENTO – CONAB. **Conj. Agropec.** Disponível em: <www.conba.gob.br/OlalaCMC/uploads/arquivos/a41e31ef08d7970f89 f5d00dadc3c4ef.pdf>. Acesso em: 22 fev. 2010.

COMPANHIA NACIONAL DE ABASTECIMENTO – CONAB. **Acompanhamento da safra brasileira de grãos, safra 2010/2011.** Disponível em: < http://www.conab.gov.br/OlalaCMS/uploads/arquivos/11_01_06_08_41_56_boletim_graos_4o_ lev_safra_2010_2011..pdf> Acesso em: 23 mar. 2012.

CUNHA, J. M.; OLIVEIRA, A. F. F. Estudo sobre fertilidade e densidade de semeio de feijão. In: EPAMIG. **Projeto feijão:** Relatório 73/75. Belo Horizonte: 1978. p. 18-20.

FONTES, J. R. A. et al. Efeitos de herbicidas no controle de plantas daninhas na cultura do feijão-mungo-verde (*Vigna radiata* L. Wilczek). **Ci. Agrotecnol.**, v. 25, n. 5, p. 1087-1096, 2001.

KNAK, E. L.; SLIFE, F. W. Giant foxtail seeded at various times in corn and soybeans. **Weeds**, v. 13, n. 4, p. 331-334, 1965.

KARAM, D.; CRUZ, M.B. Características do herbicida foamsulfuron + iodosulfuronmethyl- sodium na cultura do milho. Sete Lagoas: Embrapa Milho e Sorgo, 2004. 4 p. (Embrapa Milho e Sorgo.Circular Técnica, 58).

LAMEGO, F. P. et al. Resistência de *Brachiaria plantaginea* aos herbicidas inibidores de ACCase. **R. Bras. Herbic.**, v. 3, n. 1, p. 162-168, 2002.

LUNKES, J. A. Manejo integrado de plantas daninhas na cultura do feijão. In: FANCELLI, A. L.; DOURADO-NETO, D. **Tecnologia da produção do feijão irrigado.** Piracicaba: ESALQ/USP, 1997. p. 9-19.

MOURA, R. L. et al. Efeitos da adubação nitrogenada, do espaçamento e densidade de semeadura sobre o rendimento do feijão. In: REUNIÃO TÉCNICA ANUAL DO FEIJÃO, 14., 1977, Porto Alegre. **Ata...** Porto Alegre: IPAGRO, 1977. p. 79-86.

PAES, J. M. V. et al. Capina e adubação nitrogenada em cobertura realizada em diferentes estádios de desenvolvimento do feijoeiro, cultivo de "inverno". **Ci. Rural**, v. 29, n. 2, p. 239-245, 1999.

PARREIRA, M. C. et al. Influencia de las malezas sobre el cultivo de frijol en función de espaciamiento y de la densidad de plantas. **Planta Daninha**, v. 29, n. 4, p761-769, 2011.

PITELLI, R. A. Interferências de plantas daninhas em culturas agrícolas. **Inf. Agropec.**, v. 11, n. 129, p. 16-27, 1985.

PITELLI, R. A.; DURIGAN, J. C. Terminologia para períodos de controle e de convivência de plantas daninhas em culturas anuais e bianuais. In: CONGRESSO BRASILEIRO DE HERBICIDAS E PLANTAS DANINHAS, 15., 1984, Belo Horizonte. **Anais...** Piracicaba: SBHED, 1984. p. 37.

RODRIGUEZ, M. M. A.; FAIGUENBAUM, H. Capacidad competitiva de frijol (*Phaseolus vulgaris* L.), maravilha (*Heliothis annuus*) y papa (*Solanum tuberosum*) frente a lãs malezas y periodo crítico de competencia. **Simiente**, v. 55, n. 1/2, p. 40, 1985.

SALGADO, T. P. et al. Interferência das plantas daninhas no feijoeiro carioca. **Planta Daninha**, v. 25, n. 3, p. 443-448, 2007.

STONE, L. F.; SILVEIRA, P. M. Limites de competição dos componentes da produtividade de grãos da cultivar de feijoeiro-comum cv. Pérola. **Biosci. J.**, v. 24, n. 1, p. 83-88, 2008.

TEIXEIRA, I. R. et al. Resposta do feijoeiro (*Phaseolus vulgaris* L. cv. Pérola) a diferentes densidades de semeadura e doses de nitrogênio. **Ci. Agrotecnol.**, v. 24, n. 2, p. 399-408, 2000.

VIDAL, R. A. et al. Período anterior ao dano na renda econômica (PADRE): Uma nova abordagem aos períodos de convivência entre plantas daninhas e cultivadas. **Planta Daninha**, v. 23, n. 3, p. 387-396, 2005.