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COMPETITIVE INTERACTION OF MAIZE GENOTYPES WITH DIFFERENT TECHNOLOGIES IN COEXISTENCE WITH WILD POINSETTIA AND ALEXANDERGRASS

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ABSTRACT – Genetically modified maize hybrids, especially those resistant to herbicides, have been released in the Brazilian market. In this context, the study aimed to evaluate the competitive ability of three maize genotypes, 2B433 (Enlist®), Pioneer 30F53 (VYHR®), 13K288 PWE (Enlist®), and a control (conventional, non-transgenic) variety, with different biotechnological backgrounds, when competing with wild poinsettia (*Euphorbia heterophylla*) and Alexandergrass (*Urochloa plantaginea*). The experiment was a randomized block design with four replicates. Maize and competitors were studied at different plant proportions: 20:0; 15:5; 10:10; 5:15 and 0:20 plants per pot or 100:0; 75:25; 50:50; 25:75 and 0:100% (crop: weed) in replacement series experiments. Fifty days after emergence, stomatal conductance, transpiration rate, water use efficiency, relative chlorophyll content, as well as plant height and stem diameter were measured. The Enlist® technology maize genotypes (13K288 PWE and 2B433) showed better physiological and morphological performance compared to the conventional variety and 30F53 (VYHR®) when competing with Alexandergrass and wild poinsettia. It can be inferred that the increase in competitive capacity is due to the greater plant height of the 13K288 PWE (Enlist®) and 2B433 (Enlist®) genotypes. All maize genotypes were more competitive than the weeds, as indicated by the relative competitiveness indices. Based on these results, it can be inferred that there are differences between genotypes; however, further studies are needed to observe the relationship between competitive ability and the transgenic event.

Keywords: *Euphorbia heterophylla*, *Urochloa plantaginea*, *Zea mays*.

Maize cultivation undergoes continuous changes in management and cultural practices, to improve grain productivity. These changes begin with the adoption of seeds with higher production potential, proper mineral nutrition, adjustments in spacing and seeding density according to cultivar characteristics, and primarily the adoption of biotechnology (Aziz et al., 2022; Lopes, 2023).

Biotechnology in maize, particularly through transgenic cultivars, plays a crucial role in increasing productivity. Transgenic cultivars aim to reduce yield losses and minimize risks, such as pest damage and the high costs of weed control, enabling the application of more effective herbicides (Aziz et al., 2022).

One of the earliest successful transgenic traits in commercial crops was glyphosate tolerance (RR), known as the RR technology. While it provided substantial benefits to farmers, its indiscriminate use led to the appearance of glyphosate-resistant weeds, presenting a significant challenge to agriculture (Heap, 2008). In response, new technologies such as Liberty Link were made available for weed management in maize, offering an effective alternative to glyphosate herbicide tolerance. This technology enables the use of glufosinate ammonium for weed control in maize (Westwood et al., 2018). The tolerance to this herbicide is also present in Enlist® maize, which also allows application of haloxyfop, glyphosate, and the new 2,4-D choline.

Herbicide application, however, is not the only weed-control method available to farmers. Weed species such as Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*), which are known to affect maize productivity significantly (Carvalho et al., 2011), may not be easily controlled solely by chemical means. Plants have a natural ability to suppress the growth of surrounding plants, through either allelopathy or competitive traits (Carvalho et al., 2011; Agostinetto et al., 2013; Galon et al., 2023). In tall plants like maize, this natural suppressive effect should be preferred for weed control, thereby reducing reliance on herbicides.

The competitive ability of a given crop species varies among varieties, depending on their capacity to cope with limitations such as light, nutrients, and physical space availability, as well as pest damage (Frandoloso et al., 2019; Galon et al., 2023). Competition also extends to the root environment of plants (Wang et al., 2014), demanding varieties to be tested in competition against specific weed species.

Furthermore, during the introgression process of a transgenic trait into a commercial variety, crop breeders strive to restore the new transgenic variety to its original characteristics, but certain traits may be lost in the process (Aziz et al., 2022). Therefore, related varieties, despite sharing most of their genetic background, may vary in their capacity to compete with weeds (Frandoloso et al., 2019; Aziz et al., 2022). This aspect warrants investigation in maize varieties harboring different transgenic traits for herbicide tolerance, for their competitive ability against weeds.

Therefore, this study aimed to compare the competitive ability of transgenic maize hybrids with distinct herbicide tolerance technologies against wild poinsettia and alexandergrass.

Material and Methods

Fourteen experiments were conducted in a greenhouse, in experimental units consisting of plastic pots (8 dm^3) filled with soil from areas cultivated with annual crops, classified as Oxisol (Santos et al., 2018), 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 dm^{-3}; Ca^{2+} = 4.7 cmol dm^{-3}; Mg^{2+} = 1.8 cmol dm^{-3}; $CTC_{(t)}$ = 7.4 cmol dm^{-3}; $CTC_{(TpH7)}$ = 16.5 cmol dm^{-3}; H + Al = 9.7 cmol dm^{-3}; SB = 6.8 cmol dm^{-3}; V = 41 %; and Clay = 60 %.

The experimental design was randomized blocks with four replications. Competitors were three maize genotypes: 2B433 (Enlist®), Pioneer 30F53 (VYHR®), 13K288 PWE (Enlist®), and a control (conventional, non-transgenic), competing against the weeds wild poinsettia (*Euphorbia heterophylla*) or Alexandergrass (*Urochloa plantaginea*), at different plant proportions.

Six preliminary experiments were conducted, one for each weed species or crop cultivar in monoculture, aiming to determine the minimum plant density at which final aboveground dry mass production 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 20 plants per plot (489 plants m^{-2}), for all maize hybrids and also for the weeds.

Another eight experiments were installed to assess the competitiveness of maize genotypes 2B433 (Enlist®), Pioneer 30F53 (VYHR®), 13K288 PWE (Enlist®) and a conventional inbred (non-transgenic) variety against wild poinsettia and Alexandergrass, carried out in replacement series, in different combinations of cultivar: weed plant proportions (20:0; 15:5; 10:10; 5:15 e 0:20 or 100:0; 75:25; 50:50; 25:75 e 0:100%), keeping the total plant density constant (24 plants per plot). To establish the desired densities in each treatment and achieve uniform seedling size, the seeds were previously sown in alveolar Styrofoam trays and later transplanted to plots.

Fifty days after emergence (DAE) of the species, plant height (PH) and stem diameter (SD) were measured. Plant height was measured with a graduated tape from soil level to the tip of the highest leaf, expressed in centimeters (cm). Stem diameter was measured 2 cm above soil level for all species using a digital caliper, expressed in millimeters (mm). For both PH and SD, 16 plants were measured per treatment (4 plants per replication, 4 replications).

At the same time (50 DAE), the stomatal conductance (Gs - mol m^{-2} s^{-1}), the transpiration rate (E - mol H_2O m^{-2} s^{-1}), and the water use efficiency (WUE - µmol CO_2 mol H_2O) were measured in the middle third of the last fully expanded leaf. For this, an infrared gas analyzer (IRGA) and an ADC/LCA Pro (Analytical Development Co. Ltd., Hoddesdon, UK) were used. One block was evaluated per day, under natural light conditions between 8h and 10h ante meridiem, under clear-sky conditions, so that homogeneous environmental conditions were maintained during the analyses of plots within the same experimental block. During the same period, the relative chlorophyll content (RCC) of the maize plants was also measured. A portable chlorophyll meter, model SPAD 502 Plus, was used to determine the RCC. Measurements were taken at five points on each plant, randomly selected from the lower, middle, and upper canopy leaves.

The dataset was analyzed using the graphical analysis of variation method, or relative productivity (Cousens, 1991; Bianchi et al., 2006). The referred procedure consists of constructing a diagram 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 superimposed on the expected values as solid blue lines (———), with the respective 95 % confidence intervals (95% CI) and the original observed values (dots).

Light brown (■ / ●), 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 hand, 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 a loss in the growth of the species. When $PR_{obs} > PR_{exp}$, there is a benefit for the 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 for the 50:50 plant proportion of the species involved, according to the equations described by Cousens & O'Neill (1993). The CR represents the comparative growth of maize genotypes (X) relative to wild poinsettia or Alexandergrass (Y); K indicates the clustering ability of one species over another, and A indicates which species is most aggressive in growth. Maize cultivars (X) are more competitive than wild poinsettia and/or Alexandergrass (Y) when CR > 1, Kx > Ky, and A > 0 (Hoffman & Buhler, 2002). The joint analysis of these values provides greater precision in assessing the competitiveness of maize hybrids under weed infestation.

The results obtained for E (transpiration rate), GS (stomatal conductance), WUE (water use efficiency), RCC (relative chlorophyll content), PH (plant height), and SD (stem diameter), expressed as mean values per treatment, were subjected to analysis of variance (ANOVA) using the F-test for each of the experiments (genotypes - conventional, Enlist 13K288, 30F53 VYHR and 2B433 Enlist *versus* Alexandergrass and wild poinsettia). When significant, the treatment means were compared using Dunnett's test, with the monocultures serving as controls. For all statistical analyses, a significance level of $p \leq 0.05$ was adopted.

Results and discussion

Distinct differences in physiological variables were observed with changes in the crop ratio (Table 1). Stomatal conductance (Gs) of 13K288 PWE (Enlist®), under competition with Alexandergrass, showed significance at the 50:50 ratio. The other cultivars, 2B433 (Enlist®) and 30F53 VYHR, did not differ significantly from their controls, nor did the conventional variety. Gs, measured in leaves, can be influenced by two factors: changes in stomatal aperture and vapor pressure deficit between the leaf interior and the atmosphere (Ryan et al., 2016). Thus, increases in Gs may strongly affect water loss, thereby increasing transpiration (Bertolino et al., 2019).

Water use efficiency was significantly lower in the inbred variety at the 50:50 ratio compared with the control (Table 1). Regarding the obtained results, it can be observed that the cultivar 13K288 PWE (Enlist®) showed lower results than 2B433 (Enlist®) and, in general, higher than those found in 30F53 VYHR. The more efficient use of water is directly related to the stomatal opening time, as while the plant absorbs CO_2 for photosynthesis, water is lost through transpiration, with varying intensity depending on the potential gradient between the leaf surface and the atmosphere, following a water potential gradient (Bertolino et al., 2019; Freitas et al., 2020). Maize and Alexandergrass use a C4 carbon fixation mechanism, which allows them to use less water per unit of dry mass than other species, indicating a high water-use efficiency (Freitas et al., 2020).

Regarding transpiration rate, only the local variety showed a significant difference, with higher values than its control at the 75:25 ratio (maize: Alexandergrass). In competition with Alexandergrass, the transpiration rate of maize was significantly higher for the cultivar 13K288 PWE (Enlist®) in the 75:25 ratio, and for the cultivar 2B433 (Enlist®) in the 50:50 and 25:75 ratios. Transpiration is a primary determinant of the plant's energy balance and water status, and it is mainly influenced by stomatal conductance (Gs), radiation, and atmospheric saturation deficit (Yoshiyama et al., 2024). The data corroborate this observation, as both Gs and transpiration (E) in the cultivar 13K288 PWE (Enlist®) were significantly higher than in the control and showed proportionally higher values (Table 1).

Stomatal conductance (Gs) was significant for the cultivar 13K288 PWE (Enlist®) when competing with wild poinsettia in the 75:25 ratio, indicating greater intraspecific competition for

Table 1. Physiological responses of maize (*Zea mays*) genotypes subjected to interference from the competitor alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*), expressed in transpiration rate (E - mol H_2O m^{-2} s^{-1}), stomatal conductance (Gs - mol m^{-1} s^{-1}), water use efficiency (WUE - mol CO_2 mol H_2O^{-1}) and relative chlorophyll content (RCC) of the plants, in experiments conducted in replacement series, assessed 50 days after plant emergence. UFFS, Erechim/RS.

Plant proportion (maize : weed)	Physiological parameter							
	Alexandergrass				Wild poinsettia			
	E	GS	WUE	Chlorophyll	E	GS	WUE	Chlorophyll
	Conventional / Inbred							
100:0 (T)	0.91	0.07	6.28	35.2	0.69	0.03	4.83	32.4
75:25	1.24*	0.08	5.43	35.2	0.62	0.03	5.04	31.0
50:50	0.85	0.06	4.00*	36.4	0.59	0.03	7.96	34.4
25:75	0.98	0.06	5.26	34.4	0.69	0.03	3.75	37.0*
	13K288 PWE (Enlist®)							
100:0 (T)	1.18	0.07	7.03	33.3	0.66	0.04	9.78	35.4
75:25	1.95	0.09	6.41	35.5	0.91*	0.06*	7.69	35.8
50:50	1.53	0.11*	7.27	35.0	0.82	0.05	8.15	35.7
25:75	1.34	0.09	7.76	33.3	0.64	0.03	6.95*	38.3
	Pioneer 30F53 (VYHR®)							
100:0 (T)	1.60	0.11	7.97	35.0	1.45	0.07	5.07	36.5
75:25	1.57	0.10	7.69	36.7	1.77	0.09	5.44	39.5
50:50	1.51	0.09	7.33	35.1	1.34	0.12	8.68	41.3
25:75	1.50	0.08	7.86	36.5	1.92	0.17	6.30	41.6
	2B433 (Enlist®)							
100:0 (T)	1.50	0.08	8.19	38.6	2.91	0,07	4.13	33.1
75:25	1.61	0.10	8.35	40.3	0.70*	0,02	2.89	40.1
50:50	1.51	0.10	7.52	40.2	1.71*	0,13	5.48	38.9
25:75	1.55	0.10	8.43	36.3	1.68*	0,09	4.99	38.3

* Mean differ from the control (T) by Dunnett's ($p \leq 0.05$); Gs = stomatal conductance ($mol \cdot m^{-1} \cdot s^{-1}$); E = transpiration rate ($mol\ H_2O \cdot m^{-2} \cdot s^{-1}$); WUE = water use efficiency ($mol\ CO_2 \cdot mol\ H_2O^{-1}$); Clo = Relative chlorophyll content (RCC).

this species (Table 1). Stomatal opening, one of the major regulators of Gs, depends on a series of factors, including solar radiation, CO_2 levels in the mesophyll, air vapor pressure deficit, and others of lesser magnitude (Yoshiyama et al., 2024). Bertolino et al. (2019) state that abundant soil or air moisture increases guard cell turgor pressure, leading to greater stomatal opening, higher Gs, and potentially higher net assimilation rates. The same authors note that when water becomes limited, certain signals emerge, such as reduced hydraulic conductivity and increased abscisic acid (ABA), leading to decreased guard cell turgor pressure and reduced stomatal opening. These results highlight the importance of stomatal regulation and efficiency for plant adaptation.

Regarding the coexistence scenario, the physiological strategy of rational water use can be affected by competition, with some cultivars demonstrating greater competitive abilities than others, and some species exhibiting greater competitive skills as well. Therefore, interactions among species with similar morphological characteristics may result in greater losses than among species with distinct morphological traits. Alexandergrass, a monocotyledon, explores the same root zone and demands similar nutrient amounts as maize plants, thereby reducing the availability of essential resources for the crop (Rodrigues et al., 2014).

For water-use efficiency (WUE), the cultivar 13K288 PWE (Enlist®) showed a lower value than its control in the 25:75 ratio, indicating that interspecific competition was more detrimental in this case (Table 1). Additionally, this cultivar showed higher WUE compared to the others. Water use efficiency (WUE) represents the amount of CO_2 fixed for the production of dry mass relative to the amount of water transpired; in other words, crops that are more efficient in water use can accumulate more dry mass per gram of water transpired (Yoshiyama et al., 2024).

Plants in competition tend to shade each other. Leaves growing in shaded environments tend to have higher chlorophyll content, especially chlorophyll b (Liu et al., 2020). Thus, plants in shaded environments invest more energy in producing pigments that capture light, allowing them to utilize nearly all the available light. In this case, wild poinsettia competing with conventional maize at a 25:75 ratio showed significantly higher RCC (Table 1). Maize, regardless of genotype, in coexistence with Alexandergrass, did not show significant differences in RCC. Ribeiro et al. (2017), in a competition study among beans, beggarticks, and Brachiaria grass, observed no difference in relative chlorophyll content among the species due to competition, corroborating results from a study with maize cultivars competing with Alexandergrass. Thus, it can be inferred that the RCC is altered only in the conventional genotype (25:75), which was more affected by competition compared to its control without wild poinsettia, due to its higher RCC. For the other maize genotypes, regardless of the competing weed, no differentiation in the crop's RCC was observed.

The following figures illustrate competition between maize cultivars, Alexandergrass, and wild poinsettia for various plant morphological variables. Figure 1 shows the relative and total productivity of plant proportions for cultivars 2B433 (Enlist®), Pioneer 30F53 (VYHR®), 13K288 PWE (Enlist®), and the inbred variety, with wild poinsettia as the competitor, regarding plant height. The interaction was significant for relative plant height productivity among the cultivars 2B433 (Enlist®), 13K288 PWE (Enlist®), and the inbred variety. For significance to be observed, at least two plant proportions must differ significantly (Bianchi et al., 2006). For the Pioneer 30F53 (VYHR®) cultivar, relative productivity was close to expected levels. For the cultivar 2B433 (Enlist®), relative productivity (PR) exceeded expectations in the 25:75, 50:50, and 75:25 ratios. Similarly, for the cultivar 13K288 PWE (Enlist®) and the local variety, PR was higher than expected in the 50:50 and 25:75 ratios.

Regarding total relative productivity (PRT), most ratios yielded values close to the expected levels determined by the straight line. However, across all cultivars at the 50:50 ratio, a concave curve was observed, indicating that growth was negatively affected in at least one of the species. Plant height is a crucial variable in assessing competitiveness, as taller plants are more competitive because they capture more solar radiation than shorter plants (Lamego et al., 2013). Shading caused by taller plants over shorter ones reduces the density of photosynthetically active photons, leading to decreased photosynthetic rates (Wandscheer et al., 2013) and, consequently, reduced biomass.

Figure 2 reports the interaction of maize cultivars in competition with Alexandergrass. The interaction was significant for relative productivity (PR) in the cultivars 2B433 (Enlist®) and 13K288 PWE (Enlist®), characterized by a convex line above the expected line. The inbred variety showed results above expectations at the 50:50 ratio, indicating that competition with Alexandergrass did not impair maize growth at this ratio. The cultivar 30F53 (VYHR®) exhibited a straight line, indicating minimal competition between the species.

Total relative productivity (PRT) for the cultivar 30F53 (VYHR®) and the inbred variety indicates that both species experienced negative impacts from competition, as shown by the concave line. The cultivars 2B433 (Enlist®) and 13K288 PWE (Enlist®) had PRT close to expected levels at lower interspecific competition levels, but as competition increased, the lines became concave, indicating that competition was detrimental to the growth of both species. These results are similar to those found by Wandscheer et al. (2013), who observed in a study of maize competition with crabgrass that relative productivity for maize plant height decreased in the presence of equal and greater proportions of the weed.

Relative productivities for stem diameter (SD) of maize in competition with wild poinsettia

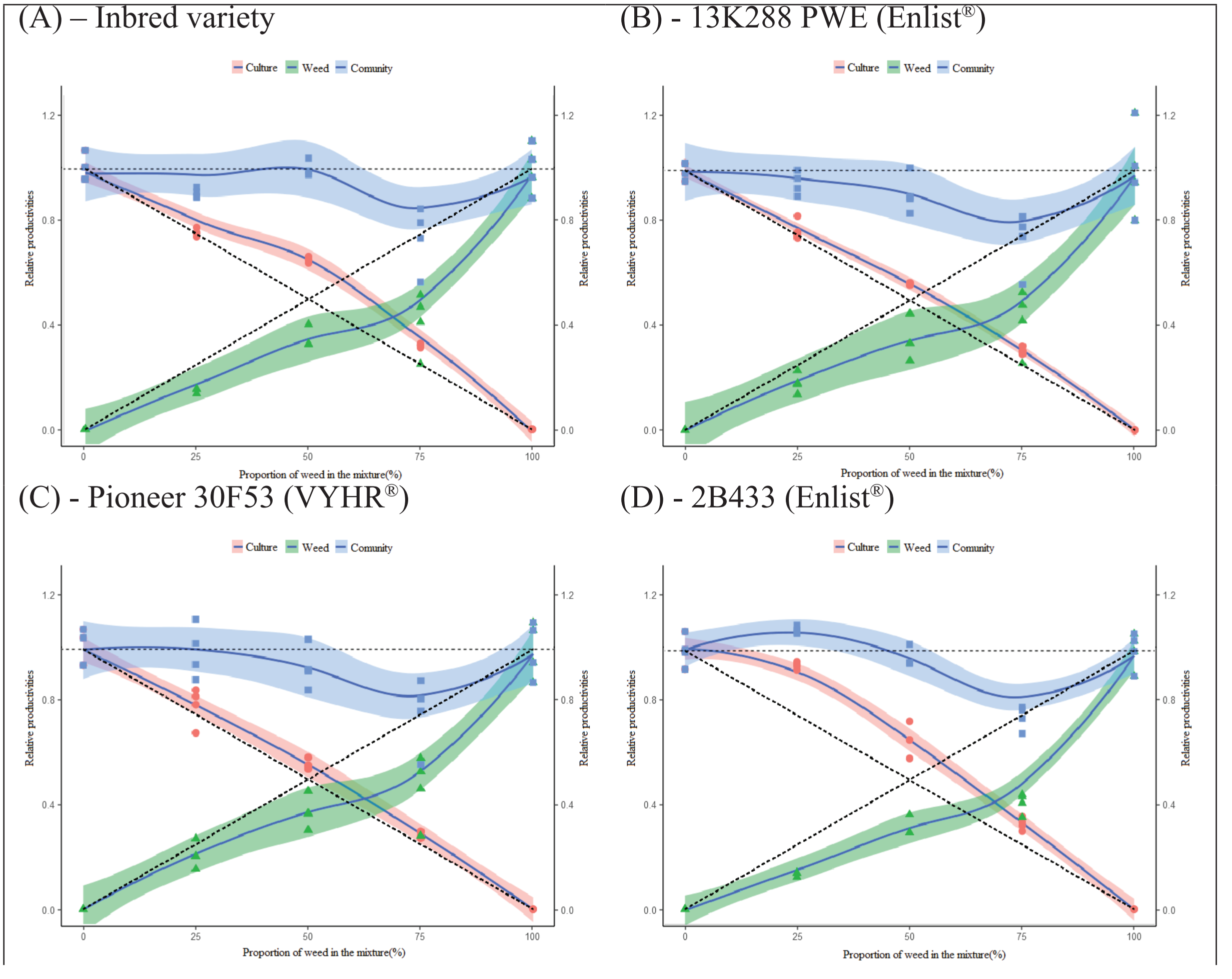

Figure 1. Relative productivity (PR) for plant height of maize (●) and wild poinsettia (▲), and total relative productivity (PRT) of the community (■) as a function of the proportion of associated plants (maize : wild poinsettia). UFFS, Erechim/RS.

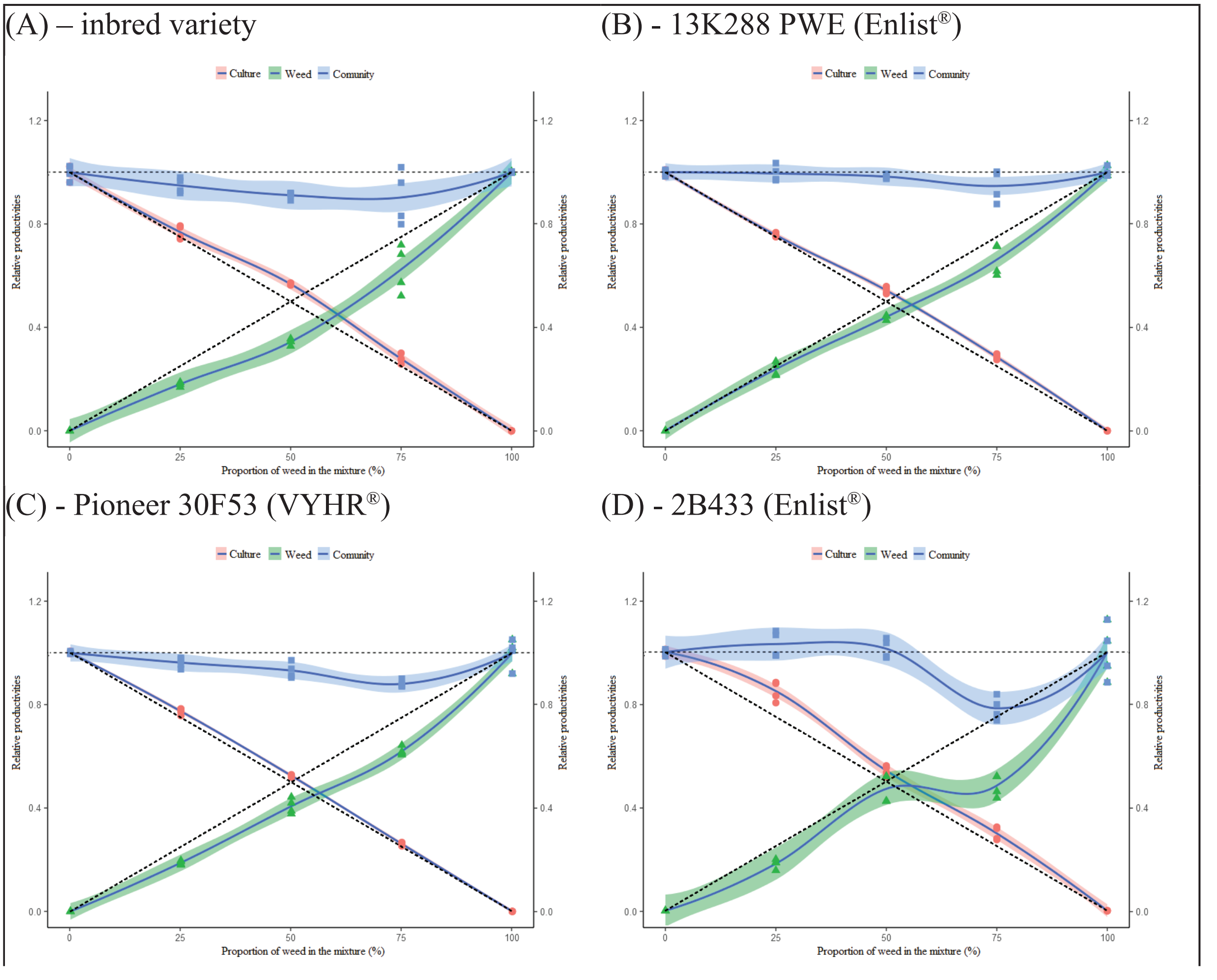

Figure 2. Relative productivity (PR) for plant height of maize (●) and Alexandergrass (▲), and total relative productivity (PRT) of the community (■) as a function of the proportion of associated plants (maize : Alexandergrass). UFFS, Erechim/RS.

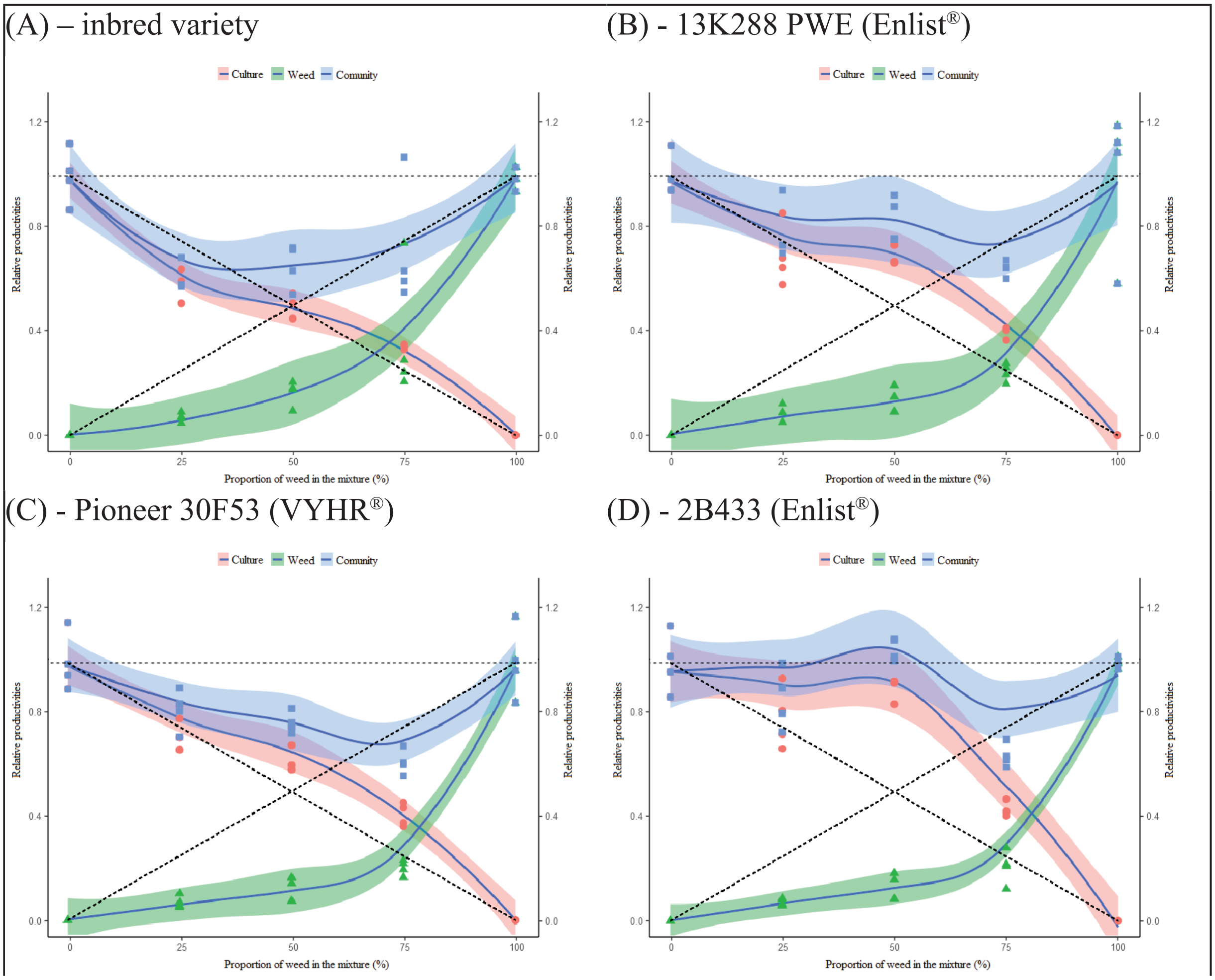

Figure 3. Relative productivity (PR) for stem diameter of maize (●) and wild poinsettia (▲), and total relative productivity (PRT) of the community (■) as a function of the proportion of associated plants (maize : wild poinsettia). UFFS, Erechim/RS.

showed a convex line for 2B433 (Enlist®) and 13K288 PWE (Enlist®), indicating no harm in this variable for the crop, as shown in Figure 3. The inbred variety showed results very close to the expected. On the other hand, the cultivar 30F53 (VYHR®) exhibited a convex line, suggesting that the competition between the crop and the weed was not sufficient to impair crop growth.

Total relative productivity (TRP) generally showed a concave relationship across most cultivars, indicating mutual detriment to species growth. Only the cultivar 2B433 (Enlist®) showed results close to expected in ratios with lower interspecific competition; however, as the proportion of wild poinsettia increased, TRP also formed a concave line, similar to the other cultivars. The maize stalk serves as a reserve organ for plant growth, and its importance is so great for production that experiments have shown that removing leaves from the stalk decreases plant weight, but ear filling continues normally until the reserve is depleted, indicating the translocation of photosynthates from the stalk reserve to the ear (Floss, 2011).

Figure 4 shows the relative productivity (PR) for maize stem diameter (SD) in competition with Alexandergrass. The PR for the inbred variety was close to expected levels, as indicated by the straight line. The cultivar 13K288 PWE (Enlist®) displayed a concave line at lower interspecific competition levels and a convex line at higher levels, indicating that intraspecific competition was more detrimental. The cultivar 2B433 (Enlist®) showed a convex line across all competition ratios with Alexandergrass. Similarly, the cultivar 30F53 (VYHR®) also exhibited a convex line from the 25:75 ratio onward. This effect, observed in nearly all cultivars, can be explained by the concave shape of the competitor below the expected line, indicating that Alexandergrass growth did not interfere with maize stem diameter. When species grow in a community, and competition occurs, plants often prioritize stem elongation over the development of other organs (etiolation) to compete more effectively for light by increasing height. According to Pierik and Ballaré (2021), light is one of the most important resources during the early growth stages of plants, and when its availability is limited under competitive conditions, the crop's productive potential may be affected.

Regarding total relative productivity (TRP), the effect was significant across all cultivars, as indicated by a concave line below 1. This result indicates that the growth of one species interfered with the other's due to competition for the same resources, resulting in losses for both. According to Carvalho et al. (2011), the maize organs most affected by competition with various weed species are the stalk and the leaf.

Table 2 presents the results for maize and weed plant height (PH) and stem diameter (SD) under competition. According to the results, as the proportion of competitors increases, the damage to maize's morphological variables decreases. The increase in weed density led to higher plant height and stem diameter in the crop. However,

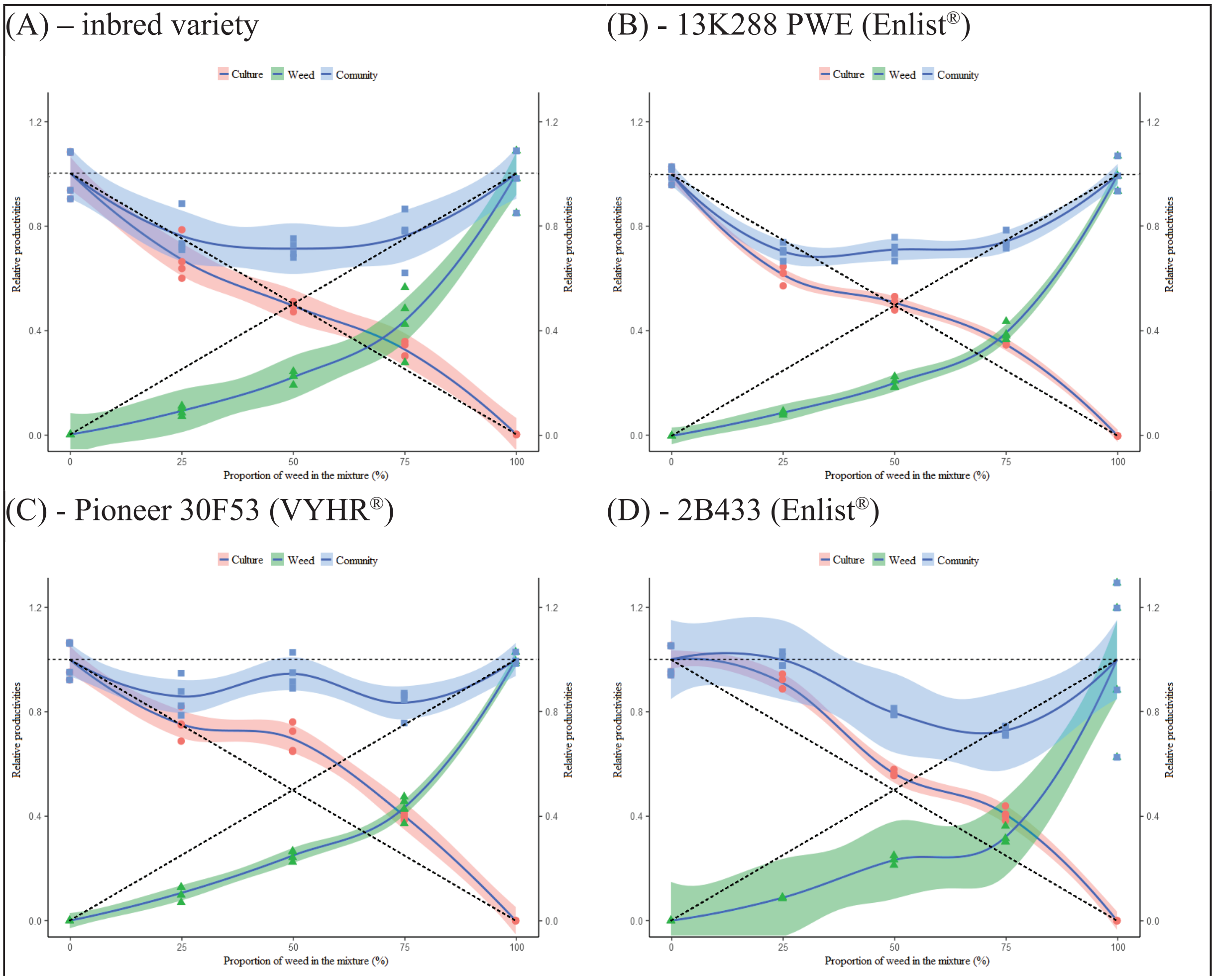

Figure 4. Relative productivity (PR) for stem diameter of maize (●) and Alexandergrass (▲), and total relative productivity (PRT) of the community (■) as a function of the proportion of associated plants (maize : Alexandergrass). UFFS, Erechim/RS.

both weeds were more negatively impacted under greater interspecific competition. Studying the presence of a weed community in sorghum, Giancotti et al. (2019) described the negative effect on the height and stem diameter of crop plants, with a reduction compared to the control treatment without weeds. In the present study, maize competing with wild poinsettia showed significant growth at 50:50 and 25:75 proportions, indicating greater interspecific competition across all evaluated maize genotypes. An increase in SD was observed for all maize genotypes at the 25:75 ratio. The highest SD values were obtained for the 30F53 (VYHR®), which, along with the others, showed an average increase of 30 cm in height, indicating strong competitiveness against wild poinsettia.

Intraspecific competition is more detrimental to maize than interspecific competition, whereas the opposite is true for weeds. Lower-intensity competition leads to greater investment in stem development compared to other parts of the plant, to achieve greater height as a strategy to increase light absorption, since light resources are a major limiting factor for plant growth (Page et al., 2010). The PH of all evaluated maize genotypes increased as interspecific competition with Alexandergrass increased (Table 2). However, compared to wild poinsettia, the height increase of maize competing with Alexandergrass was less pronounced. The maize genotype 2B433 Enlist showed the greatest increase in height among the others. The obtained SD values were higher at the 25:75 ratio, where interspecific competition is the greatest.

For the weeds, wild poinsettia and Alexandergrass, interspecific competition was more damaging to their SD and PH (Table 2). A reduction in these variables was observed as the proportion of weeds increased. Galon et al. (2023) observed similar results when evaluating the competitive ability of maize hybrids with hairy beggarticks, finding lower height and stem diameter values for wild poinsettia and Alexandergrass when maize was present in smaller proportions. For Alexandergrass and wild poinsettia, intraspecific competition was more harmful than interspecific competition. This observation can be explained by the damage to crop and weed growth when they compete within a specific community (Forte et al., 2017; Frandoloso et al., 2019).

The greater competitive ability of maize over both weeds was illustrated by the competitiveness indices CR, K, and A (Bianchi et al., 2006; Agostinetto et al., 2013). The superior competitive ability of maize was also confirmed by significant differences in at least two competitive indices (Bianchi et al., 2006). The greater competitive ability of maize over Alexandergrass was confirmed by CR, which was above 1 for plant height and stem diameter (Table 3).

The relative clustering coefficients (K) indicate the relative dominance of maize over Alexandergrass ($K_{maize} > K_{Alexandergrass}$) (Table 3). Additionally, the positive aggressiveness coefficient (A) suggests that maize is more

Table 2. Morphological variables of maize hybrids (*Zea mays*) subjected to interference from competitors, wild poinsettia (*Euphorbia heterophylla*) and Alexandergrass (*Urochloa plantaginea*), expressed in plant height (PH) and stem diameter (SD), in an experiment conducted in replacement series, evaluated 50 days after plant emergence. UFFS, Erechim/RS.

Plant proportion (maize:weed)	Morphological variables							
	$PH_{maize\ x\ wild\ poinsettia}$		$SD_{maize\ x\ wild\ poinsettia}$		$PH_{maize\ x\ Alexandergrass}$		$SD_{maize\ x\ Alexandergrass}$	
	Maize	Weed	Maize	Weed	Maize	Weed	Maize	Weed
	Conventional maize							
100:0 (T)	129.75	53.71	10.75	4.39	149.50	82.41	9.46	5.37
75:25	132.96	29.54*	8.08*	1.50*	153.14	68.58*	8.44	3.12*
50:50	168.32*	37.21*	10.54	1.27*	169.62*	56.67*	9.30	2.36*
25:75	166.50*	32.31*	14.74*	1.45*	166.41*	59.50*	12.29*	1.94*
C.V (%)	3.22	14.00	8.27	14.80	4.30	9.00	10.00	20.20
	Hybrid Enlist 13K288							
100:0 (T)	137.41	52.42	9.28	5.27	140.89	83.46	9.27	6.38
75:25	137.66	35.25*	7.88*	1.52*	142.17	73.67*	7.63*	3.36*
50:50	154.74*	39.00*	13.01*	1.21*	153.00*	73.46*	9.46	2.59*
25:75	168.67*	41.00	14.68*	1.83*	160.54*	79.62	12.96*	2.27*
C.V (%)	2.95	14.63	6.35	12.67	2.70	8.20	3.50	8.10
	Hybrid 30F53 VYHR							
100:0 (T)	126.34	47.72	10.13	5.53	128.12	86.25	9.04	5.91
75:25	137.67	33.25*	10.09	1.50*	132.23*	71.23*	9.07	3.41*
50:50	140.58*	37.92	13.24	1.26*	134.48*	70.21*	12.59*	2.94*
25:75	145.55*	40.13	16.58*	1.29*	133.65*	64.98*	14.52*	2.51*
C.V (%)	4.62	14.63	11.00	20.14	1.80	6.00	7.30	12.00
	Hybrid 2B433 Enlist							
100:0 (T)	104.58	59.17	8.29	4.95	136.46	89.42	8.25	5.20
75:25	131.33*	33.94*	8.69	1.58*	154.56*	57.70*	10.02*	2.22*
50:50	132.00*	35.17*	15.34*	1.08*	147.87	84.34	9.30*	2.41*
25:75	134.59*	32.31*	14.28*	1.45*	163.15*	65.04*	13.45*	1.83*
C.V (%)	4.50	5.91	9.51	13.63	6.20	12.1	5.40	30.80

* Means differ from the control (T) by Dunnett's ($p<0.05$).

Table 3. Competitiveness indices between maize genotype (*Zea mays*) and the weed, Alexandergrass (*Urochloa plantaginea*) and wild poinsettia (*Euphorbia heterophylla*), competing in equal proportions of plants (50:50), expressed by relative competitiveness (CR), relative clustering coefficients (K), and aggressiveness (A), fifty days after emergence, obtained in experiments conducted in replacement series. UFFS, Erechim/RS.

Genotype x weed[1]	CR[2]	Kx[3] $_{(maize)}$	Ky $_{(weed)}$	A[4]
	Plant height			
Inbred x Alexandergrass	1.652 ± 0.028*	1.311 ± 0.011*	0.524 ± 0.014	0.224 ± 0.006*
Enlist 13K288x Alexandergrass	1.234 ± 0.026*	1.189 ± 0.031*	0.786 ± 0.013	0.103 ± 0.010*
30F53 VYHR x Alexandergrass	1.294 ± 0.047*	1.104 ± 0.010*	0.690 ± 0.042	0.118 ± 0.015*
Enlist 2B433 x Alexandergrass	1.164 ± 0.087^{ns}	1.186 ± 0.046^{ns}	0.908 ± 0.099	0.070 ± 0.037^{ns}
	Stem diameter			
Inbred x Alexandergrass	2.258 ± 0.113*	0.970 ± 0.033*	0.282 ± 0.018	0.273 ± 0.011*
Enlist 13K288 x Alexandergrass	2.529 ± 0.089*	1.045 ± 0.044*	0.255 ± 0.016	0.308 ± 0.007*
30F53 VYHR x Alexandergrass	2.809 ± 0.163*	2.383 ± 0.324*	0.333 ± 0.018	0.447 ± 0.029*
Enlist 2B433 x Alexandergrass	2.440 ± 0.099*	1.294 ± 0.030*	0.302 ± 0.013	0.332 ± 0.012*
	Plant height			
Inbred x wild poinsettia	1.896 ± 0.051*	1.869± 0,043*	0.535 ±0.047	0.305 ±0.023*
Enlist 13K288 x wild poinsettia	1.685 ±0.178*	1.289 ±0.011*	0.545 ±0.095	0.217 ±0.039*
30F53 VYHR x wild poinsettia	1.513 ±0.100*	1.257 ±0.052*	0.609 ±0.082	0.183 ±0.022*
Enlist 2B433 x wild poinsettia	2.111 ±0.182*	1.964 ±0.260*	0.462 ±0.039	0.341 ±0.044*
	Stem diameter			
Inbred x wild poinsettia	3.205±0.536*	0.974±0.095 *	0.200±0.033	0.325±0.023*
Enlist 13K288 x wild poinsettia	5.900±0.900*	2.390±0.220*	0.152±0.033	0.571±0.010*
30F53 VYHR x wild poinsettia	6.750±1.667*	2.002±0.358*	0.131±0.030	0.540±0.059*
Enlist 2B433 x wild poinsettia	8.335±1.845*	1.173±0.527	0.150±0.034	0.797±0.057*

[1] Assessment of the indicated parameter at the defined variable at density 50 : 50, compared to the respective controls by Dunnett's ($p \leq 0.05$). [2] Significant when differing from 1, by T-test; [3] Difference between Kx and Ky at the same competition levels, compared by T-test using Welch's criterion; [4] Significant when differing from 0, by T-test. * Significant difference at the $p<0.05$ level.

competitive, and significant differences were observed in plant height (PH) and stem diameter (SD) for the inbred varieties 13K288 PWE (Enlist®) and 30F53 (VYHR®). Plant height is an important morphological characteristic for plant growth and development, as it is related to greater light interception capacity (Galon et al., 2023), providing greater competitive ability, as observed in maize competing with Alexandergrass.

Greater competitive ability may be associated with increased growth and greater efficiency in using available resources (Agostinetto et al., 2013), as observed in maize compared to Alexandergrass. Additionally, the crop may exhibit greater competitive ability than the weed on an individual basis, as the weed's competitiveness is more closely related to its plant density than to its individual competitive ability (Agostinetto et al., 2013).

In a competitive environment, depending on the plant density, maize tends to become more effective in gas exchanges, maximizing the use of available resources (Barros et al., 2017). The cultivar that demonstrated the greatest effectiveness in utilizing available resources was 2B433 (Enlist®). The physiological characteristic that contributed to the greater relative growth of this cultivar in competition with wild poinsettia was its water-use efficiency, which directly increased plant height and stem diameter. The CO2-assimilation metabolism (C4) exhibited by maize provides greater efficiency in storing the energy found in nature (Floss, 2011). Since maize and Alexandergrass are from the same family, they share some physiological and morphological similarities and therefore compete for the same resources with similar intensity (Freitas et al., 2020), unlike maize and wild poinsettia, which explains the lower level of competition between these species.

Conclusion

Maize genotypes with Enlist® technology, 13K288 PWE (Enlist®) and 2B433 (Enlist®), showed better physiological and morphological performance compared to the local variety and 30F53 (VYHR®) when competing with wild poinsettia and Alexandergrass. It can be considered that the increase in competitive ability is due to the greater plant height achieved by the genotypes 13K288 PWE (Enlist®) and 2B433 (Enlist®). Intraspecific competition was most harmful to the crop, while interspecific competition was most damaging to the weeds. Based on these results, it can be inferred that differences exist among the genotypes; however, further studies are needed to examine the relationship between competitive ability and the transgenic event.

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