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COMPETITIVE ABILITY OF SOYBEAN CROP WITH C_3 AND C_4 WEEDS

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ABSTRACT

Production potential of soybean crops may be negatively affected by their competition with weeds, since species that are morpho-physiologically close to these crops tend to have similar requirements for resources, a fact that intensifies competition. Therefore, this study aimed at evaluating the relative competitive ability of soybean (C_3) against both weeds blackjack (C_3) and slender amaranth (C_4), by considering growth variables. Experiments were carried out as replacement series of soybean with blackjack (first experiment) and slender amaranth (second experiment). Populations of plants in the first and the second experiments were 14 and 10 plants pot^{-1}, equivalent to 337 and 241 plants m^{-2}, respectively. Ratios under investigation were 100:0 (soybean monoculture), 50:50 and 0:100% (weed monoculture). Variables under evaluation were height, leaf area and shoot dry matter. Results show that soybean was more competitive than blackjack, whereas slender amaranth was more competitive than soybean. In general, in the cases of C_3 species (soybean and blackjack), interspecific competition was predominant and led to decrease in growth variables, while, in the case of slender amaranth, intraspecific competition led to higher loss than the interspecific one.

Keywords: *Amaranthus viridis*, *Bidens pilosa*, Competition, *Glycine max*, Replacement series

1. INTRODUCTION

Soybean (*Glycine max* L.) is one of the most profitable and common agricultural products worldwide. It is consumed either as a vegetable crop or as its food by-products. Brazil ranks as the second largest producer and exporter of soybean in the world, since its total production was about 114 million tons (FAO, 2018). However, it should be highlighted that several factors may interfere in its productivity, mainly competition with weeds.

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Competition among plants occurs when at least one of the essential resources for their development and growth is found in limited amounts to meet the needs of all individuals in the environment (Radosevich et al., 2007). Weeds may affect crop development, since they compete for resources and decrease grain productivity in up to 93% in soybean (Silva et al., 2009). Besides, loss of soybean productivity which results from competition with weeds may vary, depending on the plant species and the level of infestation in the area.

In order to determine competitive interactions between weeds and crops, several methods, which consider many factors, such as plant population, proportion of species and spatial arrangement, have been developed (Radosevich, 1987). They comprise four general types of experiments: additive, systematic, response surface and replacement series.

Replacement series experiments include monoculture analyses, as well as mixtures of species, whose proportions vary, while the total plant population is kept constant in all treatments (Cousens, 1991; Radosevich et al., 2007). These models enable interspecific and intraspecific competition to be studied, since productivity of associations may be determined by comparison with monocultures. A study of wild poinsettia as a weed of soybean showed that both produced higher biomass than expected and more together than in their respective monocultures (Rizzardi et al., 2004). Silva et al. (2014) showed that intraspecific competition was more important to hairy fleabane when it was a weed of soybean.

It has been known that weeds that cause the highest losses of crop productivity are C_4 plants, such as slender amaranth (*Amaranthus* spp.), while most crops of relevance are C_3 ones, such as soybean (Valerio et al., 2011). Even though many magnoliopsida weeds which compete with soybean crops have a C_3 photosynthetic route, such as blackjack (*Bidens* spp.), due to their phenotypical and physiological proximity, they may strongly compete with crops for environmental resources.

Studies of evaluation of competitive interaction among plants with different photosynthetic routes (C_3 or C_4), mainly crop/weed interaction in agricultural systems, become important when the environment undergoes changes. Besides, studies of interaction help to develop strategies to select plants with more competitive ability, to plan the structure and composition of plant communities and to carry out changes in the geographical distribution of species.

Therefore, the hypothesis of this study is that competitive ability of soybean, whose photosynthetic route is C_3, is similar to the one of blackjack (C_3) and lower than the one of slender amaranth (C_4). This study aimed at evaluating the relative competitive ability of both weeds blackjack and slender amaranth with soybean crops, by considering growth variables.

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2. MATERIAL AND METHODS

This study comprised two replacement series experiments which were carried out from December 2014 to February 2015, repeated from November 2015 to January 2016, in both 2014/15 and 2015/16 crops, respectively. Experiments were conducted in a green house in a completely randomized design, with four replicates.

The study used the soybean cultivar NA 5909 RG, while slender amaranth and blackjack seeds were collected in a non-agricultural area. Sowing was carried out on polyethylene trays; when plants had their first expanded true leaves, i. e., after 10, 12 and 15 days in the cases of soybeans, blackjack and slender amaranth, respectively, they were transplanted to 4-liter pots, 22cm in diameter, filled with Red-Yellow Argisol, with sandy loam texture. Fertility was corrected in agreement with the soil analysis.

Replacement series treatments were composed of proportions of plants with different photosynthetic routes: soybean (C_3) with blackjack (C_3) (first experiment) and soybean with slender amaranth (C_4) (second experiment). Proportions were 100:0 (pure stand of soybean), 50:50 and 0:100% (pure stand of blackjack or slender amaranth), equivalent to 14:0, 7:7 and 0:14 plants pot^{-1} in the first experiment and 10:0, 5:5 and 0:10 in the second experiment.

Plant population was determined by a previous experiment, in which populations of 8, 12 and 18 plants were found per experimental unit, equivalent to193, 289 and 434 plants m^{-2} in soybean crop, slender amaranth and blackjack, respectively, in agreement with the "law of final constant yield" (Radosevich et al., 2007) (data not shown). Population per experimental unit was found by calculating the arithmetic mean of populations, which resulted in 14 and 10 plants pot^{-1}, equivalent to 337 and 241 plants m^{-2}, when blackjack and slender amaranth were both weeds of soybean, respectively.

Evaluations of height (HEI), leaf area (LA) and shoot dry matter (SDM) were carried out 45 days after transplant (DAT) in the first experiment and 50 DAT in the second experiment. HEI was measured in all plants of every replicate by a millimeter ruler, considering the length from the soil to the apex of the plant with the leaf blade distended. LA was determined by an LA meter, model LI 3200 C; values were found as cm^2 were converted into cm^2 plant^{-1}. SDM was quantified after leaves were dried in an oven with forced air circulation at 60°C for 72 hours; values were expressed as g plant^{-1}.

In order to analyze data on HEI, LA and SDM, the method of graphical analysis of relative productivity was used (Radosevich, 1987; Cousens, 1991). It consists in constructing diagrams based on relative (RP) and total (TP) productivity in the following plant proportions: 0, 50 and 100% of the crop and its competitors. RP was calculated by the mixture mean/monoculture

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mean; mean per plant of every species in every experimental unit was used. TP is found by adding RP's of the competitor and the crop in respective plant proportions.

In the diagrams, results were compared to values of the hypothetical line – which unites both points zero and one in the diagram – that represented absence of interference among genotypes. If RP results in a concave line, it means there is damage to the growth of one or both species, while a convex line shows growth benefit of one or both species. When TP is equal to the unit (one) (straight line), it means that there is competition for the same resources. When it is above one (convex line), competition is avoided, either because the supply of resources is higher that the demand or because species search for different resources in the environment. When it is below one (concave line), it means that there is antagonism and, thus, mutual damage to growth (Cousens, 1991; Radosevich et al., 2007).

Besides RP and TP, indexes of relative competitiveness (RC), besides coefficients of relative clustering (K) and competitiveness (C), were calculated. RC represents comparative growth of the crop (soybean) in relation to its competitors (either slender amaranth or blackjack); K indicates relative dominance of a species over others; and C shows which species is more competitive (Cousens, 1991). When values of RC, K and C are interpreted together, competitive ability of species is clearly shown. Thus, soybean crop is more competitive than its competitor when RC > 1, Ksoybean > Kcompetitor and C > 0 (Hoffman and Buhler, 2002). However, the competitor is more competitive than soybean when RC < 1, Ksoybean < Kcompetitor and C < 0. Indexes of RC, K and C were calculated by the following equations proposed by Cousens and O‟Neill (1993): RC = RPsoybean / RPcompetitor; Ksoybean = RPsoybean / (1 - RPsoybean); Kcompetitor = RPcompetitor / (1 - RPcompetitor); C = RPsoybean – RPcompetitor.

In order to analyze relative productivity statistically, firstly, the difference between RP (DRP) values found in the proportion of 50% of plants and values of hypothetical lines found in the respective proportions was calculated (Bianchi et al., 2006). Then, the t test was applied ($p<0.05$) to evaluate differences in DRP, TP, RC, K and C (Roush et al., 1989; Hoffman and Buhler, 2002). Null hypotheses to test differences between DRP and C say that means are equal to zero (OH=0); in the case of TP and RC, means are equal to one (OH=1); and, in the case of K, means of differences between Ksoybean and Kcompetitor are equal to zero [OH=(Ksoybean-Kcompetitor)=0]. The criterion to consider the existence of differences in competitive ability of indexes RC, K and C was that the t test should detect differences in at least two indexes (Bianchi et al., 2006).

Data on HEI, LA and SDM of plants, expressed as mean values per plant, were submitted to the analysis of variance ($p\leq0.05$). When the F test ($p\leq0.05$) showed statistical significance,

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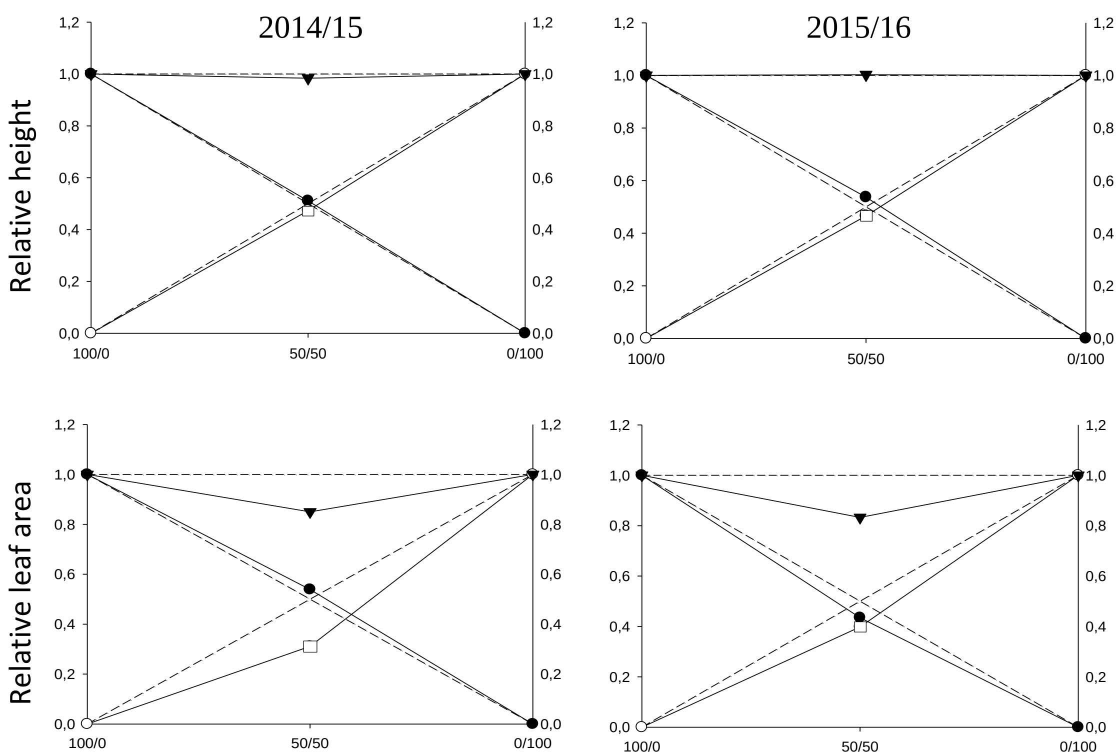
proportions were compared by the t test (p≤0.05) in the cases of every competitive species and analyzed separately in both experiments and seasons.

3. RESULTS AND DISCUSSION

The analysis of combinations of soybean and blackjack plants (first experiment) in the case of HEI showed that the deviation of the RP line was represented by a line close to the hypothetical one for the crop in the first season (2014/15) and a convex line in the second season (2015/16) (Figure 1). In the case of blackjack, deviations of RP lines are represented by concave lines in both crop seasons (Figure 1). Relative difference was found between observed lines (DRP) and expected ones in the case of soybean competing with blackjack for HEI in the second year of the experiment, when values were higher than the expected ones (Table 1). Regarding HEI, LA and SDM of blackjack in both years, DRP values were found to be lower than the expected ones (Table 1).



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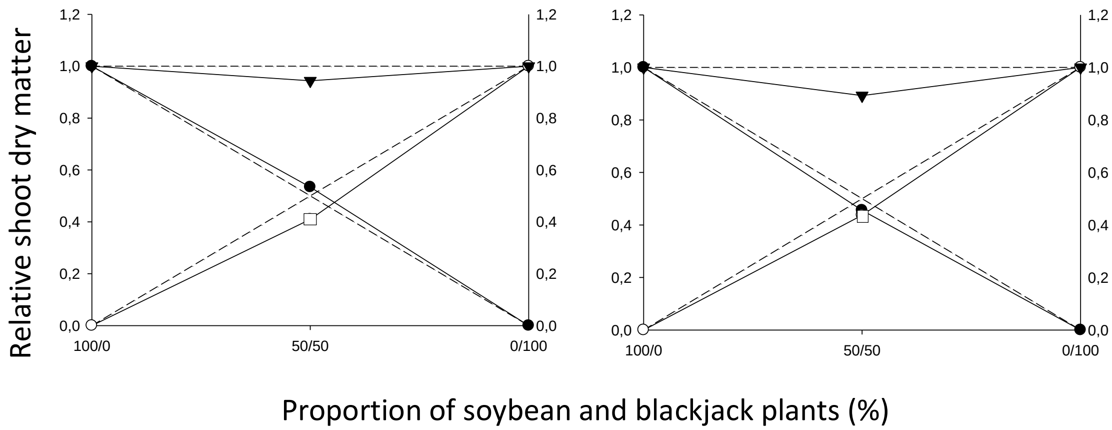

Figure 1. Relative (RP) and total (TP) productivity for height, leaf area and shoot dry matter of soybean and blackjack plants, regarding proportions among species in the population, in two growing seasons (2014/15 and 2015/16). Full circles (●) show soybean RP; empty squares (□) show blackjack RP; and full triangles (▼) show TP. Dashed lines refer to hypothetical relative productivity, when a species does not interfere in others.

Table 1: Relative differences in productivity (DRP) for height, leaf area, shoot dry matter and total relative productivity (TP) in the proportion of 50% of soybean plants associated with blackjack or slender amaranth plants in two growing seasons (2014/15 and 2015/16)

		2014/15	
	Height	Leaf area	Shoot dry matter
$DRP_{soybean}$	0.01 (±0.01)^{ns}	0.04 (±0.00)*	0.03 (±0.01)*
$DRP_{blackjack}$	-0.03 (±0.00)*	-0.19 (±0.01)*	-0.09 (±0.01)*
TP	0.98 (±0.01)^{ns}	0.85 (±0.01)^{ns}	0.94 (±0.02)*
$DRP_{soybean}$	-0.03 (±0.00)*	-0.10 (±0.04)^{ns}	-0.08 (±0.04)^{ns}
$DRP_{slender\ amaranth}$	0.08 (±0.02)*	0.26 (±0.05)*	0.19 (±0.06)^{ns}
TP	1.05 (±0.02)^{ns}	1.16 (±0.06)^{ns}	1.10 (±0.03)^{ns}
		2015/16	
$DRP_{soybean}$	0.04 (±0.01)*	-0.07 (±0.00)*	-0.04 (±0.01)*
$DRP_{blackjack}$	-0.03 (±0.00)*	-0.10 (±0.03)*	-0.06 (±0.01)*
TP	1.00 (±0.01)^{ns}	0.83 (±0.03)*	0.89 (±0.01)*
$DRP_{soybean}$	-0.04 (±0.02)^{ns}	-0.18 (±0.01)*	-0.17 (±0.02)*
$DRP_{slender\ amaranth}$	0.05 (±0.03)^{ns}	-0.08 (±0.03)^{ns}	-0.12 (±0.01)*
TP	1.01 (±0.04)^{ns}	0.74 (±0.03)*	0.71 (±0.02)*

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ns Non-significant and * significant, in relation to the hypothetical line, by the t test ($p<0.05$). Values between parentheses represent standard errors of means.

In certain conditions, competition for light increases the height of the species, a fact that was observed in soybean with competitor C_3 in the second growing season; it showed that the crop was affected by the weed. In the case of blackjack, since there was damage to its growth, it may be inferred that the weed had lower competitiveness than the crop and could be suppressed. Results of this study partly corroborate the ones of soybean HEI when it competed with wild poinsettia: deviations in RP were represented by a line close to the hypothetical line for the crop and a concave one for the weed (C_3) (Ulguim et al., 2016). Thus, there was damage to the growth of wild poinsettia as a weed of soybean, whereas the crop was not affected.

Concerning variables LA and SDM of soybean growing with blackjack, RP of the crop was characterized by convex lines in the first growing season and by concave ones in the second (Figure 1). Both variables of soybean exhibited differences in DRP when competing with blackjack in both growing seasons (Table 1). In the first season, there was increase in LA and SDM of the crop growing with the weed, while there was decrease in the variables in the second season. Soybean grew more vigorously in the first season than in the second, a fact that may have influenced findings of this study, together with high temperatures, which favored fast development of the crop.

Regarding blackjack, this weed was characterized by concave lines for LA and SDM in both growing seasons (Figure 1). In both years, DRP of blackjack competing with soybean exhibited differences in LA and SDM, whose values were lower than the expected ones (Table 1). Similar result was found in ryegrass (C_3) competing with soybean, i. e., the competitor exhibited significant DRP for LA and SDM (Oliveira et al., 2014).

Concave lines for the crop (in the second growing season) and the weed show that there might have been antagonism between C_3 species in association, due to competition for environmental resources and mutual damage to plant growth. Therefore, in general, soybean, at the same proportion as blackjack, harmed the development of the weed in both seasons. In the case of soybean, this crop was slightly harmed in the second season, a fact that corroborates data provided by the graphical analysis of combinations.

Studies of the effect of blackjack and/or wild poinsettia on soybean showed the occurrence of concave lines for crops (C_3) and competitors (C_3) in the cases of variables LA and SDM (Forte et al., 2017); it corroborates findings of the second growing season, in which species under study exhibited similar competitive abilities. Likewise, RP values of soybean competing with hairy fleabane, in the cases of variables HEI, LA and SDM, were represented by concave lines, thus,

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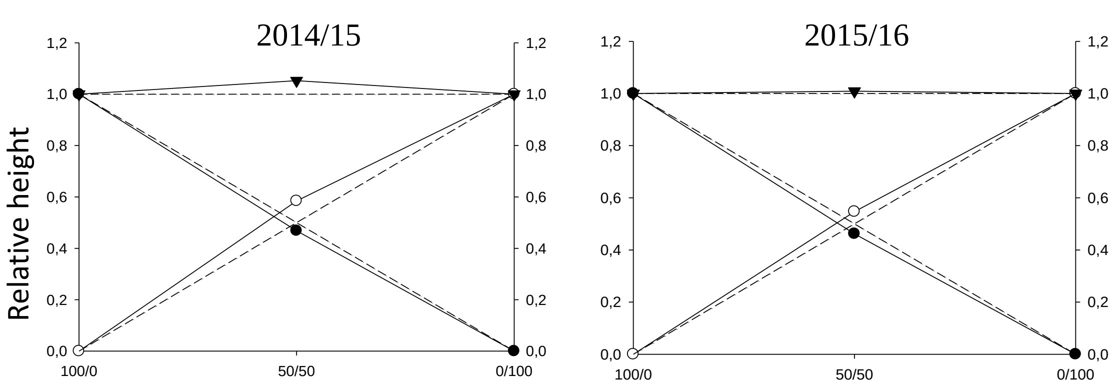
showing crop losses due to the competition with C_3 weeds (Silva et al., 2014). Moraes et al. (2017) observed that, regardless of the proportion of species, bean plants were more competitive and exhibited higher relative productivity of dry mass and height than blackjack.

Concerning TP, there were differences in SDM in both growing seasons, as well as in LA in the 2015/2016 season, i. e., values were lower than one (Table 1). However, there was no mutual damage to species growth in the first year under study, since RP of soybean was represented by convex lines for LA and SDM, while blackjack was represented by concave lines for all variables (Figure 1).

Thus, it may be inferred that decrease in TP resulted mainly from the low contribution of the weed (C_3) caused by the high competitiveness of soybean, rather than by the occurrence of mutual damage between both species (Agostinetto et al., 2013). However, in the second year of this study, RP for LA and SDM was represented by concave lines for soybean and blackjack; it shows decrease in growth which may result from the coexistence of plants (Figure 1). Similar results were found by the analysis of competitive ability of soybean cultivars which live with blackjack and wild poinsettia (Forte et al., 2017).

In the second experiment, the analysis of combinations of soybean and slender amaranth plants for variables HEI, LA and SDM, showed that the deviation observed in the line of RP was represented by concave lines for the crop in both growing seasons (Figure 2). Differences in relative productivity (DRP) were found between actual lines and expected ones for HEI of the crop competing with the weed in the first growing season and for LA and SDM in the second season. All exhibited values below the expected ones (Table 1). Thus, soybean and slender amaranth at equal proportions led to changes in the development of the crop in both growing seasons; it may have decreased capture of photosynthetically active energy and accumulation of photoassimilates to produce biomass.



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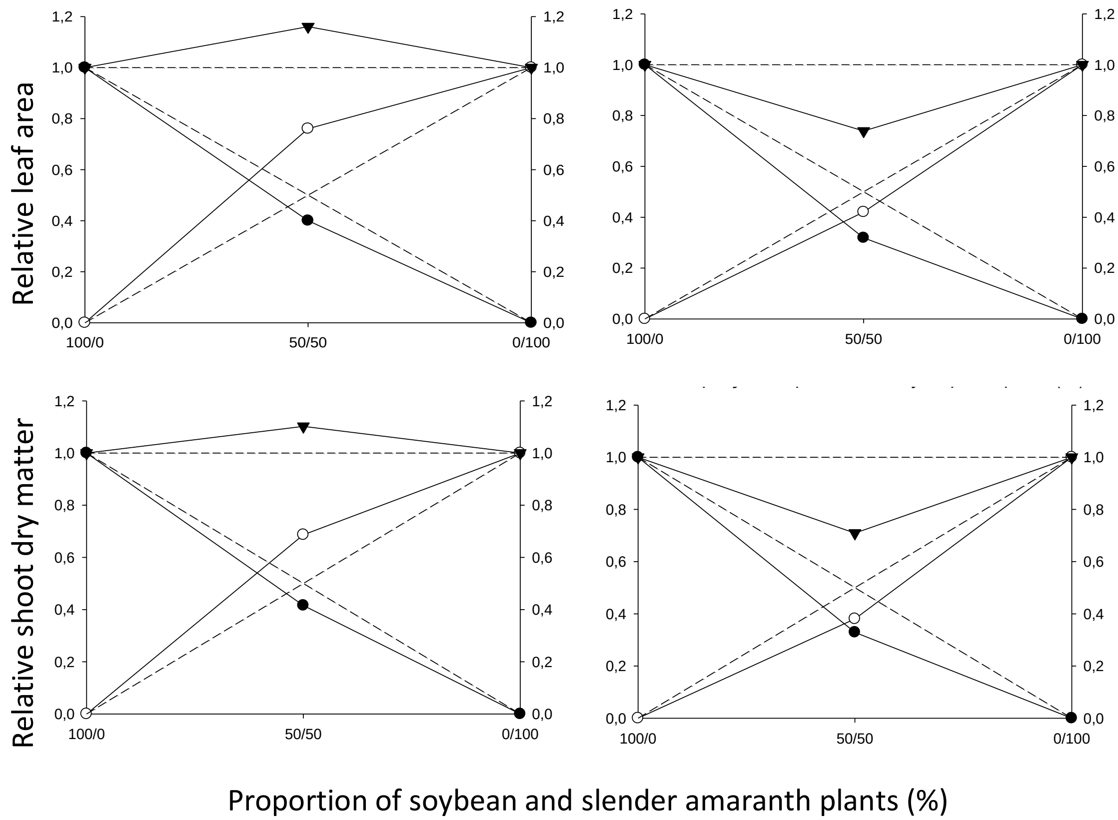

Figure 2. Relative (RP) and total (TP) productivity for height, leaf area and shoot dry matter of soybean and slender amaranth plants, regarding proportions among species in the population, in two growing seasons (2014/15 and 2015/16). Full circles (●) show soybean RP; empty squares (□) show slender amaranth RP; and full triangles (▼) show TP. Dashed lines refer to hypothetical relative productivity, when a species does not interfere in others.

Similar results to these ones were found by a study of soybean competing with hairy fleabane, which, in general, exhibited significant values of DRP for HEI, LA and SDM, lower than the expected ones (Silva et al., 2014). Different results from the ones of this study were found when goosegrass was a weed of soybean and the crop exhibited higher competitive ability (Franco et al., 2017).

In the case of slender amaranth, deviation of the RP line was represented by convex lines for HEI, LA and SDM in the first growing season, while convex lines for HEI and concave ones for LA and SDM were found in the second growing season (Figure 2). When slender amaranth competed with soybean, DRP in the first year exhibited differences in variables HEI and LA with

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positive values. In the second year, only SDM was affected, with negative values (Table 1). Slender amaranth was positively affected by soybean in the first growing season; the ideal temperature to enable plant growth and early development of C_4 plants was also determinant. In the second growing season, plants were sown in November, a fact that led to slow early development of the weed and may have influenced results of the experiment.

Concerning TP, differences were only found in variables LA and SDM in the second growing season for soybean and slender amaranth, i. e., values were below one (Table 1). Thus, competition between C_3 and C_4 plants was found to harm their growth, implying competition for environmental resources. This result disagrees with those found by studies of competitive ability of soybean competing with crabgrass (C_4) and hairy fleabane (C_3) (Agostinetto et al., 2013; Silva et al., 2014).

In order to compare competitive abilities of species, indexes RC, K and C must be analyzed; when they are interpreted together, competitiveness among species can be safely indicated (Cousens, 1991). Results found in the first experiment for variables HEI, LA and SDM, in the first growing season, enable to infer that the soybean crop was more competitive than blackjack. The same happened to this weed for HEI in the second year (Table 2). In the second experiment, in the first growing season, regarding HEI and LA, slender amaranth was more competitive than soybean. The same happened for HEI in the second growing season.

Similar results were found for soybean, since it exhibited more competitiveness than blackjack and wild poinsettia; the latter was more competitive than blackjack by making soybean cultivars produce less LA and SDM (Forte et al., 2017). The soybean crop also had high competitive ability when it co-existed with wild poinsettia (Ulguim et al., 2016) and goosegrass (Franco et al., 2017). However, there are cases in which weeds are more competitive than crops, such as hairy fleabane competing with soybean (Silva et al., 2014).

The high competitive ability of crops – by comparison with weeds – shown by replacement series experiments may result from the fact that the damage caused by weeds results from both individual competitive ability and level of infestation (Vilà et al., 2004), as well as the plant species involved in the competition. In agricultural crops, their populations are kept constant whereas weed populations vary, depending on the soil seed bank and environmental conditions that influence infestation (Agostinetto et al., 2013; Galon et al., 2011).

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Table 2: Indexes of competitiveness between soybean with blackjack and slender amaranth, expressed as relative competitiveness (RC), coefficients of relative clustering (K) and competitiveness (C) in two growing seasons (2014/15 and 2015/16)

Variable	2014/15			
	RC	$K_{soybean}$	$K_{blackjack}$	C
Height	1.08 (±0.02)*	1.04 (±0.04)*	0.90 (±0.02)	0.04 (±0.01)*
Leaf area	1.74 (±0.04)*	1.17 (±0.02)*	0.45 (±0.01)	-0.23 (±0.01)*
Shoot dry matter	1.30 (±0.01)*	1.15 (±0.04)*	0.69 (±0.02)	0.12 (±0.01)*
	RC	$K_{soybean}$	$K_{slender\ amaranth}$	C
Height	0.80 (±0.02)*	0.88 (±0.01)*	1.42 (±0.10)	-0.12 (±0.02)*
Leaf area	0.54 (±0.07)*	0.68 (±0.10)*	3.59 (±0.70)	- 0.36 (±0.07)*
Shoot dry matter	0.63 (±0.10)*	0.73 (±0.11)^{ns}	2.57 (±0.69)	-0.27 (±0.09)^{ns}
Variable	2015/16			
	RC	$K_{soybean}$	$K_{blackjack}$	C
Height	1.15 (±0.02)*	1.16 (±0.05)*	0.87 (±0.01)	0.07 (±0.01)*
Leaf area	1.11 (±0.08)^{ns}	0.77 (±0.00)^{ns}	0.67 (±0.07)	0.04 (±0.03)^{ns}
Shoot dry matter	1.05 (±0.05)^{ns}	0.84 (±0.03)^{ns}	0.78 (±0.04)	0.02 (±0.02)^{ns}
	RC	$K_{soybean}$	$K_{slender\ amaranth}$	C
Height	0.85 (±0.03)*	0.86 (±0.06)*	1.23 (±0.12)	-0.08 (±0.02)*
Leaf area	0.77 (±0.06)*	0.47 (±0.02)^{ns}	0.74 (±0.10)	-0.10 (±0.03)^{ns}
Shoot dry matter	0.87 (±0.07)^{ns}	0.50 (±0.05)^{ns}	0.62 (±0.03)	-0.05 (±0.03)^{ns}

^{ns} Non-significant and * significant by the t test ($p<0.05$). Values between parentheses represent standard errors of means.

In this study, the soybean crop only showed decrease in absolute values of LA when it co-existed with blackjack in the second year of the experiment. The other crop variables and period did not show any statistical difference. Concerning the mixture of blackjack and soybean, decrease in growth variables was also observed in both growing seasons for LA and, in the second, for HEI and SDM (Table 3). In this case, even though interspecific competition damaged both species, co-existence influenced the C_3 weed more and led to damage in both growing seasons.

This result is different from the one found by a study of wild poinsettia as a weed of soybean, in which both produced more biomass than expected, thus, showing higher production as a mixture than as monocultures (Rizzardi et al., 2004). Besides, Silva et al. (2014) found that intraspecific competition was more important to hairy fleabane than to soybean when they co-existed. In a study carried out by Carvalho & Christoffoleti (2008), intraspecific competition harmed the bean crop more than it harmed slender amaranth, while the interspecific one harmed slender amaranth

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more; it suggests that damage caused by weeds are more related to high infestation density than to the intrinsic competitive ability of the species. Some plant characteristics, such as vigorous growth, high stature and large leaf area of bean plants were the components that surpassed vegetative characteristics of blackjack and, consequently, intraspecific competition caused more damage to the crop, while the interspecific one caused more damage to the weed (Moraes et al., 2017).

Table 3: Response of soybean to the interference of blackjack and slender amaranth in two growing seasons (2014/15 and 2015/16)

Plant proportion	2014/15			2015/16		
	Height (cm)	Leaf area (cm^2 $plant^{-1}$)	Shoot dry matter (g $plant^{-1}$)	Height (cm)	Leaf area (cm^2 $plant^{-1}$)	Shoot dry matter (g $plant^{-1}$)
	Soybean:blackjack					
100% soybean	27.09 ^{NS}	380.10 ^{NS}	2.42 ^{NS}	28.08 ^{NS}	239.68 a[1]	2.03 ^{NS}
50% soybean	27.66	409.86	2.59	30.20	208.32 b	1.85
C.V. (%)	4.45	5.63	3.80	5.87	2.40	5.68
100% blackjack	44.23 ^{NS}	207.59 a	1.10 ^{NS}	37.83 a	196.65 a	1.63 a
50% blackjack	41.86	129.11 b	0.90	35.24 b	156.61 b	1.42 b
C.V. (%)	4.55	3.05	11.40	3.50	12.14	5.33
	Soybean:slender amaranth					
100% soybean	27.70 ^{NS}	310.07 ^{NS}	1.72 ^{NS}	27.11 ^{NS}	359.42 a	2,36 a
50% soybean	25.93	248.08	1.43	25.04	229.22 b	1,55 b
C.V. (%)	4.45	15.94	15.17	8.98	6.34	9,44
100% amaranth	21.55 b	189.51 b	1.86 b	26.21 ^{NS}	379.87 ^{NS}	2,92 a
50% amaranth	25.19 a	288.20 a	2.56 a	28.66	319.36	2,22 b
C.V. (%)	5.09	15.48	17.06	9.07	12.71	4,29

^{NS} Non-significant by the F test ($p<0.05$). [1] Means followed by the same letter in a column, in the comparison of proportions of every species for every variable, do not differ statistically by the t test ($p<0.05$).

In interspecific competition, species usually separate their niches in space and/or time, a fact that was observed in the case of C_3 species used by this study. The larger the plant population of the infesting community, the larger the number of individuals that compete for environmental resources and the more intense the competition with the crop. Besides, species that are morpho-physiologically close usually have similar requirements of resources, a fact that intensifies competition.

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In the second experiment, the soybean crop only exhibited decrease in LA and SDM when it co-existed with slender amaranth (50:50) in the second year of the experiment, thus, showing that interspecific competition harmed the crop (Table 3). The weed exhibited increase in HEI, LA and SDM when it competed with soybean in the first year of the experiment, while, in the second growing season, there was decrease in SDM of slender amaranth as a weed of soybean. Thus, intraspecific competition led to more damage to the weed, but there was a positive effect on its growth as the result of the co-existence with the soybean crop.

The way in which plants with different photosynthetic routes respond to environmental changes is especially important to the interaction between crops and weeds in agricultural systems. Most weed species that cause productivity loss in crops are C_4 plants, while most crops of relevance are C_3 ones (Valerio et al., 2011). High competitiveness of species of slender amaranth may be related to the C_4 carbon assimilation cycle, to germination velocity and period, to growth velocity and to infestation density (Carvalho & Christoffoleti, 2008). Besides, interaction between crops and weeds may vary as the result of geographical region and its local conditions, such as temperature and precipitation.

4. CONCLUSION

In the competition among plants whose photosynthetic route is C_3, the soybean cultivar used by this study was more competitive than blackjack, but with plants which had other routes, slender amaranth (C_4) was more competitive than the crop. Besides, in the cases of soybean and blackjack, interspecific competition predominated and harmed both species, while intraspecific competition caused more damage to slender amaranth than the interspecific one.

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