PLANTA DANINHA

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS

<http://www.sbcpd.org>

ISSN 0100-8358 (print)
1806-9681 (online)

Article

Relative Competitiveness of Common Bean Cultivars in Coexistence with Volunteer Corn

Competitividade Relativa de Cultivares de Feijão-Comum em Convivência com Milho Voluntário

AGUIAR, A.C.M.[1]*
BASSO, C.J.[2]
SILVA, D.R.O.[2]
GHELLER, D.P.[2]
NOVELLO, B.D.[2]
RIEDER, E.[2]

ABSTRACT - This study evaluated the relative competitiveness of two common bean cultivars in coexistence with volunteer corn emerging at different times in different proportions of plants in the association. Firstly, for both beans and volunteer corn, the plant population was determined in which the final production of dry biomass becomes constant (24 plants pot^{-1}). A completely randomized experiment design, with five replicates, was carried out in a 2×2×5 factorial scheme, involving two common bean cultivars (IPR Gralha and Fepagro Triunfo), two emergence times of volunteer corn plants (-7 and 0 days in relation to beans) and five proportions of plants in the association (100:0, 75:25, 50:50, 25:75 and 0:100). At 35 days after bean emergence, measurements of plant height, leaf area and dry biomass of the aerial part of both species were measured. The competitiveness analysis was evaluated through diagrams applied to substitutive experiments and the use of relative competitiveness indices. The height of bean cultivars is reduced when volunteer corn emerges at the highest proportions and in advance. Early emergence of volunteer corn reduces leaf area from both bean cultivars while simultaneous emergence only reduces the leaf area of Triunfo. The dry matter biomass is lowered, due to the competition of the corn emerged before the bean, and the cultivar Gralha is more tolerant. In this way, the importance of the bean sowing in an area free from infestation of volunteer corn plants is verified.

Keywords: *Phaseolus vulgaris*, *Zea mays*, volunteer plants, competition, emergence periods, replacement series.

RESUMO - Objetivou-se com este estudo avaliar a competitividade relativa de dois cultivares de feijão-comum em convivência com milho voluntário emergindo em diferentes épocas, em diferentes proporções de plantas na associação. Primeiramente, tanto para o feijão como para o milho voluntário, determinou-se a população de plantas em que a produção final de biomassa seca se torna constante (24 plantas vaso^{-1}). Posteriormente, instalou-se um experimento em esquema fatorial 2x2x5, envolvendo dois cultivares de feijão-comum (IPR Gralha e Fepagro Triunfo), duas épocas de emergência das plantas de milho voluntário (-7 e 0 dias em relação ao feijão) e cinco proporções de plantas na associação (100:0, 75:25, 50:50, 25:75 e 0:100), em delineamento inteiramente casualizado com cinco repetições. Aos 35 dias após a emergência do feijão, aferiram-se as medições de altura de planta, área foliar e biomassa seca da parte aérea de ambas as espécies. A análise da competitividade foi efetuada por meio de diagramas aplicados a experimentos substitutivos e uso de índices de competitividade relativa. A estatura das cultivares de feijão é reduzida quando o milho voluntário emerge nas maiores proporções e antecipadamente. A emergência antecipada do milho voluntário

*** Corresponding author:**
<adalin-cezar@hotmail.com>

Received: June 30, 2017
Approved: December 9, 2017

Planta Daninha 2019; v37:e019182106

[1]Universidade Federal de Viçosa (UFV), Viçosa-MG, Brasil; [2] Universidade Federal de Santa Maria, (UFSM-FW), Frederico Westphalen-RS, Brasil.

Doi: 10.1590/S0100-83582019370100097

reduz a área foliar de ambas cultivares de feijão, enquanto que a emergência simultânea reduz somente para área foliar da cultivar Triunfo. A biomassa da matéria seca é reduzida em função da competição do milho emergido antes do feijão, sendo que a cultivar Gralha é mais tolerante. Desta forma, verifica-se a importância da semeadura do feijão em área livre de infestação de plantas de milho voluntário.

Palavras-chave: *Phaseolus vulgaris, Zea mays,* plantas voluntárias, competição, épocas de emergência, série de substituição.

INTRODUCTION

Common bean (*Phaseolus vulgaris*) crop is an option for off-season production, to be adopted in corn succession. In the southern region of Brazil, the bean off-season comprises a cultivated area of 284 thousand hectares (Conab, 2017). As a result of this succession, the corn seeds/kernels remaining in the post-harvest field germinate during bean cultivation, and volunteer corn may become a problematic weed, under these conditions (Deen et al., 2006; Marquardt et al., 2012; Alms et al., 2016; Sbatella et al., 2016).

Although there are reports of volunteer corn competition in various crops, such as soybean *(Glycine max* (L.) Merr.), corn (*Zea mays*), beetroot (*Beta vulgaris* L.) and cotton (*Gossypium hirsutum* L.) (Thomas et al., 2007; Kniss et al., 2012; Marquardt et al., 2012; Alms et al., 2016), information on the effects of volunteer corn on bean culture is still scarce.

Since corn grains can emerge throughout the bean-growing season, and the time of emergence can considerably affect the competitive ability of the species, weeds that emerge after crops generally have a lower impact on yield because much of the interference occurs after the definition of yield components (Vandevender et al., 1997). On the contrary, weeds with early emergence show improved growth, by acquiring access to environmental resources, increasing their competitive advantage (Agostinetto et al., 2004).

The duration of the plant cycle is another factor that may be directly related to the ability of each cultivar to tolerate competition imposed by weeds (Carvalho et al., 2011). Studies have shown that cultivars of higher height and late cycle have higher competitive ability than those of early and low cycle (Bennett and Shaw, 2000). It is assumed that late-maturing cultivars produce an increased amount of biomass, which may be indicative of plants that cause greater shading (Lamego et al., 2004).

There are several methods to investigate the competitive relationships between plants, among which, the substitutive experiments (replacement series) can be highlighted. Proposed by Radosevich (1987), this method assumes that the total plant density is kept constant while the proportions of the mixture of the two species are variable. The model is important in evaluating the effects of inter-species competition on a single total density and determining the relative effects of interference within and between species to indicate which one is most competitive.

In experiments conducted in substitutive series, crops generally demonstrate greater competitiveness than weeds. However, when working with two crops where one of them acts as a volunteer plant, the competitive ability of the cultivated plant may be more severely affected.

The present study hypothesized that the use of bean cultivars of long rather than short maturation cycles presents greater potential to compete with volunteer corn. Volunteer corn has more competitive potential than beans, occurring in similar proportions. Volunteer corn presents higher competitiveness when it is established in advance of beans. Thus, the relative competitiveness of two common bean cultivars with volunteer corn at different time emergence and plant proportions was evaluated.

MATERIAL AND METHODS

Two greenhouse experiments were conducted during September 2016 to January 2017, in Department of Agronomic and Environmental Sciences of the Federal University of Santa Maria - UFSM, Campus of Frederico Westphalen-RS, Brazil. The experimental units were composed of

8-L plastic pots measuring 23 cm in diameter, filled with soil classified as typical Latossolo Vermelho Aluminoférric. The chemical characteristics of the soil used were pH = 5.1; Organic matter of soil = 1.0%; P = 3.0 mg dm^{-3}; K^{+} = 42.5 mg dm^{-3}; Al^{3+} = 1.6 cmolc dm^{-3}; Ca^{2+} = 1.5 cmolc dm^{-3}; Mg^{2+} = 0.7 cmolc dm^{-3}; CTC (cation exchange capacity) = 7.4 cmolc dm^{-3}; H+Al = 5.1 cmolc dm^{-3}; SB (base saturation) = 31.2 cmolc dm^{-3}, and clay = 61%, being previously corrected and fertilized.

The first experiment consisted of volunteer bean and corn monocultures, to determine the plant population to be established per pot, based on the constant final yield law (Radosevich et al., 2007). The experimental design was completely randomized with five replicates. In this experiment, the bean (IPR Gralha) and volunteer corn (F2 grains of the hybrid DKB 240) were seeded in the plant populations of 2, 4, 8, 16, 24, 32 and 64 plants pot^{-1} (equivalent to 40, 80, 160, 320, 480, 640 and 1,280 plants m^{-2}) for both species.

At 35 days after emergence (DAE), the shoots were collected to determine the dry matter biomass (dmb). The plants were packed in paper bags and oven-dried at 60 °C until constant weight, and the samples were then weighed. The constant final productivity of bean and volunteer corn plants was 32 and 16 plants, respectively, using the mean population of 24 plants per pot (equivalent to 480 plants m^{-2}).

The second experiment was conducted on a replacement series model. The experimental design was a completely randomized design, with five replications, in a 2×2×5 factorial scheme, involving two common bean cultivars (cv. IPR Gralha (hereafter referred to as cv. Gralha) and cv. Fepagro Triunfo (hereafter referred to as cv. Triunfo)); two volunteer corn emergence time: 7 days before the bean (-7 d) and simultaneously (0 d); in addition to five proportions of plants in the association between bean and corn (75:25, 75:25, 50:50, 25:75 and 0:100 (corn monoculture)). To simulate the volunteer corn, F2 grains of the hybrid DKB 240 were used.

Cultivar Gralha has characteristics of indeterminate growth type II, standing erect, a growth cycle maturity of 93 days, with tolerance to drought and high temperature during the reproductive phase; and stands out for its rusticity, showing resistance to the main diseases. Cultivar Triunfo presents an indeterminate growth habit type II, stands erect, has a growth cycle maturity of 75 days, lodging resistance and good tolerance to diseases.

At 35 DAE, the height of plants (HP), leaf area (LA) and the dry matter biomass (DMB) were evaluated. The bean and volunteer corn HP were measured as the distance from the ground to the tip of the topmost fully-expanded leaf. For the determination of LA (cm^2 per plant), the disc method was used, whereby 30 discs from each sample, in four positions of the leaf limb of a set of leaves (Gomide et al., 1977), were obtained using a puncher with an area of 1.76 cm^2. The discs and leaves were packed in paper bags and oven-dried at 60 °C until constant weight.

The LA (cm^2 per plant) was determined according to the equation:

$$AF = (\text{n discs}^{*}\text{drilling area})^{*}\frac{(\text{Dry weight leaf + discs})}{\text{Dry weight disc}} \quad \text{(eq. 1)}$$

where *n* discs = number of discs per sample; drilling area = area of disk drilling (mm^2); LDW = total leaf dry weight (g); and DDW = disc dry weight (g).

The DMB (g per plant) was determined as described in experiment one. From this, the samples were weighed and the weight added to that of the leaves and discs that had been used to determine the LA.

Regarding the HP, LA and DMB variables of the bean and volunteer corn, the graphical analysis of the relative productivity (RP) method was used (Radosevich, 1987), in which a diagram was constructed, based on RP and total relative productivity (TRP) in plant proportions of 0, 25, 50, 75 and 100%.

The values of *RP*, *TRP*, relative competitiveness index (CI), relative grouping coefficients (*K*) and aggressiveness (*A*) were performed, according to Bianchi et al. (2006). The HP, LA and DMB measurements of the volunteer bean and corn plants were expressed as mean values per plant. The data were tested for normality by the Lilliefors test, and no processing required. Analysis of variance was performed using the F test ($p<0.05$), and the significant differences between bean

cultivars with emergence times of the volunteer corn were compared by the *t*-test ($p<0.05$). The mean plant proportions were examined by the Dunnett test ($p<0.05$), with monocultures considered as controls.

RESULTS AND DISCUSSION

The graphical analysis of HP, referring to the combinations of bean cultivars and volunteer corn emerging at both times, showed values of RP expected near the hypothetical lines, revealing that the two cultivars responded similarly to the competition with the volunteer corn (Figure 1; Table 1).

For significance, at least two plant proportions must differ significantly (Bianchi et al., 2006). Only HP of cv. Triunfo showed alteration in at least two plant proportions (75:25 and 25:75) when volunteer corn emerged 7 days before the bean (Figure 1C; Table 1). At the highest proportion of the bean (75:25), there was an increase in the bean HP (convex line Figure 1C), whereas, for the inverse proportion (25:75), the bean HP tended to decrease (concave line, Figure 1).

There was no modification in the HP of both species when the corn and bean emerged simultaneously. In contrast, in early emergence of volunteer corn at 75:25 proportion, the bean was about 8% higher than the control in the absence of volunteer corn (Table 2). This increase possibly occurred in response to escape the shadow, that is, the change in the quality of light. Under these conditions, there is an increase in auxin biosynthesis, which is transported to the epidermis and is responsible for the control of cell elongation. Auxins also interact with

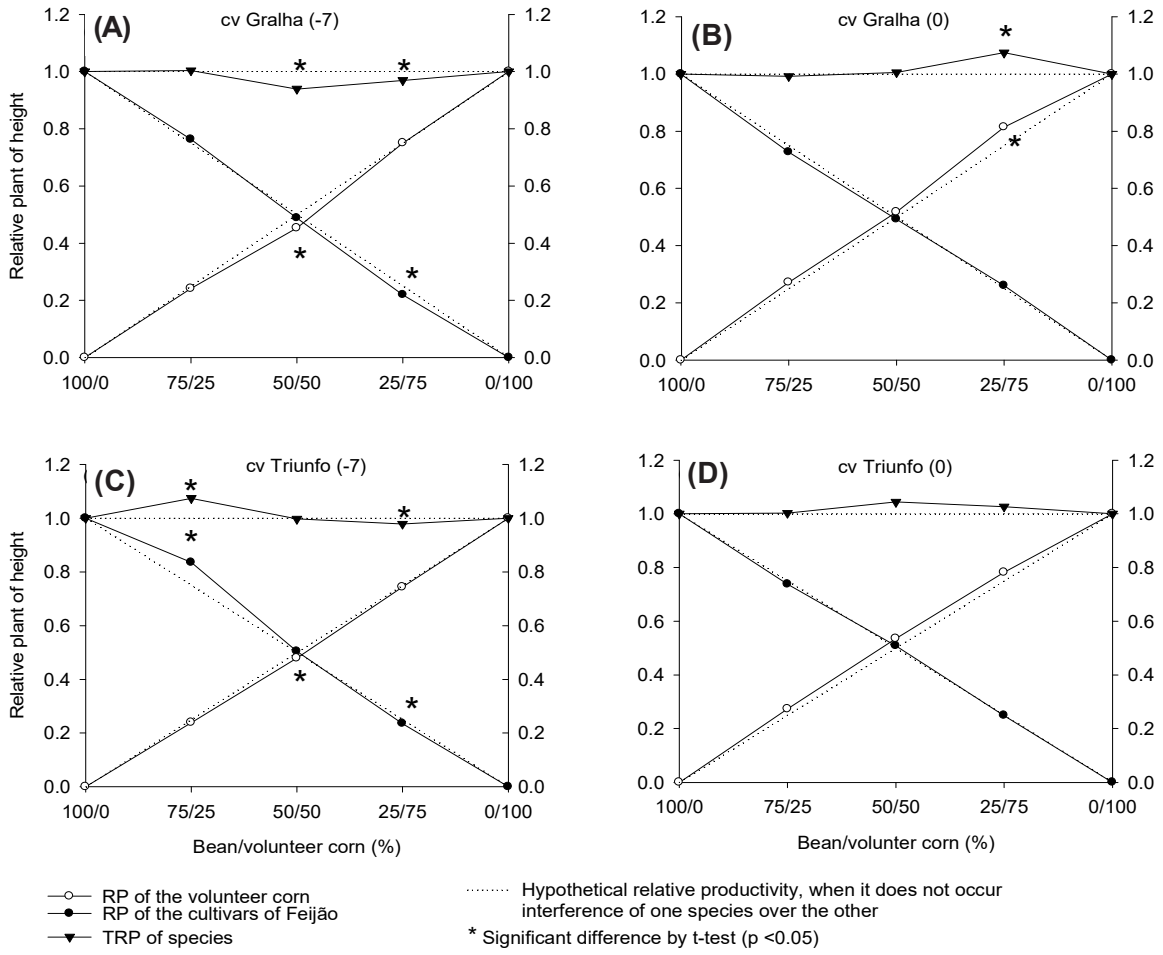

Figure 1 - Relative productivity (RP) diagram of the plant height of the cultivars IPR Gralha (A; B) and Fepagro Triunfo (C; D) and volunteer corn at two weed emergence times, -7 DAE (A), (C) and 0 DAE (B; D), as a function of the variation of the proportion of plants between the two species.

Table 1 - Differences of relative productivity (DRP) and total relative productivity (TRP) of the variables plant height, leaf area and dry matter biomass of two bean cultivars and the volunteer corn competitor, emerging seven days before (-7) and simultaneously (0) in relation to culture, at 35 days after emergence

Cultivar/Emergency season	Proportion of plant (bean: volunteer corn)		
	75/25	50/50	25/75
	Planto f height		
DRP Gralha	0.01(0.03) ns	-0.01(0.02) ns	-0.03(0.02)*
DRP Corn -7	-0.02(0.02) ns	-0.09(0.04)*	0.02(0.04) ns
TRP	1.01(0.05) ns	-0.12(0.05)*	-0.09(0.03)*
DRP Gralha	-0.02 (0.02) ns	-0.01(0.03) ns	-0.01(0.01) ns
DRP Corn 0	0.06(0.02) ns	0.03(0.03) ns	0.10(0.02)*
TRP	1.01(0.02) ns	1.04 (0.05) ns	1.13 (0.01)*
DRP Triunfo	0.09(0.04)*	0.00(0.03) ns	-0.01(0.00)*
DRP Corn -7	-0.02(0.02) ns	-0.05(0.02)*	-0.03(0.03) ns
TRP	1.12(0.04)*	0.99(0.04) ns	0.96(0.03)*
DRP Triunfo	-0.01(0.03) ns	-0.01(0.02) ns	0.00(0.02) ns
DRP Corn 0	0.02(0.02) ns	0.02(0.03) ns	0.06(0.04) ns
TRP	1.01(0.03) ns	1.08(0.03) ns	1.06(0.05) ns
	Leaf area		
DRP Gralha	-0.07(0.11) ns	-0.09(0.11)*	-0.04(0.02)*
DRP Corn -7	0.09(0.05)*	0.01(0.08) ns	-0.08(0.05)*
TRP	1.02(0.12) ns	0.92(0.07) *	0.88(0.04)*
DRP Gralha	-0.10(0.04)*	0.05(0.10) ns	0.05(0.03) ns
DRP Corn 0	0.05(0.04) ns	-0.10(0.04)*	-0.07(0.09) ns
TRP	0.95(0.03) ns	0.95(0.07) ns	0.99(0.08) ns
DRP Triunfo	-0.09(0.12) ns	-0.08(0.08)*	-0.12(0.02)*
DRP Corn -7	-0.01(0.02) ns	0.00(0.09) ns	0.04(0.08) ns
TRP	0.90(0.06)*	0.92(0.06)*	0.91(0.07)*
DRP Triunfo	-0.12(0.06)*	-0.04(0.04) ns	-0.03(0.00)*
DRP Corn 0	-0.04(0.01)*	-0.04(0.07) ns	-0.03(0.12) ns
TRP	0.84(0.07)*	0.92(0.09) ns	0.94(0.12) ns
	Dry matter biomass		
DRP Gralha	-0.05(0.01)*	-0.08(0.04)*	-0.18(0.03)*
DRP Corn -7	-0.02(0.04) ns	0.00(0.03) ns	0.03(0.04) ns
TRP	0.93(0.04)	0.92(0.04)*	0.85(0.07)*
DRP Gralha	0.02(0.02) ns	-0.02(0.03) ns	-0.14(0.08)*
DRP Corn 0	0.00(0.09) ns	0.03(0.06) ns	0.03(0.08) ns
TRP	1.02(0.09) ns	1.01(0.08) ns	0.89(0.07)*
DRP Triunfo	-0.08(0.02)*	-0.08(0.04)*	-0.17(0.05)*
DRP Corn -7	0.05(0.05) ns	0.01(0.06) ns	0.03(0.07) ns
TRP	0.96(0.04) *	0.93(0.07)*	0.92(0.07)*
DRP Triunfo	-0.02(0.01) ns	-0.04(0.04) ns	-0.04(0.05) ns
DRP Corn 0	0.19(0.05)*	0.04(0.06) ns	0.03(0.04) ns
TRP	1.17(0.10)*	1.00(0.09) ns	0.99(0.06) ns

* and ns significant and non-significant by the t-test ($p < 0.05$); Values in parentheses represent the standard error of the mean. DPR = differences in relative productivity; PRT = total relative productivity.

Table 2 - Plant of height (cm) of bean cultivars in different proportions of plants and volunteer corn emergence season

Season(1)	Proportion of plant (bean: volunteer corn)			
	100/0(T)	75/25	50/50	25/75
-7	42.0 a	44.9 b *	42.1 a ns	38.4 b *
0	42.0 a	41.5 a ns	42.5 a ns	41.5 a ns

* and ns significant and not significant by Dunnett's test ($p < 0.05$). Lower case letters compare time within each proportion of plants by the t-test ($p < 0.05$). (1) -7 indicates emergence of corn seven days before the bean, and 0 indicates simultaneous emergence of corn and beans.

brassinosteroids, which are potent growth stimulants, and, even under these conditions, ethylene production still occurs. These hormones are responsible for plant elongation in the shadow escape response (Ruberti et al., 2012).

This increase may also represent an adaptation to future competition with neighboring plants, due to the decrease in the quality of light. The plant expresses the result of the alteration through the physiological processes related to hormonal dynamics and cell division, and may also reduce its ability to absorb nutrients and water and to perform photosynthesis (Jensen et al., 1998).

The increase in volunteer corn proportion (25:75) reduced the bean HP compared with the simultaneous emergence. This lowered growth suggests that competition for soil resources occurred at enhanced intensities, as reported by Fleck et al. (2006), in studying soybeans in competition with *Raphanus sativus*. Similar results were observed in the competition between soybean and *Echinochloa* sp (Bastiani et al., 2016) and in rice cultivation between red rice and *Urochloa plantaginea* (Galon et al., 2014).

The TRP of the HP was lower than one (hypothetical line) for cv. Gralha when volunteer corn emerged early in the 75:25 and 50:50 proportions, indicating that there was competition for the same environmental resources (Figure 1A, B). For TRP at the 75:25 ratio, a convex line was noted, which implies that synergic growth occurred, mainly by cv. Triunfo. In contrast, for the inverse corn:bean proportion (25:75), the TRP reduced, which is represented by the concave line (Figure 1C, D; Table 1). It can be considered that generally, in simultaneous emergence, the effects of one species on the other were barely visible. It is probable that the lower interference on HP is associated with the strategy to capture more light, which leads to the formation of elongated shoots and less energy investment for leaf development (Galon et al., 2011).

The RP of the LA of Triunfo that emerged simultaneously with volunteer corn was represented by a concave line and reduced at 75:25 and 25:75 (Figure 2B, Table 1). In comparison, when the volunteer corn plants emerged 7 days earlier, the LA reduction of both cultivars was higher, with the RP of the bean represented by a concave line in the 50:50 and 25:75 ratios. It is worth noting that the RP of the volunteer corn was not affected by the competition with the bean since they present a greater competitive capacity because of the more efficient use of the environmental resources, regardless of the emergence time.

The LA reduction is related to the morphology of the corn, which reaches higher PH and establishes a canopy above the bean. In this case, the competition for light leads to a reduction in LA (Page et al., 2010), besides being related to the C4 cycle of carbon assimilation. Competition for light is an important factor in triggering morphological changes in response to competition between plants (Page et al., 2010). Thus, both the quality and quantity of light are related to the first environmental resource that modifies competitive relations (Afifi and Swanton, 2012). Similar characteristics to these are noticed in volunteer corn in competition with crops (Deen et al., 2006; Marquardt et al., 2012; Alms et al., 2016; Sbatella et al., 2016).

Cultivar Gralha produced a lower LA (-17%) when compared with cv. Triunfo, at the 75:25 ratio, in the treatments with co-emergence (Table 3). However, when volunteer corn emerged 7 days earlier, for the corn:bean proportion of 25:75, cv. Gralha produced about 50% higher LA than cv. Triunfo, indicating a higher tolerance capacity in the presence of volunteer corn. This result may be related to the difference in the characteristics of the cultivars used in the study since, although both present an indeterminate type II growth habit, cv. Gralha has a longer cycle than cv. Triunfo. It has been found that for soybeans, in some environments, long-cycle cultivars are more competitive than their short-cycle counterparts (Nordby et al., 2007).

Regarding the TRP, there was a change in the values for the LA variable in most treatments, with mean values lower than one (Figure 2). This effect was not seen in the simulations of the cultivars when the emergence coincided (Figure 2B, D), but in the early emergence of the volunteer corn, there were reductions in LA values, represented by the concave line, with significance in at least two proportions (Figure 2A, C). It indicates that there was competition for the same environmental resources, and, for the plants grown in the area at the same proportion, occurring antagonism between species transpired when there was an early emergence of volunteer corn.

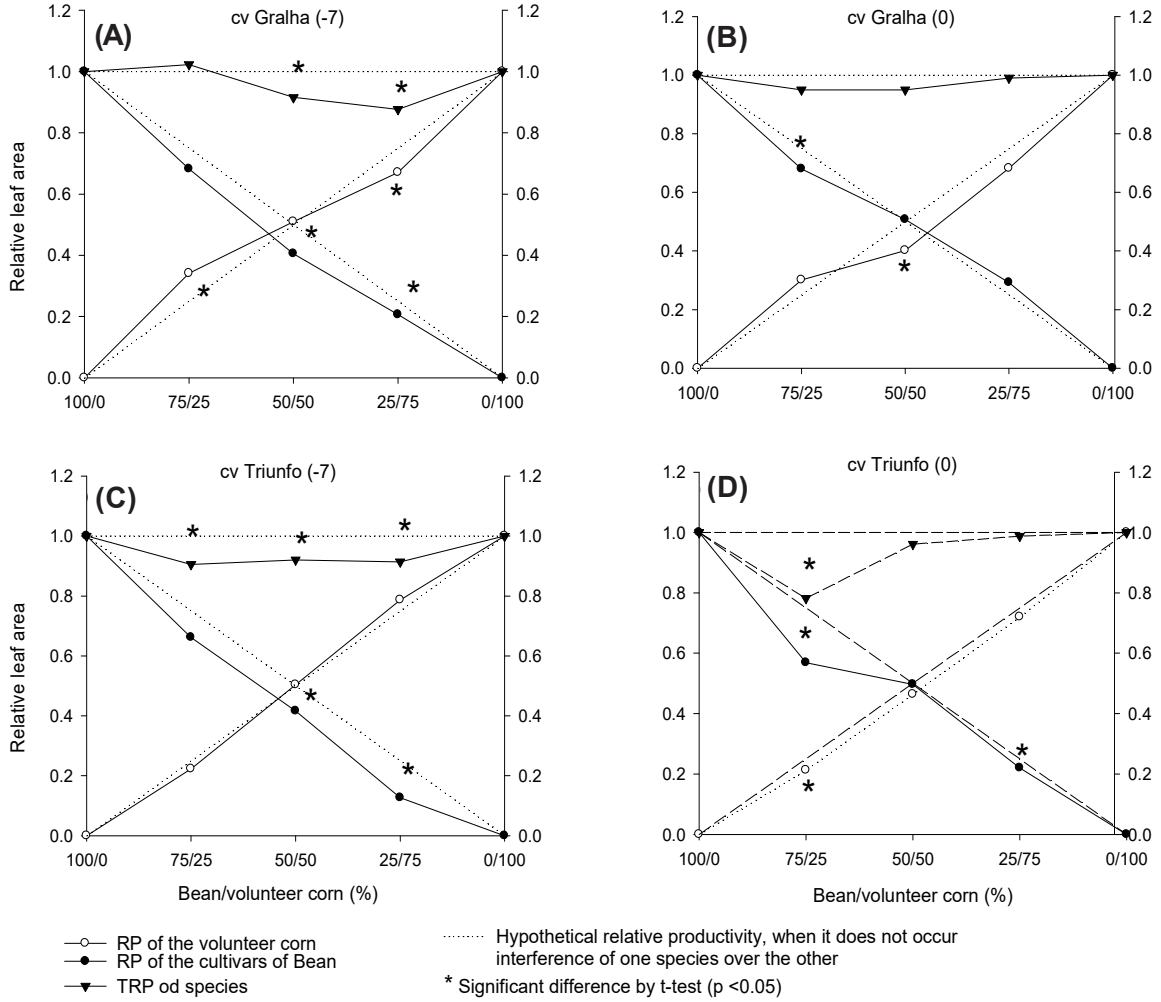

Figure 2 **-** Relative productivity (RP) of the foliar area of the cultivars IPR Gralha (A; B) and Fepagro Triunfo (C; D) and volunteer corn in two weed emergence times, -7 DAE (A; C) and 0 DAE (B; D), depending on the variation of the proportion of plants between the two species.

Table 3 **-** Leaf area (cm² per plant) of bean cultivars in different proportions of plants and volunteer corn emergence season

Cultivar	Season[(1)]	Proportion of plant (bean: volunteer corn)			
		100:0(T)	75:25	50:50	25:75
Triunfo	-7	356.5 Aa	314.5 Aa*	294.6 Aa*	180.7 Bb ns
Triunfo	0	356.5 Aa	377.1 Aa ns	332.3 Aa ns	270.6 Aa ns
Gralha	-7	377.0 Aa	310.7 Aa*	270.6 Ab*	342.9 Aa ns
Gralha	0	377.0 Aa	313.1 Ba*	324.1 Aa ns	298.6 Aa*

* and ns significant and non-significant by Dunnett's test (p <0.05). Capital letters compare cultivar within the time and proportion of plants by the t test (p <0.05). Lower case letters compare time within the cultivar and proportion by t-test (p <0.05). (1) -7 indicates emergence of corn seven days before the bean, and 0 indicates simultaneous emergence of corn and beans.

The RP of the bean DMB showed differences in regards to the hypothetical lines, confirming the absence of competitive superiority for both bean cultivars, when in simultaneous emergence with volunteer corn (Figure 3B, D; Table 1). Similarly, the TRP was not affected by the competition during co-emergence, demonstrating that the bean and volunteer corn species do not compete for environmental resources under these conditions.

In early emergence, the DMB of volunteer corn was not affected, even in competition at the highest bean proportions, as reflected in the non-modification of the RP with respect to the hypothetical line (Figure 3; Table 1). In contrast, the RP of both bean cultivars displayed a concave

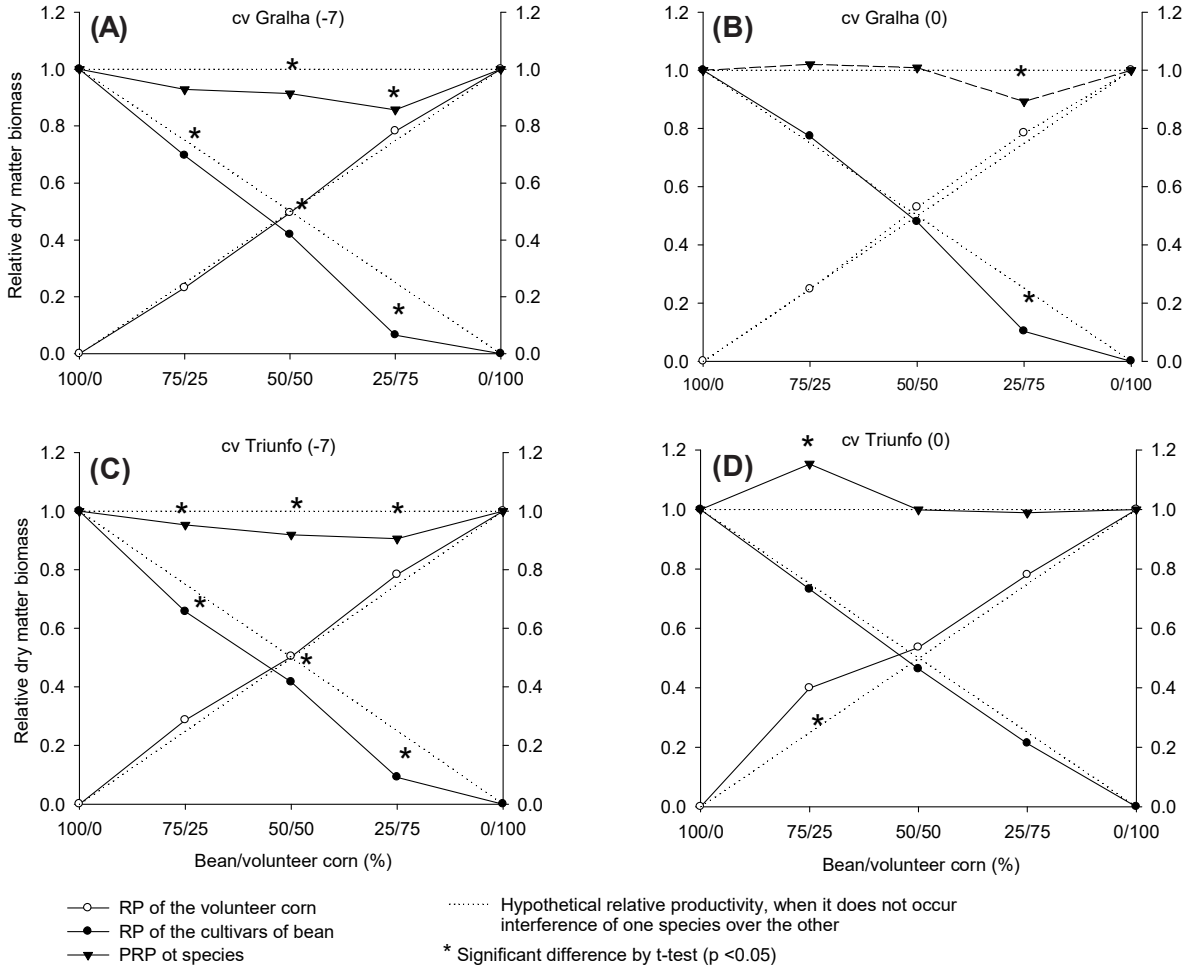

Figure 3 **-** The relative productivity (RP) of the dry matter biomass of the IPR bean cultivars Gralha (A; B) and Fepagro Triunfo (C; D) and of the volunteer corn in two weed emergence times, -7 DAE (A; C) and 0 DAE (B; D), as a function of the variation of the proportion of plants between the two species.

line, indicating interference at all ratios (Figure 3A, C; Table 1). Plants with early emergence have a comparatively greater growth because they gain an advantage by accessing the resources of the environment, increasing their competitive ability, and thereby intensely affecting the crop (Agostinetto et al., 2004).

The TRP of the DMB was less than one in both bean cultivars and for at least two proportions. The bean and volunteer corn showed mutual impairment in their development when the emergence of volunteer corn was anticipated (Figure 3). It shows that species compete for the same resources available in the environment, resulting in lower growth and development, which contributes little to TRP (Galon et al., 2011).

A higher DMB of cv. Gralha compared to cv. Triunfo was detected in monoculture and at the 50:50 and 25:75 proportions (Table 4). This observation can be explained by the relatively long cycle of development for cv. Gralha and the intrinsic characteristics of each cultivar when competing with weeds (Galon et al., 2011; Wandscheer et al., 2013). These differences can serve as an indicator of competitive ability; the greater accumulation of DMB might indicate that the plant excelled in utilizing the surrounding resources (Tironi et al., 2014).

There was a reduction in DMB at all proportions when volunteer corn the emerged in advance of the bean (Table 4). Conversely, no change was verified in the co-emergence. When volunteer corn emerged before the bean, it had a greater capacity to extract the resources of the environment, thereby dominating the surroundings and developing more than the species that emerged later. Similar results were observed for barley, which had a higher competitive ability than ryegrass and turnip when it emerged 8 days before the weeds (Tironi et al., 2014).

Table 4 **-** Dry matter biomass (g per plant) of bean cultivars in different proportions of plants and volunteer corn emergence season

Cultivar	Proportion of plant (bean: volunteer corn)			
	100:0(T)	75:25	50:50	25:75
Triunfo	2.22 B	ns 1.92 A	*1.88 B	*1.78 B
Gralha	2.58 A	ns2.42 A	ns2.26 A	*2.42 A
Seasons(1)	100:0(T)	75:25	50:50	25:75
-7	2.40 a	*1.82 b	*1.86 b	*1.76 b
0	2.40 a	ns2.10 b	ns2.28 a	ns2.44 a

* and ns significant and not significant by Dunnett's test ($p < 0.05$). Upper case letters compare cultivar within the proportion by the t-test ($p < 0.05$). Lower case letters compare time within the proportion by the t test ($p < 0.05$). (1) -7 indicates emergence of corn seven days before the bean, and 0 indicates simultaneous emergence of corn and beans.

For the analysis of competitive superiority, the CI, *K* and *A* indices should be analyzed together. The criterion used to prove the competitive advantage was the occurrence of the significance of at least two indices (Bianchi et al., 2006).

For the variable HP when cv. Gralha emerged after the volunteer corn, the corn was more competitive. Already in co-emergence, cv. Gralha was more competitive than volunteer corn (Table 5). Regarding cv. Triunfo, the indices were not significant for any corn emergence season, indicating the greater ability of the cultivar to grow at sufficient PH to avoid shading caused by volunteer corn. Similar results of competitive advantage were documented for the bean crop in competition with *U. plantaginea* when emerging together (Passini et al., 2003). However, studies related to the anticipated emergence of weeds in coexistence with beans are not found in the literature, even more in coexistence with volunteer corn.

There were no significant differences among the CI, *K* and *A* indices for the LA variable (Table 5). However, for the DMB, the CI of the beans of both cultivars was below one when competing with the early emergence of the volunteer corn. When the volunteer corn and bean crop co-emerged, the CI was not significant. The same trend was apparent for the *K* and *A* indices, showing the competitive advantage of volunteer corn over both bean cultivars, but only in early emergence.

Table 5 **-** Competitiveness indices of volunteer bean and maize cultivars, expressed by relative competitiveness (CR), relative grouping coefficients (Ka and Kb) and aggressiveness (A), obtained in experiments conducted in substitute series

Plant/Season(1)	CR	Ka (bean)	Kb (corn)	A
	Height of plants			
Gralha x Corn -7	0.77(0.04)*	0.95(0.06)*	1.07(0.29)	-0.04(0.01)*
Gralha x Corn 0	1.22(0.11)*	0.98(0.12)*	0.90(0.06)	0.02(0.01)*
Triunfo x Corn -7	1.12(0.10) ns	0.83(0.11)*	1.02(0.07)	0.01(0.01) ns
Triunfo x Corn 0	0.99(0.09)ns	1.04(0.08) ns	1.08(0.14)	0.00(0.02) ns
	Leaf area			
Gralha x Corn -7	0.83(0.36) ns	0.74(0.40) ns	1.08(0.34)	-0.03(0.05) ns
Gralha x Corn 0	1.39(0.37) ns	1.29(0.52) ns	0.68(0.12)	0.04(0.03) ns
Triunfo x Corn -7	0.87(0.32) ns	0.73(0.22) ns	1.06(0.34)	-0.02(0.03) ns
Triunfo x Corn 0	0.99(0.16) ns	0.84(0.13) ns	0.89(0.25)	0.00(0.02) ns
	Dry matter biomass			
Gralha x Corn -7	0.85(0.10)*	0.72(0.11)*	0.99(0.13)	-0.02(0.01)*
Gralha x Corn 0	0.91(0.10) ns	0.92(0.09) ns	1.16(0.31)	-0.01(0.01) ns
Triunfo x Corn -7	0.82(0.19)*	0.75(0.13)*	1.07(0.14)	-0.02(0.01)*
Triunfo x Corn 0	0.87(0.11) ns	0.87(0.14) ns	1.19(0.31)	-0.02(0.02) ns

* and ns significant and non-significant by the t-test ($p < 0.05$); Values in parentheses represent the standard error of the mean. Ka and Kb = coefficients of relative clustering of the bean and volunteer corn, respectively; CR = relative competitiveness; K = relative grouping coefficient; A = aggressiveness. (1) -7 indicates emergence of corn seven days before the bean, and 0 indicates simultaneous emergence of corn and beans.

Several authors described the use of CI to evaluate the ability of crops and their weeds: forage turnip was more competitive than soybean genotypes (Galon et al., 2011); *Lolium multiflorum* showed higher competitive ability than barley cultivars (Galon et al., 2011); rice stood out relative to *Digitaria horizontalis* (Agostinetto et al., 2013), and there was more competitive rice than *Brachiaria plantaginea* (Galon et al., 2014). However, literature results concerning the competitive ability of crops with volunteer crops are still sparse.

The results allow concluding that in general, the PH of bean cultivars is reduced when volunteer corn emerges early and in the highest proportions. Early emergence of volunteer corn reduces the LA of both bean cultivars while simultaneous emergence only reduces the LA of cv. Triunfo. The DMBis decreased, owing to the competition of the corn emerging before the bean, and cv. Gralha is more tolerant than cv. Triunfo. On the contrary, volunteer corn is more competitive than the beans when the emergence is early, highlighting the importance of bean sowing in volunteer corn-free areas.

REFERENCES

Afifi M, Swanton C. Early physiological mechanisms of weed competition. Weed Sci. 2012;60(4):542-51.

Agostinetto D, Fleck NG, Rizzardi MA, Balbinot Jr AA. Perdas de rendimento de grãos na cultura de arroz irrigado em função da população de plantas e da época relativa de emergência de arroz-vermelho ou de seu genótipo simulador de infestação de arroz-vermelho. Planta Daninha. 2004;22(2):175-83.

Agostinetto D, Fontana LC, Vargas L, Markus C, Oliveira E. Habilidade competitiva relativa de milha em convivência com arroz irrigado e soja. Pesq Agropec Bras. 2013;48(10):1315-22.

Alms J, Moechnig M, Vos D, Clay SA. Yield loss and management of volunteer corn in soybean. Weed Technol. 2016;30(1):254-62.

Bastiani MO, Lamego FP, Agostinetto D, Langaro AC, Silva DC. Competitividade relativa de cultivares de soja com capim-arroz. Bragantia. 2016;75(4):435-45.

Bennett AC, *Shaw* DR. Effect of Glycine max cultivars and weed control on weed seed characteristics. Weed Sci. 2000;48(4):431-5.

Bianchi MA, Fleck NG, Lamego FP. Proporção entre plantas de soja e plantas competidoras e as relações de interferência mútua. Cicen Rural. 2006;36(5):1380-7.

Carvalho FP, Santos JB, Cury JP, Silva DV, Braga RR, Byrro ECM. Alocação de matéria seca e capacidade competitiva de cultivares de milho com plantas daninhas. Planta Daninha. 2011;29(2):373-82.

Companhia Nacional de Abastecimento – Conab. Acompanhamento de safra brasileiro – grãos: Décimo primeiro levantamento, agosto 2017 – safra 2016/2017. Brasília, DF: Companhia Nacional de Abastecimento; 2017. [acessado em: 06 dez. de 2017]. Disponível em: http://www.conab.gov.br/OlalaCMS.

Deen W, Hamill A, Shropshire C, Soltani N, Sikkema PH. Control of volunteer glyphosate resistant corn (*Zea mays*) in glyphosate resistant soybean (*Glycine max*). Weed Technol. 2006;20(1):261-6.

Fleck NG, Bianchi MA, Rizzardi MA, Agostinetto D. Interferência de *Raphanus sativus* sobre cultivares de soja durante a fase vegetativa de desenvolvimento da cultura. Planta Daninha. 2006;24(3):425-34.

Galon L, Guimarães S, Lima AM, Radunz AL, Beutler NA, Burg GM, et al. Interação competitiva de genótipos de arroz e papuã. Planta Daninha. 2014;32(3):533-42.

Galon L, Tironi SP, Rocha PRR, Concenco G, Silva AF, Vargas L, et al. Habilidade competitiva de cultivares de cevada convivendo com azevém. Planta Daninha. 2011;29(4):771-81.

Gomide MB, Lemos OV, Tourino D, Carvalho MM, Carvalho JG, Duarte CS Comparação entre métodos de determinação de área foliar em cafeeiros Mundo Novo e Catuaí. Cienc. Prática. 1977;1(2):118-23.

Jensen PJ, Hangarter RP, Estelle M. Auxin transport is required for hypocotyl elongation in light-growth but not dark-growth Arabdopsis. Plant Physiol. 1998;116(2):455-62.

Kniss A.R., Sbatella G.M., Wilson R.G. Volunteer glyphosateresistant corn interference and control in glyphosate resistant sugar beet. Weed Technol. 2012;26:348-55.

Lamego FP, Fleck NG, Bianchi MA, Schaedler CE. Tolerância a interferência de plantas competidoras e habilidade de supressão por genótipos de soja – II respostas de variáveis de produtividade. Planta Daninha. 2004;22(4):491-8.

Marquardt PT, Krupde C, Johnson WG. Competition of transgenic volunteer corn with soybean and the effect on western corn rootworm emergence. Weed Sci. 2012;60(2):193-8.

Nordby DE, Alderks DL, Nafziger ED. Competitiveness with weeds of soybean cultivars with different maturity and canopy width characteristics. Weed Technol. 2007;21(4):1082-8.

Page ER, Tollenaar M, Lee EA, Lukens L, Swanton CJ. Shade avoidance: an integral component of crop-weed competition. Weed Res. 2010;50(4):281-88.

Passini T, Christoffoleti PJ, Yada IFU. Competitivity of the common-bean plant relative to the weed alexandergrass [*Brachiaria plantaginea* (Link) Hitch.]. Sci Agric. 2003;60(2):259-68.

Radosevich SR, Hold JS, Ghersa CM. Ecology of weeds and invasive plants. 3rd.ed. New York: Wiley; 2007.

Radosevich SR. Methods to study interactions among crops and weeds. Weed Technol. 1987;1(3):190-8.

Ruberti I, Sessa G, Ciolfi A, Possenti M, Carabelli M, Morelli G. Plant adaptation to dynamically changing environment: the shade avoidance response. Biotechnol Adv. 2012;30(5):1047-58.

Sbatella GM, Kniss AR, Omondi EC, Wilson RG. Volunteer corn (Zea mays) interference in dry edible bean (*Phaseolus vulgaris*). Weed Technol. 2016;30(4):937-42.

Thomas WE, Everman WJ, Clewis SB, Wilcut JW. Glyphosate-resistant corn interference in glyphosate-resistant cotton. Weed Technol. 2007;21(2):372-77.

Tironi ST, Galon L, Silva AF, Fialho CMT, Rocha PRR, Faria AT, et al. Época de emergência de azevém e nabo sobre a habilidade competitiva da cultura da cevada. Cienc Rural. 2014;44(9):1527-33.

Vandevender KW, Costello TA, Smith RJ. Model of rice (*Oryza sativa*) yield reduction as a function of weed interference. Weed Sci. 1997;45(2):218-24.

Wandscheer ACD, Rizzardi MA. Interference of soybean and corn with *Chloris distichophylla*. Cienc Agrotec. 2013;37(4):306-12.