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Morphophysiological responses of conventional and gm soybean with distinct biotechnological background to weed competition

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ABSTRACT

New technologies developed to control weeds in crops are flourishing in recent years. Therefore, the objective of this work was to study the competitive ability of soybean cultivars C2531E (Enlist®), M6410 IPRO (RR2®) and BRS 257 (conventional), with distinct biotechnological background, when competing against *Euphorbia heterophylla* and *Urochloa plantaginea*. Crops and competitors were studied in distinct plant proportions: 24:0; 18:6; 12:12; 6:18 and 0:24 plants per plot. Fifty days after emergence, plant height, leaf area (AL) and aboveground dry mass (DM), photosynthetic and transpiration rates and stomatal conductance were assessed. Crop responses to competition tended to be species-specific. Soybean M6410 IPRO presents better morphophysiological performance compared to C2531E and BRS 257 when it competed against *U. plantaginea*. The soybean BRS 257 showed greater LA when competing against *U. plantaginea*. The competitiveness indices showed that M6410 IPRO responses to competition by accumulating aboveground DM while C2531E responsesby increasing LA. There was difference among cultivars in their strategy to deal with the weed competition, and M6410 IPRO had better competitive ability than the other cultivars when it competed against *E. heterophylla*.

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1. Introduction

The agronomic performance of the crop, as well as grain quality and yield of soybean can be affected by several factors, among which competition with weeds is highlighted (Forte et al. 2017; Song et al. 2017) when they are not properly controlled. Weeds compete with soybean plants for environmental resources such as light, water, nutrients, and physical space; they may release allelopathic substances to soil and can also harbor pests and diseases (Soltani et al. 2017; Konzen et al. 2021).

With the ease of weed management in soybean crop promoted by RR®, the use of glyphosate started to be made indiscriminately (Sausen et al. 2020). The result of this was the appearance of resistant weeds, and increased densities of tolerant species, to glyphosate as wild poinsettia (*Euphorbia heterophylla*). This weed is resistant to EPSPs, ALS and PROTOX inhibitors, while Alexandergrass (*Urochloa plantaginea*) has resistant biotypes to ALS and ACCase inhibitors (Heap 2022). These weeds, thus, may pose limitation for chemical weed control in soybean fields since these mechanisms of action are the most used for weed control in soybean. Grain yield losses due to defficient control of resistant and/or tolerant weeds in soybean can reach 92.5% (Silva et al. 2009; Soltani et al. 2017; Song et al. 2017). To minimize crop damage and reduce the impact caused by weed resistance, investments have been made in the development of new herbicide-resistant transgenic cultivars with different mechanisms of action (Hammer et al. 2018).

The Enlist® technology was developed in soybeans, aiming at concomitant resistance to the herbicide 2,4-D, glyphosate and ammonium glufosinate (Fast et al. 2016; Papineni et al. 2017). In this way, combining the technology Enlist® with most competitive soybean genotypes allow to minimize production costs, and to lessen the demand for herbicides. There is, however, little information about the competitive ability of Enlist® soybean cultivars against weeds, especially wild poinsettia and Alexandergrass, as this technology is recent to date.

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Weed population in an area varies according to soil seed bank, edaphoclimatic conditions, management and cultural treatments (Agostinetto et al. 2013; Forte et al. 2017). Therefore, it is important to analyze the influence of crop: weed proportion and the performance of distinct soybean cultivars in order to develop weed management strategies (Bianchi et al. 2006; Agostinetto et al. 2013; Konzen et al. 2021). The greater competitive ability of a species in relation to another one indicates that it will have a greater capacity to assimilate environmental resources and, therefore, will have greater potential to grow and develop (Bianchi et al. 2006; Agostinetto et al. 2013).

In weed species, genetic differences between the susceptible and the resistant biotype to a given herbicide often do not cause differences in weed's competitive ability (McKenney et al. 2007; Schreiber et al. 2018; Henckes et al. 2019), but in some cases this effect was reported (Brandler et al. 2021). Thus, even small changes in plant's genetic background could pose some limitation to its developmental performance, or alternatively to increase the yield of a given answer to stressing factors (Raymond et al. 2011; Liu et al. 2021). The breeding process aiming to insert genes into a plant that confer herbicide tolerance, may also be causing similar responses, and this was not previously investigated in soybean. This is the novelty of the present study.

The hypothesis of this work is that genetically modified soybean cultivars demonstrate greater competitive ability in the presence of wild poinsettia and Alexandergrass compared to conventional soybean. Therefore, the objective of this work was to study the competitive ability of soybean cultivars C2531E (Enlist®), M6410 IPRO (RR2®) and BRS 257 (conventional), with distinct biotechnological background, when competing against wild poinsettia and Alexandergrass.

2. Material and methods

2.1. edaphoclimatic traits and experimental design

Eleven experiments were conducted in greenhouse of Universidade Federal da Fronteira Sul, campus Erechim/RS, Laboratório Manejo Sustentável dos Sistemas Agrícolas, in experimental units consisting of plastic pots with 8 dm^3, filled with soil from areas cultivated with annual crops, classified as Humic Red Alumino Ferric Latosol, previously corrected and fertilized. Chemical and physical soil properties were: pH_{water}= 4.8; OM = 3.5%; p = 4.0 mg dm^{-3}; K = 117 mg dm^{-3}; Al^{3+} = 0.6 $cmol_c$ dm^{-3}; Ca^{2+} = 4.7 $cmol_c$ dm^{-3}; Mg^{2+} = 1.8 $cmol_c$ dm^{-3}; $CTC_{(t)}$ = 7.4 $cmol_c$ dm^{-3}; $CTC_{(TpH7)}$ = 16.5 $cmol_c$ dm^{-3}; H + Al = 9.7 $cmol_c$ dm^{-3}; SB = 6.8 $cmol_c$ dm^{-3}; V = 41%; and Clay = 60%. The experimental design was randomized blocks, with four replications.

2.2. Species used in experiments, preliminary tests, and assessed variables

Competitors were soybean cultivars C2531E (Enlist®), M6410 IPRO (RR2) and BRS 257 (conventional, non-transgenic), competing against the weeds wild poinsettia (*Euphorbia heterophylla*) or Alexandergrass (*Urochloa plantaginea*), at different plant proportions.

Five preliminary experiments were installed, three monoculture crops of C2531E, M6410 IPRO and BRS 257, and two monoculture weeds of *E. heterophylla* and *U. plantaginea*, aiming to determine the minimal plant density from which the final production of aboveground dry mass becomes constant and independent of planting density. For this, 1, 2, 4, 8, 16, 24, 32, 40, 48, 56 and 64 plants per plot were tested (equivalent to 24, 48, 96, 192, 384, 576, 768, 960, 1,152, 1,344 and 1,536 plants m^{-2}). The final constant production of aboveground dry mass was obtained with 24 plants per pot, for soybean cultivars C2531E, M6410 IPRO and BRS 257, and the weeds *E. heterophylla* and *U. plantaginea*.

2.3. Definitive experiments installed in a substitutive series

Another six experiments were installed to assess the competitiveness of the soybean cultivars C2531E, M6410 IPRO and BRS 257 against wild poinsettia and Alexandergrass, carried out in a replacement series, in different combinations of cultivars: weed plant proportions (24:0; 18:6; 12:12; 6:18 and 0:24 or 100:0; 75:25; 50:50; 25:75 and 0:100%), keeping the total plant density constant (24 plants per plot). To establish the desired densities in each treatment and obtain seedling size uniformity, the seeds were previously sown in alveolar Styrofoam trays, being later transplanted to plots.

Fifty days after emergence (DAE) of the species, plant height (AP - cm), leaf area (AF - cm^2 $plot^{-1}$) and aboveground dry mass (DM - g $plot^{-1}$) were measured. AP was measured with a ruler from soil to the tip of the longest leaf of soybean and weed plants. For AF determination, a portable leaf area meter model CI-203 (BioScence, Inc.) was used, being quantified the AF for all plants of each species, into the plot. After AF determination, plants were cut at soil level and placed in kraft paper bags,

dried into oven with forced air circulation at 60 ± 5 °C, and later weighted for DM.

At the same time (50 DAE) the photosynthetic rate (A - μmol CO_2 m^{-2} s^{-1}), stomatal conductance (Gs - mol m^{-2} s^{-1}) and the transpiration rate (E - mol H_2O m^{-2} s^{-1}) were measured in the middle third of the last fully expanded leaf of soybean and weed plants. For this, an infrared gas analyzer (IRGA), ADC/LCA Pro (Analytical Development Co. Ltd, Hoddesdon, UK) was used. One block was evaluated per day, under natural light conditions between 08:00 and 10:00am, under clear sky conditions, so that homogeneous environmental conditions were maintained during the analyses of plots into the same experimental block.

2.4. Experimental analysis

The data set was analyzed using the method of graphical analysis of variation, or relative productivity (Cousens 1991; Bianchi et al. 2006). The referred procedure consists in the construction of a diagrams based on the relative (PR) and total (PRT) productivities. In graphs, the black straight dashed lines (- - - -) represent the expected values for PR and PRT in each situation. The observed (experimental) values are superposed to the expected ones as solid blue lines (———), with the respective 95% confidence intervals (95% CI) and the original observed values (dots).

Light red (■/●), green (■/▲) and blue (■/▪) colors were used to represent both the 95% CI and the original values for PR_{crop}, PR_{weed} and PRT, respectively. In sections where the confidence intervals included the respective expected dashed line, there was no difference between expected and observed values; on the other side, in sections where the expected dashed line was out of the respective colored 95% CI, treatments were considered to differ. When $PR_{observed} < PR_{expected}$, there was loss in the growth of the species. When $PR_{obs} > PR_{exp}$, there is a benefit for growth of the species. When $PRT_{obs} = PRT_{exp}$, there is competition for the same resources; when $PRT_{obs} > PRT_{exp}$, competition is avoided, and when $PRT_{obs} < PRT_{exp}$, there is mutual damage to growth (Cousens 1991).

The relative competitiveness index (CR), relative clustering coefficient (K) and aggressiveness (A) were calculated. To calculate the indices, the 50:50 proportions of the species involved in the experiment (soybean versus wild poinsettia or Alexandergrass) were used, that is, the densities of 12:12 plants pot^{-1}, using the equations: RC = RPx/RPy; Kx = RPx/(1-RPx); Ky = RPy/(1-RPy); A = RPx-RPy, according to Cousens and O'Neill (1993). The CR represents the comparative growth of soybean cultivars (X) in relation to wild poinsettia or Alexandergrass (Y); K indicated the clustering ability of one species over another, and A indicates which species is most aggressive in its growth. Soybean cultivars (X) are more competitive than wild poinsettia and/or Alexandergrass (Y) when CR > 1, Kx > Ky and $A > 0$ (Hoffman and Buhler 2002). The joint analysis of these values indicates with greater precision the competitiveness of soybean cultivars when facing weed infestation.

The physiological (A, GS and E) and morphological (plant height, leaf area and aboveground dry mass) parameters of soybean and/or weeds, expressed in mean values per plant, were submitted to analysis of variance by the F-test. When significant, treatment means were compared by Dunnett's, considering the respective monocultures as controls. For all statistical analyzes, the probability of error was adopted as $p \leq 0.05$.

3. Results and discussion

3.1. Physiological variables

The variance analysis of the data demonstrated a significant effect between the proportions of plants of each cultivar soybean and/or wild poinsettia and Alexandergrass for all evaluated variables. Table 1 shows the physiological plant responses to competition. The physiological variables showed different behavior according to plant proportion; when the crop competed with wild poinsettia at a ratio of 25:75, the photosynthetic rate (A) of cv. C2531E was the highest for this cultivar and for other cultivars, under competition, being 2x higher than its control (100:0). This type of competition is known as intraspecific and corroborates with Forte et al. (2017) who reported that interspecific competition is less harmful than intraspecific competition, in a study on competition between soybean and weeds. Bastiani et al. (2016) also reported that soybean in competition with barnyardgrass suffered greater intraspecific interference, resulting in negative effects on morphophysiological traits.

In the proportion 25:75, cv. C2531E differed from the respective control and also presented higher values than the proportions (50: 50 and 75: 25) in the photosynthetic (A) and transpiration (E) rates, and stomatal conductance (Gs). The higher Gs may reflect higher transpiration rates, but it does not necessarily indicate lower efficiency in the water use (Holloway-Phillips 2020).

This inference can be observed in relation to the results obtained by cv. M6410 IPRO, in the 75:25 ratio. As proposed by Bastiani et al. (2016), the larger opening of stomatal pores represented by Gs,

Table 1. Physiological responses of soybean (*Glycine max*) under competition with wild poinsettia (*Euphorbia heterophylla*) and Alexandergrass (*Urochloa plantaginea*) in terms of photosynthesis rate (A-μmol m^{-2} s^{-1}), stomatal conductance (Gs-mol m^{-1} s^{-1}) and transpiration rate (E-mol H_2O m^{-2} s^{-1}) in substitutive series experiment, assessed 50 days after emergence. UFFS, Erechim/RS, 2017/18.

	Physiological variables					
	Wild poinsettia			Alexandergrass		
Proportion between soybean:weed	A	Gs	E	A	Gs	E
	BRS 257 (Conventional)					
100:0 (T)	10.34	0.17	1.83	11.27	0.16	2.06
75:25	8.87	0.14	2.15	8.46	0.12	2.31
50:50	9.11	0.16	2.15	10.92	0.17	3.07*
25:75	5.10*	0.07	1.55	1.96*	0.05*	0.69*
C.V (%)	32.36	40.55	25.35	26.97	25.96	20.83
	C2531E (Enlist®)					
100:0 (T)	3.65	0.08	0.80	5.30	0.08	1.03
75:25	6.65	0.14	0.99	5.60	0.09	1.15
50:50	7.90*	0.15	1.13	10.71*	0.20*	1.72*
25:75	11.75*	0.28*	1.54*	11.43*	0.22*	1.80*
C.V (%)	26.97	25.96	20.83	36.19	42.07	24.82
	M6410 IPRO (RR2®)					
100:0 (T)	10.09	0.19	1.47	9.75	0.24	1.68
75:25	11.70	0.21	1.72	7.34	0.14	1.35
50:50	10.11	0.16	1.61	11.52	0.25	2.03
25:75	9.05	0.15	1.48	11.94	0.28	2.17
C.V (%)	29.66	31.86	18.20	27.98	43.16	24.34

*Mean differ from the respective control (T) by Dunnett's at 5 % probability.

allows the plant to have more CO_2 available in leaf mesophyll and potentially incorporate it faster by photosynthesis (Table 1). These results corroborate those reported by Ulguim et al. (2017), who reported that the increase in Gs resulted in an increase in the values of A in a study with RR soybeans, indicating that Gs is closely linked to A.

The conventional soybean cultivar showed high E when competing with wild poinsettia, as well as low A (Table 1). This behavior is the result of greater interspecific competition. In interspecific competition, species generally separate the occupation of the niche in space and/or time when coexistence is more peaceful, that is, when competition does not occur for the same factors or conditions. On the other hand, when competition occurs for the same resources and it is not enough for everyone, there is predominance in the survival of the most competitive plants or species (Ulguim et al. 2016); the one with the greatest capacity to capture light, which presents rapid initial growth, or even the one that demands less resource requirement, will take advantage (Bianchi et al. 2006; Bastiani et al. 2016).

For Alexandergrass (Table 1), results similar to those found for wild poinsettia were observed. Cultivars C2531E and M6410 IPRO, in the 25: 75 ratio (crop:weed), provided the highest Gs values, which in turn contributed to the better performance of A. Concomitantly, higher values of Gs and E indicate greater water loss by transpiration during stomatal opening, which under certain conditions could limit photosynthesis by promoting stomatal closure (Galon et al. 2013). However, in the present study, Gs and E were higher when species were in competition, indicating that interspecific competition (soybean: Alexandergrass) was not enough to physiologically harm soybean, but activated a physiological reaction of the crop to escape the competitive process.

In the conventional cultivar BRS 257, the proportion between soybean: Alexandergrass differing most from the control was 25:75, with low A highlighted (Table 1). This is due to changes in the physiological characteristics of growth and development that usually occur when plants are subjected to competition (Galon et al. 2013), which results in differences in the use of environmental resources, especially water, influencing directly the availability of CO_2 in the leaf mesophyll and, consequently, the photosynthetic efficiency of the plant (Bastiani et al. 2016).

3.2. Morphological variables

The graphical analysis of the competition (Figures 1, 2 and 3) indicate that the cultivars showed similarities in their reaction to weed competition. Forte et al. (2017) in a study evaluating competitive ability of transgenic soybean cultivars against weeds, reported that cvs. BMX Alvo RR and Fundacep 55RR showed similarities in terms of competition against hairy beggarticks.

Regarding the PRT, there were significant differences between the expected and observed values in at least two proportions in relation to plant height (Figure 1), leaf area (Figure 2) and aboveground dry mass (Figure 3) for all cultivars, when competing with either weed species. In this case, there is mutual

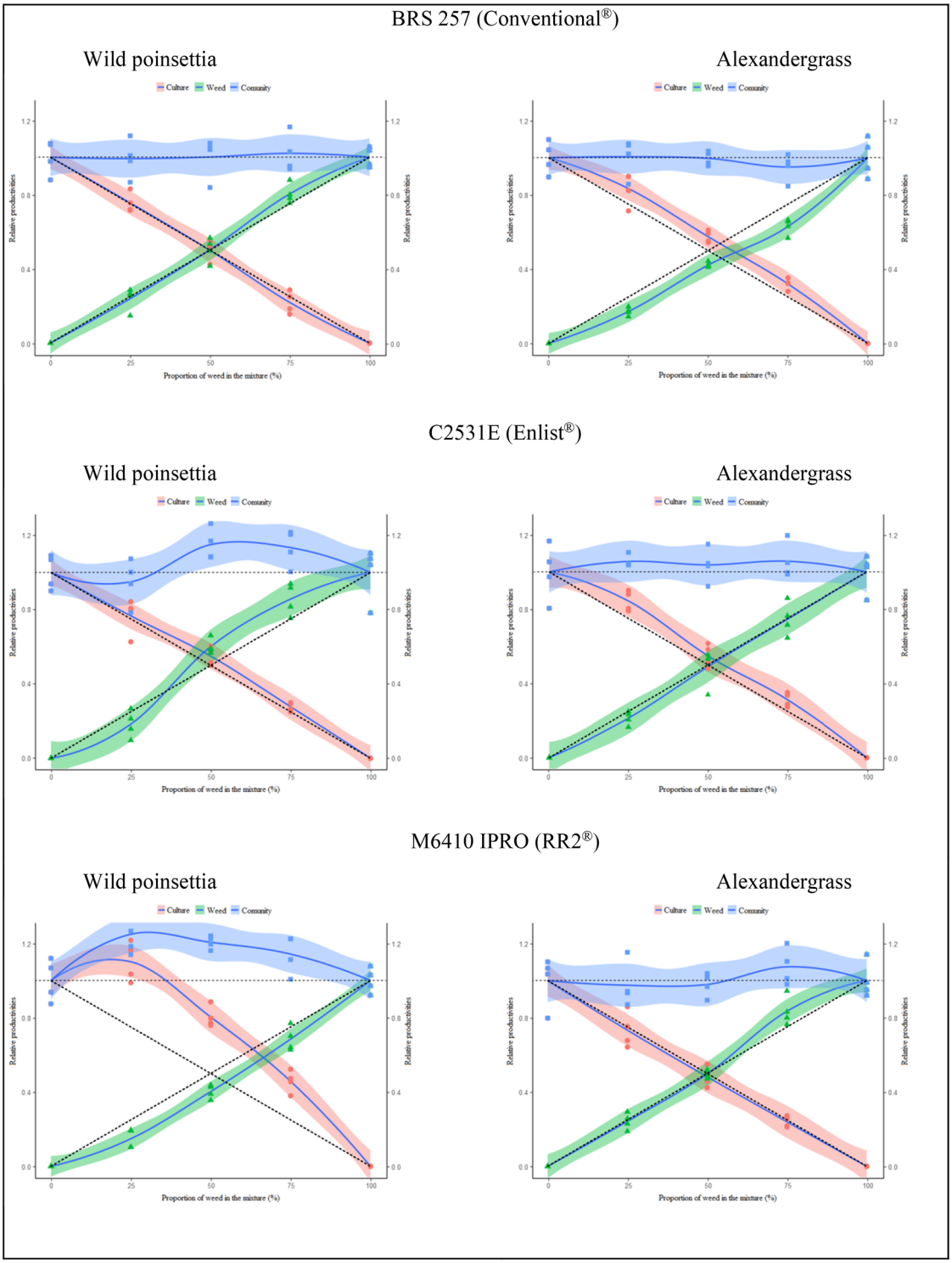

Figure 1. Relative productivity (PR) for plant height of soybean (●) and the competitor (▲) and relative productivity of the community (PRT) (■) as a function of plant proportion (soybean: wild poinsettia or soybean : Alexandergrass) and soybean cultivar. UFFS, Erechim/RS, 2017/18.

antagonism between species (Bianchi et al. 2006). Similarly, Agostinetto et al. (2013), in a study evaluating competitive ability between millet, rice and soybean, found that the leaf area and aboveground dry mass indicated competition between soybean and grabgrass, for the same resources.

Soybean plant height, when the crop competed with wild poinsettia (Figure 1), presented values very close to those expected for PR, for cv. C2531E and BRS 257; M6410 IPRO, on the other hand, was superior than the weed. Cvs. C2531E (Enlist®) and M6410 (RR2®) are genetically related, with very similar genetic background, differing mostly on the introduced herbicide resistance technology. Thus, differences reported between these cultivars are mostly related, directly or indirectly, to the genes which were modified by the introduction of the transgenic technology, or alternatively by their

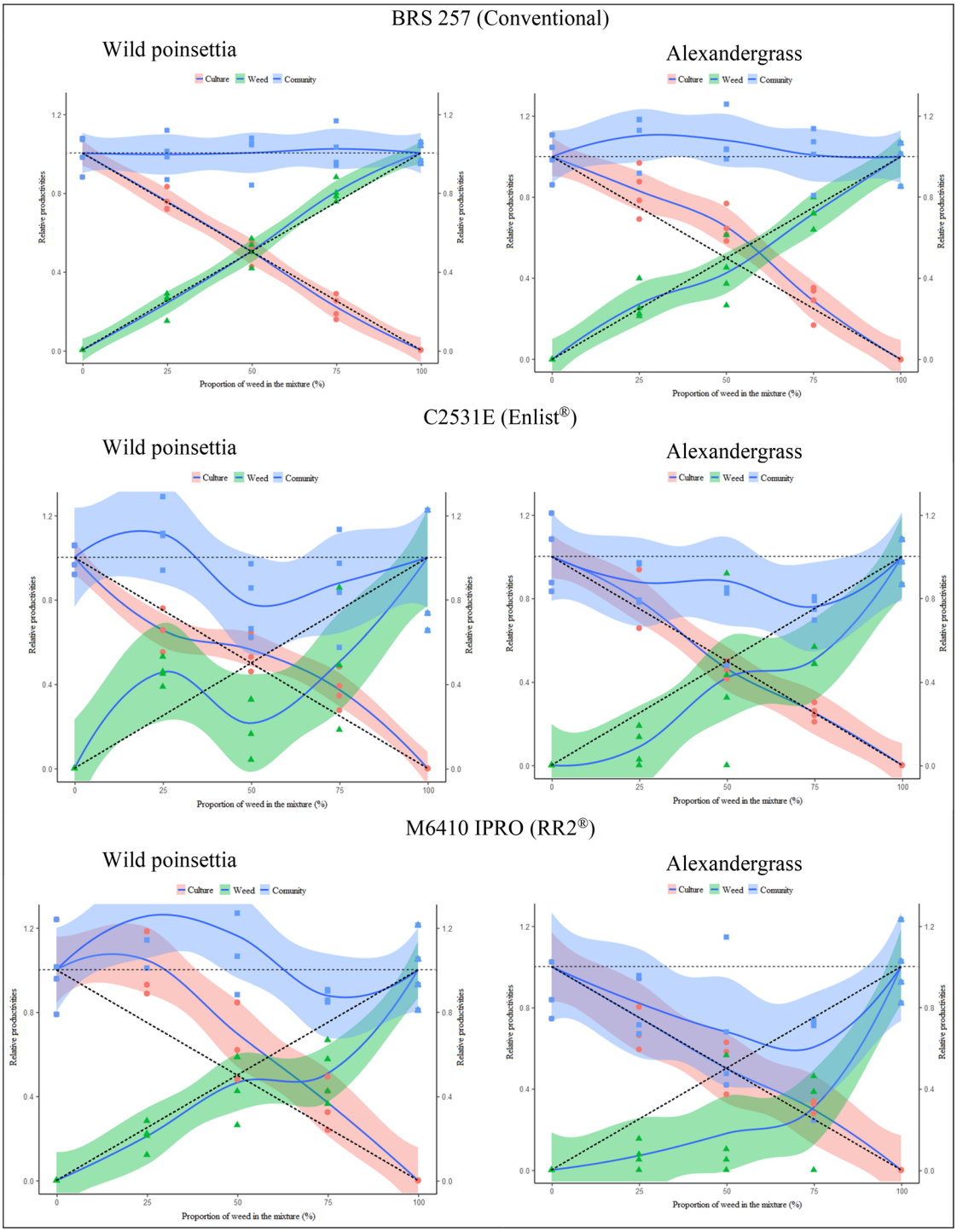

Figure 2. Relative productivity (PR) for leaf area of soybean (●) and the competitor (▲) and relative productivity of the community (PRT) (■) as a function of plant proportion (soybean : wild poinsettia or soybean : Alexandergrass) and soybean cultivar. UFFS, Erechim/RS, 2017/18.

impact on the expression of other genes. In the present study, RR2 soybean was considered more competitive than the others tested, in certain situations (Figure 1). The PRT presented values very close to those expected, for the conventional, and slightly convex for both RR2® and Enlist® cultivars, indicating that competition was avoided.

When the crop competed with Alexandergrass (Figure 1), values close to the expected for PR were observed for all cultivars, indicating that crop and weed present equivalent competitive abilities. PRT also presented values very close to the expected for all cultivars, indicating that there was competition for the same resources.

For leaf area (Figure 2), it was observed that when soybean plants competed with wild poinsettia, they presented PR values close to the expected for C2531E and the conventional cultivars; for M6410 IPRO, the PR indicated benefit when it competed in the proportion of 25: 75 and 50: 50 (crop: weed).

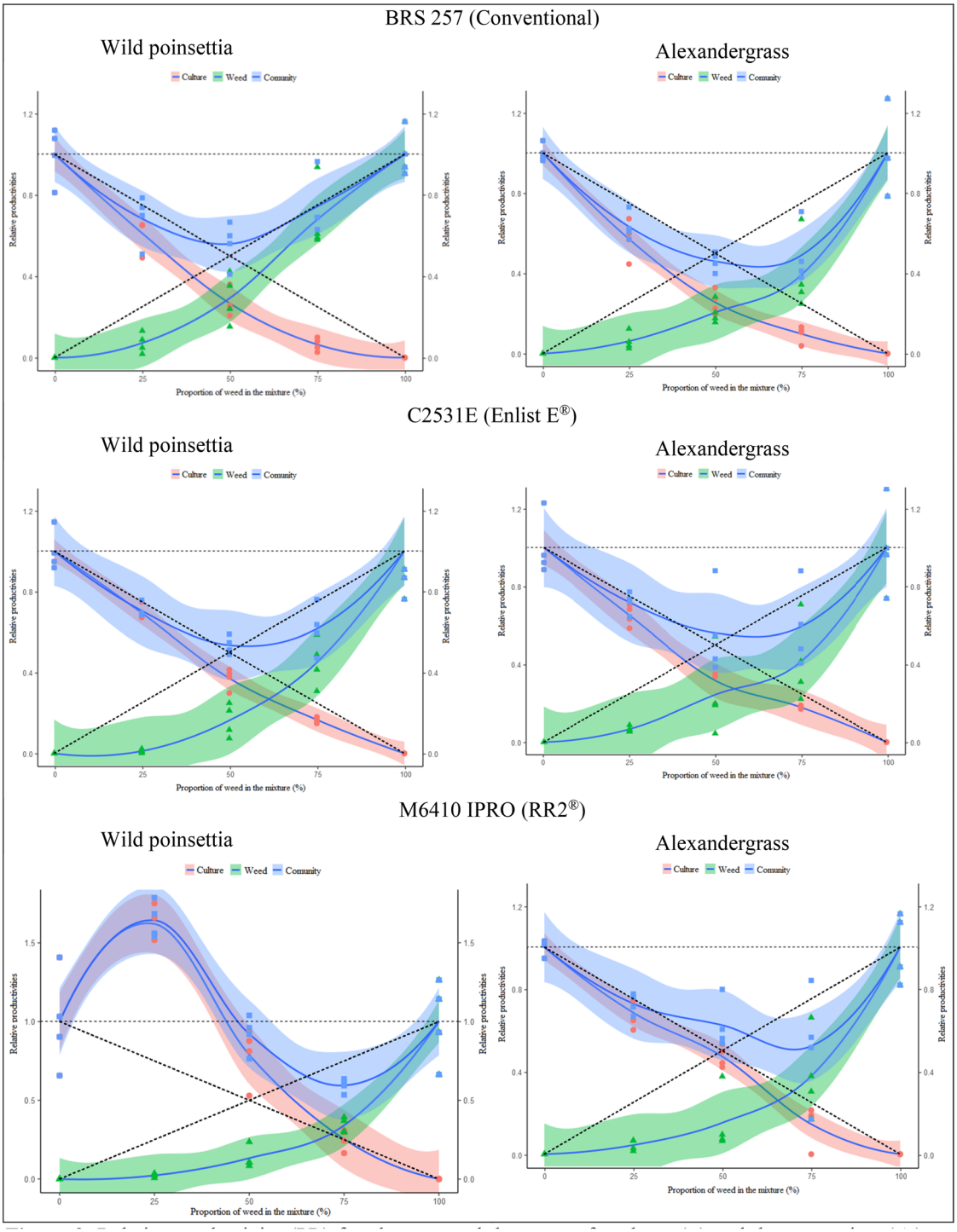

Figure 3. Relative productivity (PR) for aboveground dry mass of soybean (●) and the competitor (▲) and relative productivity of the community (PRT) (■) as a function of plant proportion (soybean : wild poinsettia or soybean: Alexandergrass) and soybean cultivar. UFFS, Erechim/RS, 2017/18.

BRS 257 presented values close to the expected for PRT, while the values were lower than the expected for C2531E. The RR2® cultivar showed values higher than the expected, indicating that competition was avoided. For wild poinsettia, therefore, it is believed that the experimental values were random, and thus in most cases the crop is equivalent to the weed in competitive ability. Regarding the leaf area, when the crop competed with Alexandergrass, it was observed that PR was close to the expected for RR2® and Enlist® cultivars. The conventional cultivar BRS 257 presented PRT_{obs}>PRT_{exp}, showing that competition was avoided. For the RR2® and Enlist® cultivars, there was damage to the crop.

For aboveground dry mass, soybean plants presented loss in growth when competing with wild poinsettia (Figure 3). When the crop competed with this weed 50: 50, the reduction in DM was 46.68% and 25.61% for the conventional and Enlist® cultivars, while there was increase of 57.71% for RR2®. The

PRT for the conventional and Enlist® cultivars reported mutual harm. The lowest accumulated DM describe high interspecific competition, and species competed for the same environmental resources, data that was also reported by Bianchi et al. (2006) studying forage radish and soybean cultivars.

For competition with Alexandergrass, the PR and PRT values are close to those found when the cultivars competed with wild poinsettia, since DM indicated damage to the crop (Figure 3). When the crop competed with Alexandergrass 50:50, the conventional, Enlist® and RR2® cultivars reduced DM by 48.93, 36.53 and 5.66%, respectively.

3.3. Competitiveness indexes

Regarding the morphological variables AP, AF and DM of soybean cultivars, these were negatively affected when they competed with wild poinsettia and/or Alexandergrass in all plant proportions (Table 2). It was observed that the higher the proportion of competitors, the greater the damage to soybean. Similar results were reported by Konzen et al. (2021). Furthermore, soybean AP was not affected for BRS 257 and C2531E competing against wild poinsettia, and for M6410 IPRO competing against Alexandergrass (Table 2).

As for the competitiveness indexes (Table 3), when the competition took place wild poinsettia, the cultivar C2531E was most competitive for leaf area and aboveground dry mass (DM), as CR > 1, Kx > Ky and $A > 0$. In addition, to prove competitive superiority, it is necessary to have differences in at least 2 indices (Bianchi et al. 2006). According to these requirements, the cultivar RR2® M6410 IPRO was most competitive than wild poinsettia only for DM.

The other associations, such as M6410 IPRO with wild poinsettia, and BRS 257 and M6410 IPRO with

Table 2. Morphological responses of soybean cultivars to interference promoted by Alexandergrass (*Urochloa plantaginea*) or wild poinsettia (*Euphorbia heterophylla*) in terms of aboveground dry mass plant height and leaf area, in substitutive series experiments assessed 50 days after emergence.

	Morphological Variables					
	Plant height (cm)		Leaf area (cm^2 $plant^{-1}$)		Dry mass (g $plot^{-1}$)	
Soybean (%) :	BRS 257 (conventional) *versus* wild poinsettia					
Weed (%)	Soybean	Wild poinsettia	Soybean	Wild poinsettia	Soybean	Wild poinsettia
100:0 (T)	62.96	84.88	5.05	4.95	72.65	69.80
75:25	63.32	90.80	5.10	5.35	59.20	63.15
50:50	62.80	85.30	4.65	4.85	38.73*	40.78*
25:75	55.08	80.97	4.00	4.10	18.70*	9.98*
C.V (%)	16.50	16.40	32.50	53.90	21.70	32.50
Soybean (%) :	C2531E (Enlist E®) *versus* wild poinsettia					
Weed (%)	Soybean	Wild poinsettia	Soybean	Wild poinsettia	Soybean	Wild poinsettia
100:0 (T)	61.39	79.15	4.35	2.45	82.02	121.48
75:25	62.72	90.41	3.80	1.65	75.87	72.82*
50:50	67.47	95.07	4.90	1.05*	61.01*	39.56*
25:75	68.05	58.07	6.50*	4.47*	54.55*	5.41*
C.V (%)	11.00	19.60	20.30	35.90	10.80	44.10
Soybean(%) :	M6410 IPRO (RR2®) *versus* wild poinsettia					
Weed(%)	Soybean	Wild poinsettia	Soybean	Wild poinsettia	Soybean	Wild poinsettia
100:0 (T)	38.40	98.38	3.55	4.95	33.91	85.29
75:25	56.38*	89.83	4.95	3.35	73.28*	38.77*
50:50	61.72*	79.15	4.95	4.60	53.48*	22.59*
25:75	70.30*	58.40*	5.25	4.15	34.36	7.75*
C.V (%)	12.10	16.70	27.10	31.20	21.90	38.10
Soybean(%) :	BRS 257 (conventional) *versus* Alexandergrass					
Weed(%)	Soja	Papuã	Soja	Papuã	Soja	Papuã
100:0 (T)	59.47	100.02	3.25	3.75	86.22	76.12
75:25	66.12	83.97*	3.60	3.60	65.63*	39.74*
50:50	68.35	84.42*	4.25	3.20	44.03*	31.14*
25:75	76.2*	68.6*	3.75	4.10	33.79*	18.76*
C.V (%)	9.90	10.10	20.40	26.90	20.40	39.30
Soybean(%) :	C2531E (Enlist E®) *versus* Alexandergrass					
Weed(%)	Soybean	Alexandergrass	Soybean	Alexandergrass	Soybean	Alexandergrass
100:0 (T)	58.80	85.80	4.80	1.85	99.65	101.36
75:25	66.15	85.30	5.05	1.25	86.52	55.89
50:50	64.46	84.09	4.45	1.55	63.24*	49.45*
25:75	73.45*	73.10	4.85	0.65	71.52*	30.02*
C.V (%)	12.90	17.30	16.30	66.30	16.80	53.70
Soybean(%) :	M6410 IPRO (RR2®) *versus* Alexandergrass					
Weed(%)	Soybean	Alexandergrass	Soybean	Alexandergrass	Soybean	Alexandergrass
100:0 (T)	75.95	71.72	4.30	1.95	81.73	100.18
75:25	74.22	79.83	4.30	0.80*	74.47	50.34*
50:50	73.22	71.30	4.30	0.70*	77.10	30.35*
25:75	72.72	69.35	5.10	0.55*	64.87*	17.53*
C.V (%)	14.20	12.70	24.80	72.60	9.80	50.70

*Means differ from the respective control (T) by Dunnett's at 5 % probability.

Table 3. Competitiveness indexes between soybean (*Glycine max*) cultivars (BRS 257 - conventional, C2531E - Enlist E® and M6410 IPRO - RR2®) and the competitor (wild poinsettia or Alexander grass) in equal plant proportion (50 : 50), expressed as relative competitiveness (CR), clustering ability (K) and aggressiveness (A), 50 days after emergence. UFFS, Erechim/RS, 2017/18.

	CR^2	Kx (soybean)	Ky (competitor)	A
Variables		Leaf area		
Conventional x wild poinsettia	1.174 ± 0.236 ns	0.899 ± 0.162	8.400 ± 7.868	−0.030 ± 0.133
Enlist® x wild poinsettia	5.403 ± 3.277	1.354 ± 0.222*	0.302 ± 0.110	0.349 ± 0.081*
RR2® x wild poinsettia	1.653 ± 0.336 ns	3.364 ± 1,215	0.981 ± 0.262	0.233 ± 0.118
Conventional x alexandergrass	1.719 ± 0.407 ns	2.042 ± 0.439	0.844 ± 0.265	0.227 ± 0.101
Enlist x alexandergrass	1.194 ± 0,288 ns	0.87 ± 0.061	3.144 ± 2.734	0.045 ± 0.197
RR2® x alexandergrass	0.891 ± 0,114 ns	1.097 ± 0.263	0.366 ± 0.310	0.321 ± 0.119
		Aboveground dry mass		
Conventional x wild poinsettia	1.087 ± 0.296 ns	0.372 ± 0.066	0.444 ± 0.123	−0.026 ± 0.080
Enlist x wild poinsettia	2.996 ± 0.984	0.600 ± 0.062*	0.203 ± 0.059	0.209 ± 0.064*
RR2® x wild poinsettia	7.343 ± 1.801*	6.805 ± 2.887	0.159 ± 0.050	0.656 ± 0.124*
Conventional x alexandergrass	1.264 ± 0,282 ns	1.097 ± 0.263	0.366 ± 0.310	0.321 ± 0.119
Enlist x alexandergrass	3.027 ± 1,901 ns	1.097 ± 0.263	0.366 ± 0.310	0.321 ± 0.119
RR2® x alexandergrass	5.221 ± 1,528 ns	1.097 ± 0.263	0.366 ± 0.310	0.321 ± 0.119

*Significant difference according to the *t*-test ($p \leq 0.05$). Values between brackets represent the mean standard error.

Alexandergrass, competed mainly for light as there was plant etiolation with density increase. Higher plant AP, thus, did not reflect in proportional aboveground dry mass. It can be said that soybean altered photoassimilate partitioning among plant organs, investing in variables that could give it greater competitive ability. Bastiani et al. (2016) reports that shaded plants tend to allocate greater amount of resources in stems, growing in height with advantages in the competition for light.

For all cases, it was observed that the interspecific competition was more expressive than intraspecific competition, with the highest averages for crop plants and weed species, when these were presented in higher densities (Table 2). Competition affects production quantitatively and qualitatively, as it modifies the efficiency of the use of environmental resources such as water, light, CO_2 and nutrients (Bianchi et al. 2006). Corroborating the results of this work, other studies also found similar results when soybeans competed with turnip (Bianchi et al. 2006), millet (Agostinetto et al. 2013), wild poinsettia, beggarticks (Forte et al. 2017) and arrowleaf sida (Konzen et al. 2021). Plants, when deprived of any factors necessary for their growth, tend to change their distribution pattern of photoassimilates and, consequently, their morphophysiological characteristics (Santos and Cury 2011). This fact also occurred in the present study with greater accumulation of DM of soybean when free from competition (100:0).

Crops are usually more competitive than weeds because the competitor's achievement is not only related to their greater individual competitive ability, but also to the density that this appears in the crops (Bianchi et al. 2006; Agostinetto al. 2013). In relation to competition with Alexandergrass, none of the cultivars was more competitive, according to the competitiveness indexes as can be seen in Table 3. This may be related to the rusticity that weeds maintain in the evolutionary process, while crops over time were genetically improved by man and in this case many important characteristics related to competition were excluded or lost (Westwood et al. 2018).

M6410 IPRO (RR2®) was the cultivar that stood out in relation to the others, for the expected PR's in the three morphological variables analyzed (AP, AF and DM) when it competed with wild poinsettia, corroborating the competitiveness indexes ($CR > 1$, $Kx > Ky$ and $A > 0$). The high competitive capacity of RR2® soybean may be related to the high photosynthetic rate (Table 1), providing a greater accumulation of biomass and growth, related to higher transpiration rate and stomatal conductance (Concenço et al. 2009). Ulguim et al. (2017) state that a determining factor for greater competitive capacity of plants is greater light interception for the photosynthetic process. Thus, desirable plant traits for superior competitiveness were seen in the RR2® soybean when it competed with wild poinsettia, presenting PR above the expected for AP, AF and DM. As for Alexandergrass, the cultivar that presented results above the expected was the conventional one, for AF, indicating a good performance of this one according to the competitiveness indices.

4. Conclusions

Soybean M6410 IPRO (RR2®) presents better physiological and morphological performance compared to C2531E (Enlist®) and BRS 257 (conventional) when it competed against wild poinsettia. Conventional soybean BRS 257 showed greater leaf area when competing against Alexandergrass, but it presents competitive equivalence with wild poinsettia. The competitiveness indices showed that soybean M6410 IPRO respondeds to competition by accumulating aboveground dry mass while C2531E increased

leaf area. Interspecific competition harms plant heigth, leaf area and aboveground dry mass, compared to the intraspecific competition. Overall, there was difference among cultivars in their strategy to deal with the weed competition. Overall, M6410 IPRO (RR2®) presents better physiological and morphological performance compared to C2531E (Enlist®) and BRS 257 (conventional) when it competed against wild poinsettia.

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