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Relative competitiveness of *Phaseolus vulgaris* with *Bidens pilosa*

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In agriculture, weeds tend to compete with the crop for scarce resources like water, light and nutrients, which incurs losses to farmers. Consequently, farmers must deal with weeds to derive maximum benefits for their crops and the environment. The aim of this paper was to assess the competitiveness of common bean crops in the presence of hairy beggarsticks (*Bidens pilosa*) at different population densities. The treatments were arranged in replacement series using five proportions (0:16, 4:12, 8:8, 12:4 and 16:0) of common bean and hairy beggarsticks in a fully randomized design, with four replicates. The analyzed variables were dry mass of the aerial part and height of plants. Competitive analysis was performed using diagrams applied to substitute experiments and indices of competitiveness. With regard to the two evaluated variables, the common bean was more resourceful than the hairy hairy beggarsticks.

Key words: Replacement series, competition, shoot dry mass, stature, *Bidens pilosa*, beans.

INTRODUCTION

Brazil is one of the world's leading producers of beans with a mean annual production of 3,500,000 tons (MAPA, 2016). The common bean is consumed mainly in the states of Paraná, Santa Catarina, Rio Grande do Sul and Rio de Janeiro. As one of the basic Brazilian food items, it is cultivated by small and large producers in all regions of Brazil (MAPA, 2016). This important component of the Brazilian diet is high in protein, carbohydrates, vitamins, minerals, fiber and antioxidant compounds that help reduce diseases. According to the Ministry of Agriculture and Supply, the MAPA (2016), seven out of ten Brazilians consume beans on a daily basis.

However, the productivity of this crop in Brazil is considered low and could potentially triple with the appropriate use of technology in farming. There are several factors that reduce the productivity of crops, including the interference of weeds, that is, the competition between species (Teixeira et al., 2009).

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According to the authors, the bean plant is one of the crops that provides less shade for the soil and suffers the most interference of weeds, thus generating losses in growth, productivity, and the operationalization of harvests.

Weeds can interfere with agricultural crops by competing for the resources they require for growth, such as water, light and nutrients, and by allelopathy (Pereira et al., 2011). One of the species of weed that is usually found in crops and may be causing losses is hairy beggarsticks (*Bidens pilosa*), which is a fast-growing erect herb, 20 to 150 cm tall, with high seed production, that grows year-round in favorable conditions (Kissmann and Groth, 1997). Considering that this weed usually infects annual crops in more than 40 countries, it can reduce productivity by 30%, as well as serve as a host to fungi, virus and nematodes (EMBRAPA, 2014).

The weed, *B. pilosa* is among the most predominant species in bean crops in the dry and rain seasons (Teixeira et al., 2009), and it can exhibit high competitiveness and significantly reduce the dry matter accumulation of crops.

Substitutive experiments are conducted to determine the competitive relationship among plants, the effects of the population, and the proportional difference of crops with weeds (Moraes et al., 2009). The replacement series includes the culture alone and in a co-culture mixture with weeds in variable proportions. The total amount of plants is constant in all the experiment treatments to indicate which species is the most competitive (Cousens & O'neill, 1993).

There is little knowledge on the interaction of common beans with black-jack. Given the inexistence of studies to shed light on this doubt, the aim of this paper was to assess the competitiveness of common bean crops in the presence of hairy beggarsticks in different population densities.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse at the experimental unit of the Universidade Tecnológica Federal do Paraná - UTFPR - Campus Dois Vizinhos, in February and March 2014. The adopted experimental design was random blocks with four replications.

The first experiment was installed in a monoculture of common bean and black-jack. Both species were planted in 8-L pots. The final constant production of dry mass in the aerial shoots of the plants was obtained from the average of both monocultures. The average population of 16 plants pot^{-1}, which is the equivalent of 400 plants m^{-2} (data not presented), was used to obtain the final constant production.

For the second experiment, seeds were planted in seedling production trays to ensure uniform germination and seedling emergence on the same day, thus preventing any advantage of one species over the other. Prior to sowing on the trays, it was observed that the difference of germination between the species was two days.

After five days of emergence, the seedlings were transplanted to 8-L pots. The replacement series experiments included different combinations per pot (0:16, 4:12, 8:8, 12:4, 16:0) of common bean plants and black-jack, respectively. The plants were irrigated as required. For both experiments, soil fertility was corrected according to the technical recommendation for bean crops.

Thirty days after emergence (DAE), the shoot dry mass and height of the common bean and hairy beggarsticks plants were recorded. To count the dry mass of the shoots, the plants were cut close to the soil and conditioned in a forced air oven at 60°C until constant weight. Height was measured using a graded ruler from the soil to the highest outstretched leaf.

Relative productivity (RP) and total relative productivity (TRP) data were analyzed using diagrams and species proportion. For RP analysis, the expected production is defined by the straight line that connects the production point of each species in pure stand (100:0) to point zero of the stand (0:100). When the RP results in a straight line, it means that one species has no effect over the other. However, when the RP results in a concave line, it implies some loss for one or both species, while a convex line implies benefits for one or both species. For the TRP, if the value is equal to 1 (straight line), there is competition for the same resources, if the value is higher (convex line), competition is avoided, and if the value is less than 1 (concave line), there are multiple losses in growth (Cousens, 1991).

The procedure to statistically analyze relative production was calculated using the difference for the RP values (DRP) from the proportions 25, 50, and 75% in relation to the values of the hypothetical straight line (Passini, 2001).

The indices of relative competitiveness (RC), relative clustering coefficient (K) and aggressiveness (A) were calculated as follows: RC represents the comparative growth of the X genotype in relation to Y, K indicates the relative dominance of a genotype over the other, and A indicates which genotype is the most aggressive. The genotype X is more competitive than Y when RC > 1, $K_x > K_y$ and A > 0, and the genotype Y is more competitive than X when RC < 1, $K_x < K_y$ and A < 0 (Hoffman and Buhler, 2002). To calculate these indices, the 50:50 proportions of the species were used with the following equations, as suggested by Cousens and O'Neill (1993):

$RC= RP_x/RP_y$, $K_x= RP_x/(1-RP_x)$, $K_y= RP_y/(1-RP_y)$, $A= RP_x – RP_y$.

The t-test was applied to test the differences in the DRP, TRP, RC, K and A indices (Hoffman and Buhler, 2002). To test the differences of DRP and A, it was considered that the null hypothesis would be the mean equal to zero ($H_o = 0$), for TRP and RC, that the means would be equal to one ($H_o = 1$), and for K, that the means of the differences between K_x and K_y would be equal to zero [$H_o = (K_x - K_y) = 0$]. The criterion to consider RP and TRP curves different from the hypothetical straight lines was that significant differences according to the t-test should occur in at least two proportions (Bianchi et al., 2006). Similarly, for the RC, K and A indices, a difference in competitiveness was considered when there was a significant difference according to the t-test in at least two indices.

The data obtained for shoot dry mass and height, expressed in means per plant, were subjected to analysis of variance (p in at least two indices. he t-teeatments were compared using Dunnett's test (p obtained for shoot monocultures were considered the control for comparison.

RESULTS AND DISCUSSION

Graphical analysis for the variable shoot dry mass of the plants showed that the RP (relative productivity) of the common bean has a convex line and the hairy beggarsticks

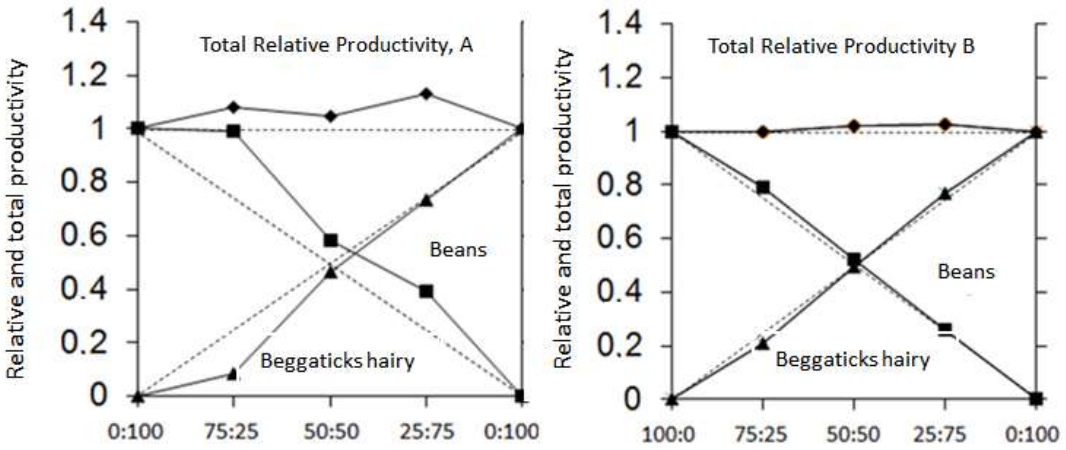

Figure 1. Diagram of relative mean production of the shoot dry mass (A) and height (B) of common bean and hairy beggarsticks plants according to variation of the ratio between the two species. UTFPR, Dois Vizinhos, PR, Brazil, 2014.

Table 1. Difference of relative productivity (DRP) and total relative productivity (TRP) of the variables shoot dry mass and height of the common bean and black-jack, 30 days after emergence. UTFPR, Dois Vizinhos, PR, Brazil, 2014.

Variables	Proportions of plants (bean: competitor)		
	75:25	50:50	25:75
Dry mass of the aerial part			
DRP common bean	0.24 (± 0.05)	0.08 (± 0.06)	0.14 (± 0.10)
DRP black-jack	-0.16 (± 0.03)*	-0.04 (± 0.10)	-0.02 (± 0.13)
TRP	1.08 (± 0.04)	1.05 (± 0.14)	1.13 (± 0.08)*
Leaf area			
DRP common bean	0.04 (± 0.05)	0.02 (± 0.05)	0.01 (± 0.03)
DRP black-jack	0.04 (± 0.07)*	-0.01 (± 0.02)	0.02 (± 0.02)
TRP	1.00 (± 0.05)	1.02 (± 0.05)	1.03 (± 0.01)

*Significant difference based on the t-test $p \leqslant 0.05$. Values in parentheses represent the standard error of the mean.

has a concave line, that is, the straight lines deviated from the expected production line. The common bean was more competitive than the weed since it captured the resources more effectively in all the assessed proportions (Figure 1A). In another study, Galon et al. (2015) conducted substitutive experiments with soybean and observed a reduction in the production of dry mass in all the tested proportions, which proves that this crop is more competitive than black-jack.

The greater RP of the common bean increased the production of the shoot dry mass of both species, that is, total relative productivity (TRP), suggesting that the common bean benefitted by growing with the weed (Figure 1A and Table 1). These results are directly associated with the fact that this crop has a greater capacity to quickly cover the soil and thus restrict the weed's search for light.

The radiation balance in the red and far-red range is perceived by the phytochromes that interconvert between the two forms, giving the plant its capacity to stretch and escape the shade to later assume a more generalized and homogenous growth with the accumulation of mass that is proportional to the size (Procópio et al., 2004).

The results of the RP and TRP of the height of common bean and hairy beggarsticks were similar to the results shown in Figure 1A and B and Table 1, although, in this case, the straight lines were close to the expected lines. The RP and the TRP showed no differences for the variables of the studied proportions (Table 1), since at least two of the proportions would have to show

Table 2. Indices of competitiveness between common bean and black-jack, expressed in relative competitiveness (RC), relative clustering coefficients (K) and aggressiveness (A), obtained in a replacement series of experiments. UTFPR, Dois Vizinhos, PR, Brazil, 2014.

Variable	RC	Kx (crop)	KY (competitor)	A
Shoot Dry Mass	1.38 (0.31)	1.52 (0.41)	0.98 (0.33)	0.12 (0.08)
Height	1.07 (0.05)	1.15 (0.23)	0.99 (0.09)	0.03 (0.07)

Table 3. Responses of bean crops and hairy beggarsticks expressed in shoot dry mass and height of plants 30 days after emergence. UTFPR, Dois Vizinhos, PR, Brazil, 2014.

Proportion (bean: competitor)	Shoot dry mass (g plant^{-1})	Height (cm)
Bean		
100:0 (T)	0.53	31.25
75:25	0.71	32.84
50:50	0.62	32.73
25:75	0.84	32.39
CV (%)	29.6	15.5
Competitor		
100:0 (T)	0.45	23.64
75:25	0.43	24.16
50:50	0.41	23.45
25:75	0.11*	19.93*
CV (%)	29.43	5.34

*Mean differs from control (T) according to Dunnett's test ($p \leq 0.05$).

significant differences for this to occur (Bianchi et al., 2006). Plant height is an important feature in the competitive processes because it has a direct influence on the plant's capacity to intercept and use light (McDonald, 2003), the higher the plant, the greater its capacity to create shade for the competing species. In a study conducted with soybean and red rice, Moraes et al. (2009) detected the influence of these crops in suppressing the competitor through shade due to the greater leaf area and quick establishment, which is similar to the findings of this study.

The common bean is a crop with low competitive potential that is classified as having low shading capacity and must therefore compete with weeds (Teixeira et al., 2009). However, some studies corroborate the results presented here where the common bean was more competitive than *Brachiaria plantaginea* (Passini, 2001) and *Amaranthus* sp. (Carvalho and Christoffoleti, 2008).

These results can be explained by the attributes of the crop, such as height, biomass accumulation, canopy architecture, and number and size of branches, that work together to better compete with the weeds (Pires et al., 2005, Bianchi et al., 2006). In this case, vigorous growth, stature, and greater leaf area of the common bean plants were the components that surpassed the vegetative characteristics of the black-jack.

The common bean proved being more competitive than the hairy beggarsticks for the shoot dry mass and height variables according to the established criteria, that is, RC > 1, $K_x > K_y$ and A > 0 (Table 2). These indices of competitiveness show which species is more competitive. In the same way, Hoffman and Buhler (2002) showed that sorghum was more competitive than *S. halapense,* soybean was more competitive than red rice (Moraes et al., 2009).

Relative growth verified using the shoot dry mass and height variables showed that both variables of the common bean culture differed from the control (monoculture) (Table 3). Both variables confirm that the bean plant prefers hairy beggarsticks in its vicinity than another common bean plant at least within the 30 days after emergence, that is, in this monoculture, the means of these variables were lower than the means found in the mixed crops. When compared with the control, shoot dry mass (36%) and height (4.5%) increased. In the 25:75 proportion, similar results were reported by Christoffoleti and Victória Filho (1996), who found that corn preferred pigweed in its vicinity than another corn plant.

For the competitor black-jack, there was no difference

in the lowest proportion of the competitor (25:75) in comparison with the control. This difference was represented by a 76% reduction for shoot dry mass and a 15.7% reduction for height in comparison with the control. The competitor in the monoculture had a higher production of shoot dry mass than when in competition, which suggests that it prefers to compete with an individual of the same species, unlike the common bean.

Species with similar growth habits will make similar demands on the limited resources for growth, but the differences in their efficiency in the utilization of these resources makes one species a better competitor than are the others (Tuor and Willians, 2002). Generally, intraspecific competition among crop plants is more severe than the interspecific effects of weeds on crop yield (Radosevich, 1987). Given the relative importance of weeds in the agricultural scenario, studies on the biology and the interference relationships of this species on different crops are fundamental (Wandscheer et al., 2013).

Regardless of the proportion of the species, bean plants were more competitive than hairy beggarsticks and had a greater relative productivity of shoot dry mass and height. Consequently, the common bean prefers hairy beggarsticks in its vicinity than another common bean plant.

Conclusions

It was concluded that regardless of the proportion of the species, the common bean showed gains in relation to the hairy beggarsticks for the analyzed variables.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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