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Research Article

Morphophysiological responses of triticale cultivars under weed competition

Respostas morfofisiológicas de cultivares de triticale em competição com plantas daninhas

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ABSTRACT

Triticale is a cereal increasingly used in human and animal nutrition. However, weeds, especially ryegrass (*Lolium multiflorum*) and turnip (*Raphanus raphanistrum* e *R. sativus*), can reduce both grain yield and quality. In this context, this study aimed to evaluate the competitive ability of triticale cultivars (BRS Ulisses, BRS Minotauro, Embrapa 53, and BRS Resoluto) in the presence of ryegrass and turnip using the replacement series method. Fourteen experiments were conducted in a randomized block design with four replicates. The treatments consisted of different proportions of crop and weed plants (100:0, 75:25, 50:50, 25:75, and 0:100%) arranged as 24:0, 18:6, 12:12, 6:18, and 0:24 plants per pot. Competitiveness was analyzed using replacement series diagrams and relative competitiveness indices. At 50 days after emergence, plant height, leaf area, gas exchange, and shoot dry matter of the crop and weeds were measured. Competition occurred between triticale cultivars and the weed species, resulting in mutual negative impacts on the growth of the species within the community. The crop and weeds exhibited similar competitive mechanisms and demands for environmental resources. Overall, physiological variables were negatively affected as weed density increased. Interspecific competition had a greater detrimental effect on the morphophysiological traits of the species than intraspecific competition.

KEYWORDS: *Triticosecale* Wittmack. *Lolium multiflorum. Raphanus raphanistrum.* Plant interaction.

RESUMO

O triticale é um cereal que vem sendo utilizado na alimentação humana ou animal. Entretanto, as plantas daninhas, especialmente o azevém (*Lolium multiflorum*), o nabo e a nabiça (*Raphanus raphanistrum* e *R. sativus*) podem reduzir a produtividade e a qualidade dos grãos. Neste contexto, objetivou-se com o trabalho avaliar a habilidade competitiva das cultivares de triticale (BRS Ulisses, BRS Minotauro, Embrapa 53 e BRS Resoluto) na presença das plantas daninhas, azevém e nabo, pelo método de arranjo em série de substituição. Foram instalados 14 experimentos em delineamento de blocos casualizados, com quatro repetições. Os tratamentos consistiram em diferentes proporções da cultura e das plantas daninhas (100:0, 75:25, 50:50, 25:75 e 0:100%) com 24:00; 18:6; 12:12; 6:18; 0:24 plantas vaso^{-1}. A análise da competitividade das espécies foi efetuada através de diagramas aplicados a experimentos substitutivos e também pelos índices de competitividade relativa. Aos 50 dias após a emergência das espécies, realizou-se a aferição da altura, área foliar, trocas gasosas e massa seca da parte aérea das plantas da cultura e dos competidores. Ocorreu competição entre as cultivares de triticale na presença de azevém e nabo com prejuízo mútuo às espécies envolvidas na comunidade. Há equivalência nos mecanismos de competição e na demanda pelos recursos do ambiente entre a cultura e as plantas daninhas. No geral, as variáveis fisiológicas foram afetadas de forma negativa conforme houve incremento da densidade das plantas daninhas. A competição interespecífica causa maior prejuízo para as variáveis morfofisiológicas das espécies do que a intraespecífica.

PALAVRAS-CHAVE: *Triticosecale* Wittmack. *Lolium multiflorum. Raphanus raphanistrum.* interação de plantas.

INTRODUCTION

Triticale (x *Triticosecale* Wittmack) is a man-made cereal resulting from the hybridization of two distinct species: wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.) (ZHU 2018, FACCINI et al. 2023, JASTRZĘBSKA et al. 2023). Triticale is an annual crop belonging to the Poaceae family, characterized by its rusticity and versatility. It is used for both human and animal consumption and also has potential for bioethanol production, dietary products, and other industrial applications (FACCINI et al. 2023).

In recent years, triticale has gained socioeconomic importance in southern Brazil, mainly due to its tolerance to low temperatures and suitability for crop rotation. In the 2023 growing season, Brazil harvested 56.2 thousand tons of triticale grains from an area of 22.9 thousand hectares, with an average yield of 2.45 t ha^{-1} (CONAB 2025). The highest production is concentrated in the states of Paraná and Rio Grande do Sul, with outputs of 30.2 and 21.2 thousand tons, respectively, in the 2023 season (CONAB 2025).

Among the factors that affect triticale production, competition with weeds stands out, primarily due to competition for environmental resources such as water, light, CO_2, nutrients, and space (YAMAUTI et al. 2011, JASTRZĘBSKA et al. 2023, KUMAR et al. 2025). In addition to resource competition, weeds can release allelopathic compounds and serve as hosts for pests and diseases (CHAUHAN 2020, FLESSNER et al. 2021, JASTRZĘBSKA et al. 2023, KUMAR et al. 2025).

The main weed species infesting winter crops in southern Brazil are ryegrass (*Lolium multiflorum* Lam.) and turnip (*Raphanus raphanistrum* L. and/or *R. sativus* L.) (LAMEGO et al. 2013, TIRONI et al. 2014, BALEM et al. 2021, MARIO et al. 2024). These species are widely used in southern Brazil as winter forage for livestock or as cover crops for no-till farming systems. This practice favors their spread, natural reseeding, and the persistence of a robust seed bank in the soil (COSTA & RIZZARDI 2015, RAMOS et al. 2021), making them highly competitive weeds.

Ryegrass is a hardy and vigorous species, considered naturalized in many areas of Rio Grande do Sul. It has a high tillering capacity and substantial seed production, which enhances its competitiveness in winter crops (AGOSTINETTO et al. 2017, PIES et al. 2019, BALDESSARINI et al. 2020, RAMOS et al. 2021, MARIO et al. 2024). Belonging to the same botanical family as winter cereals, ryegrass shares morphological characteristics with these crops, which complicates chemical control due to challenges related to selectivity and herbicide efficacy (AGOSTINETTO et al. 2017). Moreover, ryegrass control has become increasingly difficult due to resistance to herbicides targeting the ALS, ACCase, and EPSPS enzymes (MARIO et al. 2024, HEAP 2025), which are the main modes of action used to manage this species in winter crops.

Turnip belongs to the Brassicaceae family and is commonly used as a cover crop or forage (CHAUDHARI et al. 2019). However, when it infests winter crops, it becomes a highly competitive weed, often exhibiting resistance to multiple herbicides. In Argentina, *R. sativus*, and in Brazil, *R. raphanistrum*, have evolved resistance to ALS-inhibiting herbicides (PANDOLFO et al. 2013, COSTA & RIZZARDI 2015, HEAP 2025). This resistance further complicates chemical control, leading to reduced crop

yield potential, higher production costs, and lower profitability for farmers.

Weeds generally exhibit greater adaptability to adverse environmental conditions compared to crops, mainly due to their higher genetic variability (JASTRZĘBSKA et al. 2023, KUMAR et al. 2025). However, several factors influence competitive ability, including the timing of emergence, weed species, population density, and the management practices adopted. When not adequately controlled, these factors can cause significant yield losses in crops (TIRONI et al. 2014, CHAUHAN 2020, FLESSNER et al. 2021, JASTRZĘBSKA et al. 2023, KUMAR et al. 2025).

Currently, chemical control using herbicides is the most widely adopted method by farmers due to its speed, effectiveness, and practicality (BALEM et al. 2021, EHRAMPOOSH et al. 2025). However, the repeated use of herbicides with the same mode of action, without crop rotation or integrated weed management practices, has led to an alarming increase in herbicide-resistant weed populations (CHAUHAN 2020, MARIO et al. 2024, HEAP 2025).

This scenario highlights the need for alternative weed management strategies, such as using crop cultivars with greater competitive ability. Cultivars may differ genetically in characteristics such as initial growth rate, tillering or branching capacity, leaf area index, canopy architecture, biomass accumulation, root volume and length, or plant height, which can provide competitive advantages when grown in the presence of weeds (YAMAUTI et al. 2011, TIRONI et al. 2014, MWENDWA et al. 2022, JASTRZĘBSKA et al. 2023).

The use of replacement series experiments allows researchers to study the interactions between crops and weeds at different proportions. The outcomes of such studies can inform management strategies that favor crops over weeds (AGOSTINETTO et al. 2013, PIES et al. 2019). This approach also enables researchers to determine whether competition is primarily interspecific or intraspecific (BIANCHI et al. 2006), thereby supporting the development of more sustainable and conservation-oriented management strategies, including the implementation of integrated weed management. Ultimately, this can reduce excessive herbicide applications and delay or prevent the evolution of herbicide-resistant weed populations.

The hypothesis of this study is that, although ryegrass and turnip are highly adapted to the environment, they exhibit lower competitive ability when growing alongside triticale. Therefore, the objective of this study was to evaluate the competitive ability of four triticale cultivars (BRS Ulisses, BRS Minotauro, Embrapa 53, and BRS Resoluto) in the presence of ryegrass and turnip using the replacement series design.

MATERIAL AND METHODS

A total of 14 experiments were conducted in a greenhouse at the Federal University of Fronteira Sul (UFFS), Erechim Campus, located at 27º 43’ 26” S, 52º 17’ 39” O, and an altitude of 650 m, from June to September 2017. The experiments were set up in plastic pots with a volume capacity of 8 L, filled with soil classified as a typical aluminoferric Red Latosol (STRECK et al. 2018). Soil fertility correction was carried out based on chemical analysis, following fertilization recommendations for triticale crops (CQFS-RS/SC 2016). The soil presented the following physical and chemical

properties: $pH_{(H2O)}$ = 4.8; organic matter = 3.5%; P = 4.0 mg dm^{-3}; K = 117.0 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}; $CEC_{(effective)}$ = 7.4 $cmol_c$ dm^{-3}; $CEC_{(pH\ 7)}$ = 16.5 $cmol_c$ dm^{-3}; H^++Al = 9.7 $cmol_c$ dm^{-3}; base saturation = 41%; sand = 15%; silt = 25%; clay = 60%.

The experiments were arranged in a randomized block design with four replications. The competitors tested were the triticale cultivars BRS Ulisses, BRS Minotauro, Embrapa 53, and BRS Resoluto, competing against ryegrass (*Lolium multiflorum*) and turnip (*Raphanus raphanistrum*). The main characteristics of the triticale cultivars used are presented in Table 1.

Table 1. Genetic characteristics of the triticale cultivars used in the study. UFFS, Erechim, RS.

Cultivar	Growth cycle	Plant height
BRS Ulisses	Early	Short
BRS Minotauro	Medium	Medium/Tall
Embrapa 53	Early	Tall
BRS Resoluto	Medium	Medium/Tall

Six preliminary experiments were conducted, both for triticale cultivars and for ryegrass and/or turnip in monoculture, to determine the plant density at which maximum dry mass production becomes constant. The tested densities were 1, 2, 4, 8, 16, 24, 32, 40, 48, 56, and 64 plants per pot (equivalent to 25, 49, 98, 196, 392, 587, 784, 980, 1,176, 1,372, and 1,568 plants m^{-2}). At 50 days after emergence (DAE), corresponding to the beginning of the reproductive stage, the shoot biomass was harvested and oven-dried at 65 ± 5 °C until constant weight, to determine the shoot dry mass (SDM). Based on these results, the constant maximum dry mass was achieved at a density of 24 plants per pot (587 plants m^{-2}) for all triticale cultivars and the weed species (data not shown).

Following the determination of optimal plant density, eight additional experiments were carried out to evaluate the competitiveness of the triticale cultivars (BRS Ulisses, BRS Minotauro, Embrapa 53, and BRS Resoluto) in competition with ryegrass and/or turnip, as illustrated in Figure 1. All experiments followed the replacement series design, with the crop and weed species combined at varying proportions (100:0, 75:25, 50:50, 25:75, and 0:100%), corresponding to 24:0, 18:6, 12:12, 6:18, and 0:24 plants per pot, while maintaining a constant total plant density of 24 plants per pot. To ensure uniform seedling establishment, seeds were initially sown in trays and then transplanted into pots at the 1- to 2-leaf stage.

At 50 DAE, morphological and physiological traits were measured for the triticale cultivars competing with the weeds. The physiological variables assessed included intercellular CO_2 concentration (Ci, µmol mol^{-1}), stomatal conductance (g_S, mol m^{-2} s^{-1}), photosynthetic rate (*A*, µmol m^{-2} s^{-1}), and transpiration rate (*E*, mol H_2O m^{-2} s^{-1}). Carboxylation efficiency (CE, mol CO_2 m^{-2} s^{-1}) and water use efficiency (WUE, mol CO_2 mol H_2O^{-1}) were calculated using the ratios *A*/Ci and *A*/*E*, respectively. Measurements were taken using an infrared gas analyzer (IRGA) (ADC, model LCA PRO, Analytical Development Co. Ltd, Hoddesdon, UK) on the middle third of the plant

canopy. Readings were taken between 7:30 and 11:00 a.m. to maintain stable environmental conditions during data collection.

Figure 1. Experiments conducted in a replacement series involving triticale in competition with ryegrass (A) and/or turnip (B). UFFS, Erechim, RS.

The morphological variables assessed included plant height (PH), leaf area (LA), and shoot dry mass (SDM) of both the crop and the weeds. PH was measured from ground level to the tip of the flag leaf in triticale and ryegrass, or to the uppermost fully expanded leaf in turnip, using a graduated ruler (cm). LA was measured using a portable leaf area meter (CI-203, BioScence), summing the leaf area of all plants in each pot after cutting them at soil level. After LA determination, the plants were placed in paper bags and oven-dried at 60 ± 5 °C until constant weight, followed by weighing on a precision balance to determine SDM.

Data analysis was performed using the graphical analysis method for relative productivity (RP) or total relative productivity total (TRP), also known as the conventional method for replacement series experiments (BIANCHI et al. 2006). This method involves plotting diagrams based on the RP and TRP, where if the RP curve forms a straight line, it indicates that both species have similar competitive abilities. A concave curve suggests mutual suppression of one or both species, while a convex curve indicates a mutual benefit. For TRP, a value equal to 1 (straight line) suggests that both species compete for the same resources; a value greater than 1 (convex line) indicates resource complementarity; and a value less than 1 (concave line) suggests mutual competition, resulting in reduced growth for both species (RUBIN et al. 2014).

Additionally, the relative competitiveness index (RC), relative clustering coefficient (K), and aggressiveness (AG) were calculated. RC represents the comparative growth of the triticale cultivars (X) relative to the weed species (Y). K indicates the relative dominance of one species over another, while A identifies which species is more aggressive. The combined interpretation of RC, K, and AG provides a robust assessment of the competitive ability of the species (BIANCHI et al. 2006, AGOSTINETTO et al. 2013, RUBIN et al. 2014). The triticale cultivars (X) are considered more competitive than ryegrass and/or turnip (Y) when RC > 1, Kx > Ky, and AG > 0. Conversely, the weed species (Y) are more competitive than the triticale cultivars (X) when RC < 1, Kx < Ky, and AG < 0 (BIANCHI et al. 2006, AGOSTINETTO et al. 2013, RUBIN et al. 2014). These indices were calculated using data from the 50:50 species proportions (triticale and ryegrass; triticale and turnip), following the

equations: RC = RPx/RPy; Kx= RPx/(1-RPx); Ky= RPy/(1-RPy); AG = RPx – RPy (BIANCHI et al. 2006, AGOSTINETTO et al. 2013, RUBIN et al. 2014).

The statistical analysis of relative yield involved calculating the differences between the observed RP values (DRP) at 25, 50, and 75% proportions relative to the hypothetical straight RP line values (0.25, 0.50, and 0.75, respectively) (BIANCHI et al. 2006). A *t*-test was applied to assess statistical significance for DRP, TRP, CR, K, and AG (BIANCHI et al. 2006). The null hypothesis used to test differences in DPR and AG was that the means were equal to zero (Ho = 0); for TRP and CR, that the means were equal to 1 (Ho = 1); and for K, that the mean differences between Kx and Ky were equal to zero [Ho = (Kx – Ky) = 0].

Observed TRP and RP curves were considered significantly different from expected values when the expected curves (represented by dotted lines) fell outside the 95% confidence intervals of the observed curves (solid colored lines with matching confidence intervals) (CONCENÇO et al. 2018). the criterion for considering the PR and PRT curves different from the hypothetical lines was that, in at least two of the tested competitor density proportions, did not touch the colored lines, adapted from BIANCHI et al. (2006).

The morphophysiological variable means for each treatment were subjected to analysis of variance (ANOVA) using the F-test. When significant differences were detected, the means were compared using Dunnett's test, with the monocultures serving as the control treatments. In all analyses, a significance level of 5% was adopted.

RESULTS AND DISCUSSION

Analysis of variance indicated a significant interaction between the proportions of triticale plants and the weed species, ryegrass and/or turnip, for both morphological (PH, LA, and SDM) and physiological variables (Ci, g_S, *E*, *A*, CE, and WUE). The graphical results showed that the four triticale cultivars exhibited similar competitive responses when grown with ryegrass and/or turnip. Significant differences were observed for PH, LA, and SDM, since the colored lines deviated from the expected lines for relative productivity (RP) in at least two of the tested proportions. The total relative productivity (TRP) showed mean values lower than 1, with significant differences in at least two of the combinations tested. This indicates mutual suppression (crop and weeds) for practically all variables and proportions (Figures 2, 3, and 4).

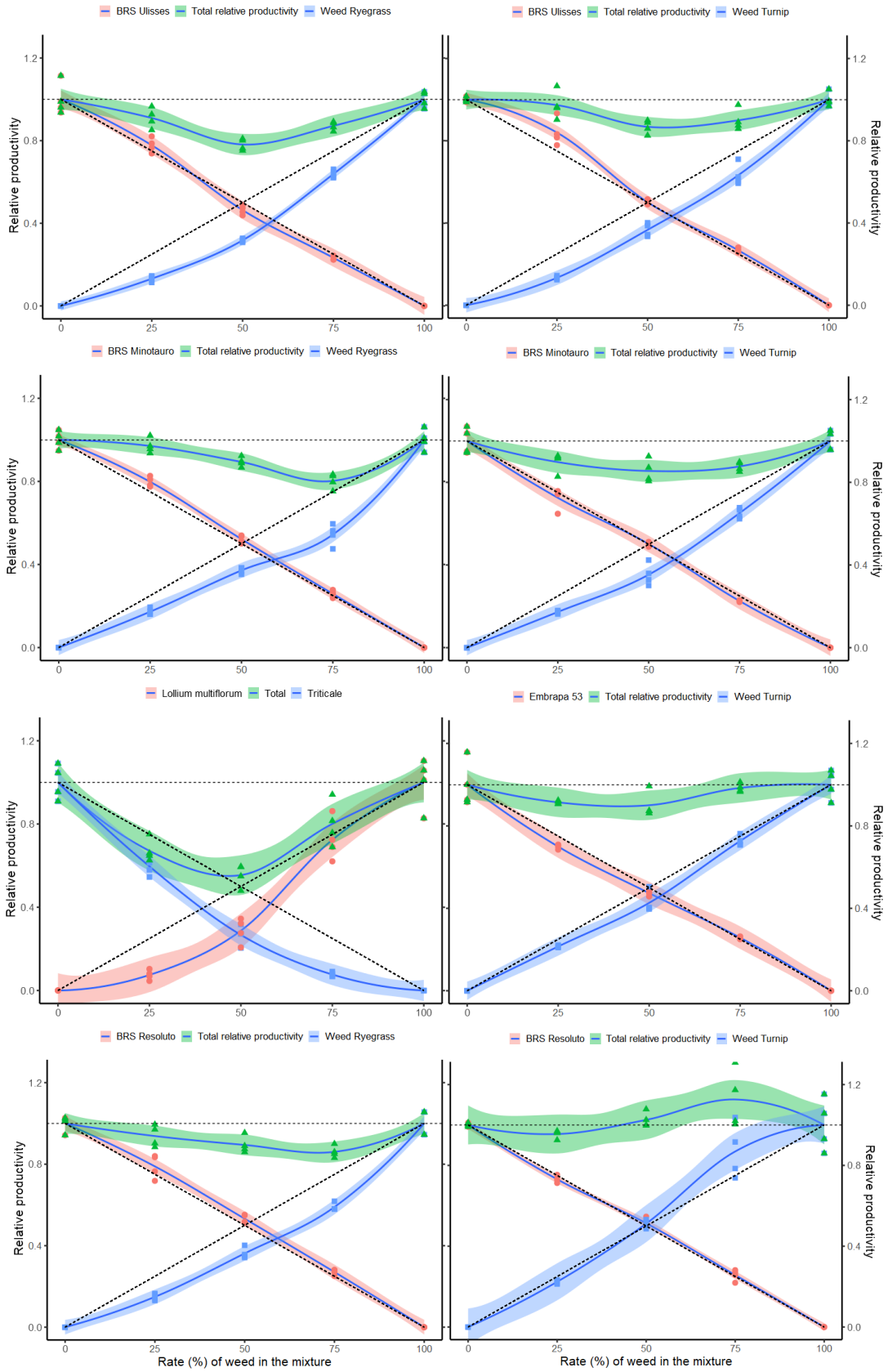

Figure 2. Relative productivity (PR) for plant heigth (AP) of triticale cultivars—BRS Ulisses, BRS Minotauro, Embrapa 53, and BRS Resoluto (●), ryegrass—*Lolium multiflorum* and turnip—*Raphanus raphanistrum* (■), and total relative productivity (TPR) of the community (▲) as a function of plant proportions (triticale: ryegrass or turnip). Dashed lines represent the expected values in the absence of competition, solid lines represent the observed values when species competed at different plant proportions, and colored bands indicate the standard deviation of the observations.

Leaf area (LA) and shoot dry mass (SDM) showed greater reductions in RP and TRP compared to plant height (PH) (Figures 2, 3, and 4). The triticale cultivars did not show significant reductions in RP for PH, with observed lines remaining close to the expected ones, a pattern not observed for LA and SDM, which were clearly affected. In all scenarios, ryegrass displayed the lowest RP values, with observed lines consistently further from the expected lines for PH, LA, and SDM when competing with triticale, indicating a lesser negative effect on the crop. Conversely, turnip exhibited RP values close to the expected lines but generally caused greater damage to the crop compared to ryegrass.

The distinct competitive responses of ryegrass and turnip can be explained by their different biological characteristics. Although ryegrass is recognized as highly competitive (LAMEGO et al. 2013), it was less competitive than turnip against triticale in this study. Turnip exhibits strong competitive ability due to its sparse, highly branched leaf cover (FRANZ et al. 2020), which allows it to dominate the environment, as previously observed in barley and canola crops (SOUZA & VELINI 1997, FRANZ et al. 2020). These authors also emphasize that turnip can rapidly suppress the growth and development of crops. Generally, when one species is more competitive than another, it indicates a greater capacity to uptake and utilize available resources (AGOSTINETTO et al. 2013).

In this study, triticale cultivars did not show substantial reductions in PH when competing with ryegrass and/or turnip (Figure 2). When species coexist in competitive environments, plants often prioritize stem elongation (etiolation) over other growth processes as a strategy to capture more light. According to PIERIK & BALLARÉ (2021), light is one of the most critical resources during early plant growth stages, and when its availability is limited due to competition, the crop’s productive potential can be significantly affected. LAMEGO et al. (2013) also reported no significant effects on the plant height of wheat cultivars competing with ryegrass and turnip, which partially aligns with the findings of this study.

The leaf area (LA) and shoot dry mass (SDM) of the triticale cultivars, when infested by ryegrass and/or turnip, generally exhibited concave RP curves in all scenarios (Figures 3 and 4). This pattern indicates competition for the same environmental resources—water, light, and nutrients. The reduction in LA and SDM may be associated with the plant reallocating resources to other structures rather than leaves. The plants may prioritize stem (culm) growth over leaf expansion due to the need to compete for light by increasing plant height. Light is one of the most limiting and important resources during the early growth stages of plants, and when its availability is reduced under competition, the crop's productive potential is negatively affected (PIERIK & BALLARÉ 2021, GOLAN et al. 2024).

An overall analysis of Figures 2, 3, and 4 reveals that, in all proportions, there was a reduction in morphological variables, particularly LA and SDM, as the density of the competing species increased. In these cases, the observed RPs were well below the expected values under no competition.

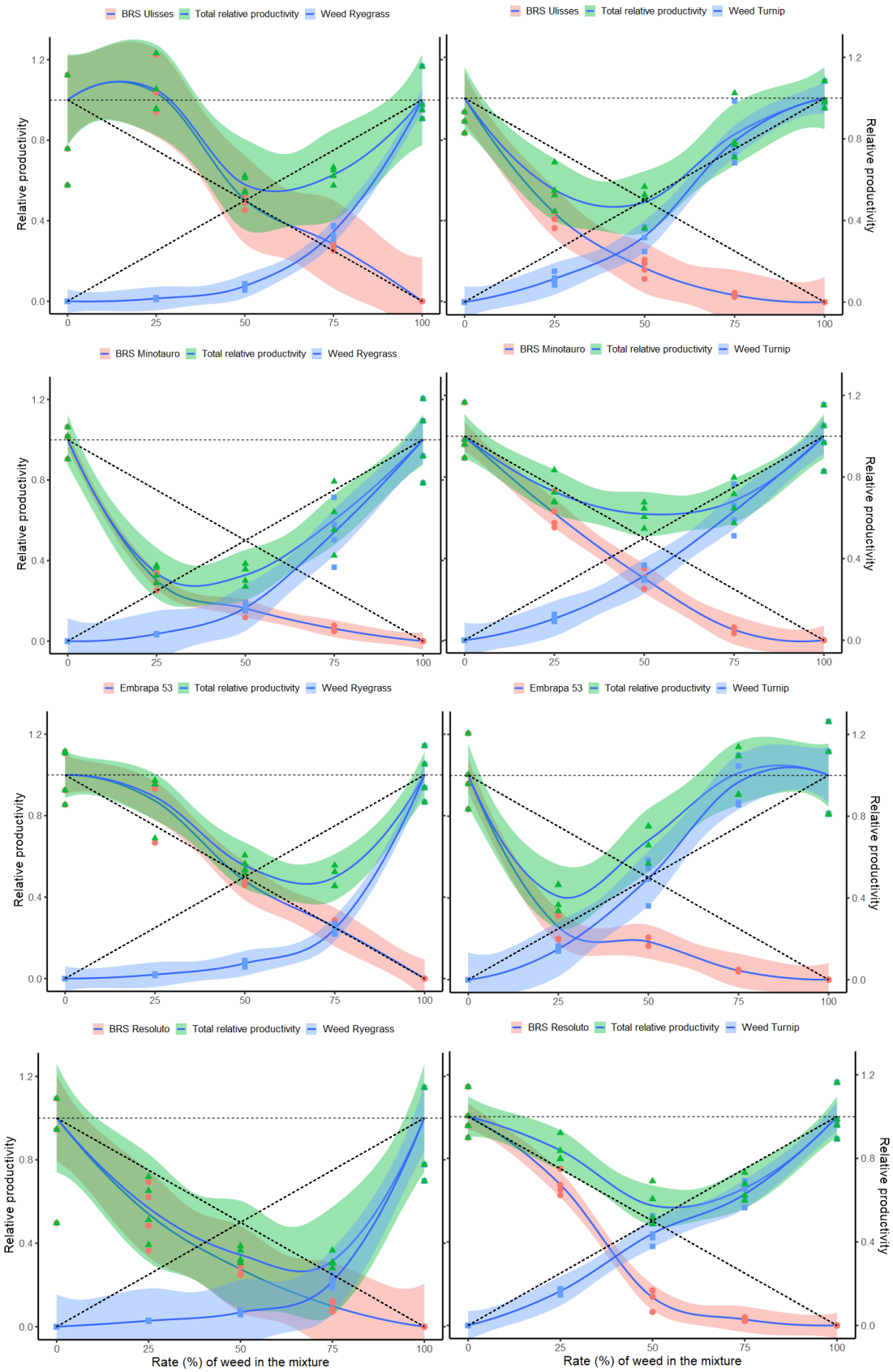

Figure 3. Relative productivity (RP) for leaf area (LA) of triticale cultivars—BRS Ulisses, BRS Minotauro, Embrapa 53, and BRS Resoluto (●), ryegrass—*Lolium multiflorum* and turnip—*Raphanus raphanistrum* (■), and total relative productivity (TRP) of the community (▲) as a function of plant proportions (triticale: ryegrass or turnip). Dashed lines represent the expected values in the absence of competition, solid lines represent the observed values when species competed at different plant proportions, and colored bands indicate the standard deviation of the observations.

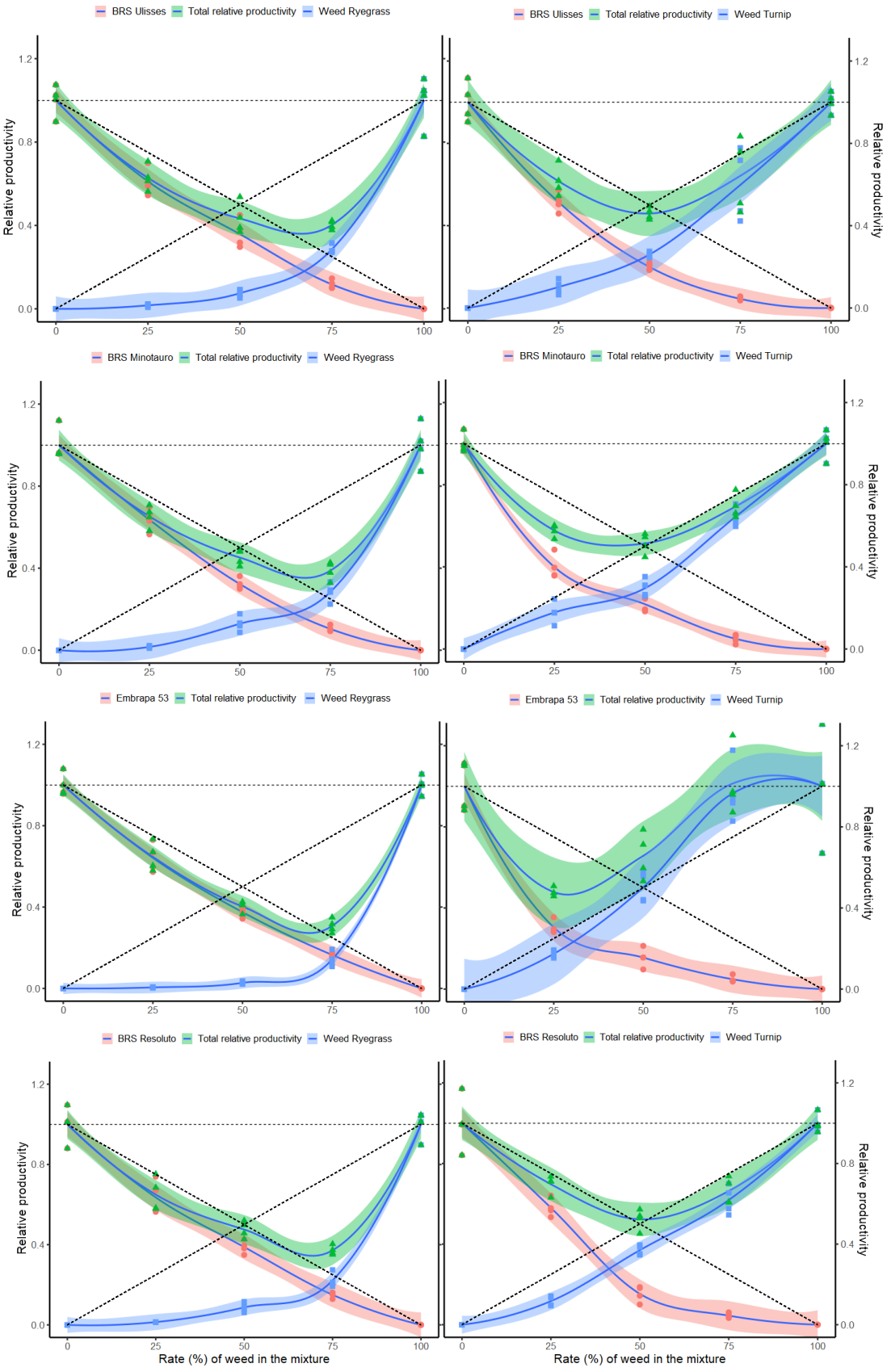

Figure 4. Relative productivity (RP) for shoot dry mass (SDM) of triticale cultivars—BRS Ulisses, BRS Minotauro, Embrapa 53, and BRS Resoluto (●), ryegrass—*Lolium multiflorum* and turnip—*Raphanus raphanistrum* (■), and (TRP) of the community (▲) as a function of plant proportions (triticale: ryegrass or turnip). Dashed lines represent the expected values in the absence of competition, solid lines represent the observed values when species competed at different plant proportions, and colored bands indicate the standard deviation of the observations.

The concave nature of the TRP curves, with values lower than 1, indicates that triticale and the weed species were competing for the same resources. When TRP < 1, it reflects a mutual antagonism between the species sharing the same resources in the environment at the same proportion (BIANCHI et al. 2006, AGOSTINETTO et al. 2013, RUBIN et al. 2014). Similar results have been reported for barley and wheat competing with ryegrass and turnip (GALON et al. 2011, COSTA & RIZZARDI 2015, TAROUCO et al. 2016, BALDESSARINI et al. 2020).

For all triticale cultivars and all plant proportions, the presence of ryegrass did not significantly affect plant height (PH), indicating a low competitive effect of this weed on this variable (Table 2).

Table 2. Morphological responses of triticale cultivars subjected to interference from the competitor ryegrass (*Lolium multiflorum*), expressed as plant height (cm), leaf area (cm² pot⁻¹), and shoot dry mass (g pot⁻¹). UFFS, Erechim, RS.

Plant proportions *Triticale: weed* Weed: triticale	Morphological traits					
	Plant height (cm)		Leaf area (cm^{-2} pot^{-1})		Shoot dry mass (g pot^{-1})	
	Ulisses	Ryegrass	Ulisses	Ryegrass	Ulisses	Ryegrass
100:0 ou 0: 100 (C)	50.56	36.66	11599.27	41822.75	41.23	23.00
75:25 ou 25:75	52.43	31.22*	16014.65	19259.50*	33.62*	8.75*
50:50 ou 50:50	46.89	23.29*	11706.23	6313.00*	29.54*	3.45*
25:75 ou 75:25	47.10	19.33*	13127.18	2266.12*	19.32*	1.53*
C.V (%)	6.30	5.60	24.00	17.20	14.70	18.40
Triticale: weed weed: triticale	Minotauro	Ryegrass	Minotauro	Ryegrass	Minotauro	Ryegrass
100:0 ou 0: 100 (C)	43.25	37.35	22829.43	18831.83	32.08	23.45
75:25 ou 25:75	46.01	27.08*	9213.91*	13573.02*	27.23*	8.87*
50:50 ou 50:50	45.16	27.75*	7423.68*	6235.24*	20.71*	6.06*
25:75 ou 75:25	44.71	25.77*	5650.41*	2679.87*	13.36*	1.52*
C.V (%)	5.00	7.80	14.00	27.60	10.30	19.00
Triticale: weed wee: triticale	Embrapa 53	Ryegrass	Embrapa 53	Ryegrass	Embrapa 53	Ryegrass
100:0 ou 0: 100 (C)	50.94	32.60	8233.75	18921.56	31.48	21.25
75:25 ou 25:75	49.04	21.20*	9582.85	6157.66*	26.94*	4.03*
50:50 ou 50:50	49.04	20.75*	7900.23	2852.95*	23.62*	1.18*
25:75 ou 75:25	57.49	18.66*	8352.69	1487.73*	20.75*	0.42*
C.V (%)	9.00	11.70	14.30	18.70	8.40	12.00
Triticale: weed weed: triticale	Resoluto	Ryegrass	Resoluto	Ryegrass	Resoluto	Ryegrass
100:0 ou 0: 100 (C)	43.16	33.16	1584.57	7232.25	30.22	22.88
75:25 ou 25:75	45.42	26.08*	1142.12	2092.15*	25.61*	6.77*
50:50 ou 50:50	45.95	24.01*	873.84*	994.00*	23.47*	4.00*
25:75 ou 75:25	46.74	19.75*	621.99*	819.76*	18.13*	1.28*
C.V (%)	6.00	8.00	38.60	46.70	11.70	14.2

* Mean differs from the control (C) according to Dunnett's test ($p<0.05$).

When evaluating PH of triticale cultivars in competition with turnip, a significant effect was observed only for BRS Ulisses at the 75:25 ratio, which showed greater plant height, and for BRS Minotauro at the 25:75 ratio, which showed reduced height (Table 3). For the other cultivars and proportions, there were no significant effects. This response seems to be more associated with plant density in the mixture rather than an individual competitive effect. Specifically, BRS Ulisses showed greater PH when grown at a higher density relative to turnip, while BRS Minotauro exhibited reduced height when present at a lower density than the competitor.

The PH of ryegrass and turnip was reduced when competing with the crop, particularly when triticale was present in higher proportions in the mixtures (Tables 2 and 3). Under field conditions, weeds typically exhibit higher competitive ability due to their higher plant density compared to crops, rather than because of their individual plant competitiveness—a fact also described by AGOSTINETTO et al. (2013). Another point to consider is that the equidistant plant distribution used in this experiment likely enhanced the competitive ability of the crop. In contrast, the typical row planting used in field conditions tends to increase crop yield losses due to weed competition (DUSABUMUREMYI et al. 2014).

Table 3. Morphological responses of triticale cultivars subjected to interference from the competitor turnip (*Raphanus raphanistrum*), expressed as plant height (cm), leaf area (cm^2 pot^{-1}), and shoot dry mass (g pot^{-1}). UFFS, Erechim, RS.

Plant proportions *Triticale: weed* Weed: triticale	Morphological traits					
	Plant height (cm)		Leaf area (cm^{-2} pot^{-1})		Shoot dry mass (g pot^{-1})	
	Ulisses	Turnip	Ulisses	Turnip	Ulisses	Turnip
100:0 ou 0: 100 (C)	46.88	57.73	9284.54	9019.60	28.61	28.24
75:25 ou 25:75	52.5*	48.66*	5396.94*	9478.53	19.61*	22.50
50:50 ou 50:50	47.00	42.32*	3103.80*	5819.80*	11.40*	14.66*
25:75 ou 75:25	50.11	30.81*	1256.67*	4129.27*	5.07*	11.49*
C.V (%)	5.30	7.70	30.00	17.50	12.30	22.70
Triticale: weed Weed: triticale	Minotauro	Turnip	Minotauro	Turnip	Minotauro	Turnip
100:0 ou 0: 100 (C)	50.16	54.27	6830.33	8639.12	23.25	26.33
75:25 ou 25:75	48.49	47.10*	5667.90*	7281.48	12.38*	22.62
50:50 ou 50:50	50.33	38.33*	4140.26*	5448.84*	10.14*	15.59*
25:75 ou 75:25	45.33*	37.50*	1404.98*	3657.08*	4.62*	18.73*
C.V (%)	5.60	8.60	15.60	16.90	14.80	17.60
Triticale: weed Weed: triticale	Embrapa 53	Turnip	Embrapa 53	Turnip	Embrapa 53	Turnip
100:0 ou 0: 100 (C)	55.00	50.83	13239.24	6065.67	26.32	18.97
75:25 ou 25:75	51.29	49.25	4556.56*	7816.06	10.69*	24.42
50:50 ou 50:50	52.11	43.35*	4924.66*	6015.19	8.18*	19.04
25:75 ou 75:25	56.67	43.66*	2371.65*	3632.13*	5.11*	13.21
C.V (%)	6.70	8.00	22.10	19.80	20.60	20.60
Triticale: weed Weed: triticale	Resoluto	Turnip	Resoluto	Turnip	Resoluto	Turnip
100:0 ou 0: 100 (C)	49.11	37.60	10727.04	8236.01	24.51	25.61
75:25 ou 25:75	47.88	43.56	9643.74	6900.40*	18.96*	21.13*
50:50 ou 50:50	50.44	38.47	2879.48*	7245.17	7.51*	18.94*
25:75 ou 75:25	50.55	33.66	1240.10*	5405.77*	4.40*	11.97*
C.V (%)	6.80	12.60	16.00	12.70	17.30	11.20

* Mean differs from the control (C) according to Dunnett's test ($p<0.05$).

Both LA and SDM were reduced when triticale was grown in competition with the weed species, regardless of the plant proportion in the mixture. An exception occurred when triticale cultivars BRS Ulisses and Embrapa 53 were grown in the presence of ryegrass, where no significant reductions were observed (Tables 2 and 3). It is noteworthy that BRS Ulisses and Embrapa 53, which are early-maturing cultivars, showed superior morphological performance, with very similar competitive behavior. Early cultivars tend to have faster initial growth, allowing them to occupy space more rapidly, which can enhance their competitiveness against weeds. Similar observations have been reported for wheat competing with ryegrass (TAROUCO et al. 2016) and

for barley cultivars growing alongside various weed species (MWENDWA et al. 2022).

The higher the proportion of the competitors (ryegrass and/or turnip) in association with the triticale cultivars, the greater the damage to the leaf area (LA) and shoot dry mass (SDM) of the crop. Conversely, ryegrass and turnip exhibited more pronounced reductions in LA and SDM when present in equal or lower proportions compared to the triticale cultivars BRS Ulisses, BRS Minotauro, Embrapa 53, and BRS Resoluto (Tables 2 and 3). Similar findings were reported by GALON et al. (2017), who observed that higher turnip densities caused greater reductions in LA and SDM in barley. Likewise, ANDREW & STORKEY (2017) demonstrated that weeds were less competitive against wheat when it was sown at high densities, a result consistent with the present study. Other studies also report growth reductions in both crops and weeds under competition (AGOSTINETTO et al. 2013, TIRONI et al. 2014, DUSABUMUREMYI et al. 2014, CHAUHAN 2020, KUMAR et al. 2025).

The lowest values for PH, LA, and SDM reflect strong interspecific competition, where species compete directly for the same environmental resources. Interspecific competition was also reported in studies involving barley and wheat coexisting with ryegrass and turnip (TIRONI et al. 2014, COSTA & RIZZARDI 2015, GALON et al. 2017, TAVARES et al. 2019, BALDESSARINI et al. 2020). Well-distributed crop stands tend to increase competitiveness, whereas row planting, typical in field conditions, generally exacerbates crop losses due to weed pressure (DUSABUMUREMYI et al. 2014, ANDREW & STORKEY 2017). Multiple crop traits contribute to competitive ability, including plant height, root system architecture, canopy structure, growth habit, development rate, and life cycle duration (JASTRZĘBSKA et al. 2023, KUMAR et al. 2025).

The highest mean values for PH, LA, and SDM occurred under lower-density mixtures, regardless of plant proportions (Tables 2 and 3). Again, interspecific competition proved more detrimental to all species involved (triticale, ryegrass, and/or turnip) than intraspecific competition. These findings are consistent with research in wheat (COSTA & RIZZARDI 2015) and barley (GALON et al. 2017) competing with turnip, where interspecific competition was more damaging than intraspecific competition.

Growth reduction under both intra- and interspecific competition is mainly due to spatial competition among plant groups occupying the same area (BIANCHI et al. 2006, AGOSTINETTO et al. 2013, CHAUHAN 2020). However, the more severe interspecific competition is not exclusive to triticale competing with weeds. Similar patterns have been observed in other crops, including barley, wheat, and triticale, growing alongside ryegrass and turnip (YAMAUTI et al. 2011, TIRONI et al. 2014, COSTA & RIZZARDI 2015, TAVARES et al. 2019, BALDESSARINI et al. 2020).

The physiological responses of triticale cultivars varied according to the proportions of plants in competition with ryegrass (Table 4). Regarding water use efficiency (WUE), the BRS Resoluto cultivar showed higher values at the 25:75 (triticale: ryegrass) ratio compared to the monoculture (100:0). The photosynthetic rate (*A*) also increased from 6.56 µmol m^{-2} s^{-1} in monoculture to 12.10 µmol m^{-2} s^{-1} at this ratio. For ryegrass in monoculture (0:100), a higher photosynthetic rate was observed compared to triticale when in competition with most cultivars. However, as the

proportion of triticale increased, significant reductions occurred in ryegrass for A and stomatal conductance (g_S).

Table 4. Physiological responses of triticale cultivars subjected to interference from the competitor ryegrass (*Lolium multiflorum*), expressed as intercellular CO_2 concentration (Ci, µmol mol^{-1}), stomatal conductance (g_S, mol m^{-2} s^{-1}), transpiration (E, mol m^{-2} s^{-1}), photosynthetic rate (A, µmol m^{-2} s^{-1}), carboxylation efficiency (CE, mol m^{-2} s^{-1}), and water use efficiency (WUE, mol mol^{-1}). UFFS, Erechim, RS.

Plant proportions Triticale/ryegrass	Physiological traits					
	Ci	g_S	*E*	*A*	CE	WUE
			BRS Ulisses			
100:0 (C)	327.15	0.16	1.38	5.38	0.01	4.18
75:25	328.75	0.17	1.63	6.59	0.02	4.20
50:50	279.27	0.13	1.46	8.75*	0.03	5.26
25:75	301.29	0.23	2.33*	6.22	0.03	4.07
C.V (%)	10.90	39.90	17.50	26.2	58.80	30.50
			Ryegrass			
0:100 (C)	320.79	0.14	2.31	6.01	0.02	2.69
25:75	308.19	0.07*	1.20*	3.48*	0.01*	3.04
50:50	316.58	0.07*	1.24*	2.79*	0.01*	2.64
75:25	288.85*	0.06*	0.94*	3.57*	0.01*	3.87*
C.V (%)	4.80	27.30	16.20	17.90	26.70	20.80
			BRS Minotauro			
100:0 (C)	270.83	0.19	3.97	8.18	0.03	2.26
75:25	298.00*	0.35	6.30*	11.48	0.04	1.85*
50:50	280.42	0.30	5.62*	10.94	0.04	2.19
25:75	260.33	0.20	4.78	10.68	0.04	2.35
C.V (%)	6.00	45.60	21.10	21.70	43.40	9.80
			Ryegrass			
0:100 (C)	255.08	0.08	2.04	6.50	0.03	3.24
25:75	298.00*	0.11	2.20	3.88*	0.02*	2.23*
50:50	310.54*	0.06	1.35	3.26*	0.01*	2.18*
75:25	328.33*	0.05	1.19*	2.83*	0.01*	1.87*
C.V (%)	5.80	30.30	29.60	35.90	35.50	20.60
			Embrapa 53			
100:0 (C)	298.58	0.32	4.09	12.50	0.04	3.28
75:25	311.17	0.31	3.89	12.56	0.04	3.44
50:50	336.19	0.35	3.21	8.35	0.03	2.45
25:75	310.54	0.47*	4.10	17.78*	0.05	3.67
C.V (%)	9.30	14.60	24.10	23.30	55.90	17.20
			Ryegrass			
0:100 (C)	332.00	0.20	1.25	6.58	0.02	5.54
25:75	348.75	0.10*	0.80*	2.16*	0.01*	4.11*
50:50	364.17	0.09*	0.76*	1.49*	0.00*	2.89*
75:25	377.33*	0.07*	0.71*	1.08*	0.00*	1.98*
C.V (%)	6.80	19.10	15.10	36.00	62.90	20.70
			BRS Resoluto			
100:0 (C)	350.63	0.31	2.55	6.56	0.02	2.63
75:25	340.48	0.29	2.43	7.09	0.03	2.96
50:50	346.75	0.32	2.70	8.21	0.02	3.10
25:75	318.48*	0.33	2.50	12.10*	0.04	4.59*
C.V (%)	4.90	13.60	19.80	15.00	47.20	20.90
			Ryegrass			
0:100 (C)	285.83	0.13	1.40	7.36	0.03	5.61
25:75	317.22*	0.06*	0.49*	2.50*	0.01*	4.18*
50:50	349.25*	0.06*	0.61*	1.84*	0.00*	2.95*
75:25	334.67*	0.08	0.65*	3.29*	0.01*	4.96
C.V (%)	4.80	41.90	33.70	20.00	31.90	18.20

* Mean differs from the control (C) according to Dunnett's test ($p<0.05$).

In the experiment involving turnip, the Embrapa 53 cultivar stood out with significant increases in *A* at the 50:50 ratio (7.56 µmol m^{-2} s^{-1}) and the 25:75 ratio (6.82 µmol m^{-2} s^{-1}) compared to monoculture (Table 5). Turnip, on the other hand, exhibited higher values of carboxylation efficiency (CE) and g_S at lower triticale densities in the mixtures.

The results indicate that the physiological performance of triticale cultivars is sensitive to the relative density of competitors, with higher efficiency observed under specific coexistence proportions (Tables 4 and 5). Previous studies have shown that competition with ryegrass reduces the physiological performance of cereal crops (TAROUCO et al. 2016, BALDESSARINI et al. 2020). Similar results were reported for turnip by SADRAS & CALDERINI (2020), who observed that wheat cultivars face stronger competition for soil nutrients due to the aggressive root system of this weed species. Additionally, the reduction in *A* of turnip under high triticale proportions suggests that this crop may be less efficient under shading conditions.

Relative competitiveness (RC), relative clustering coefficient ($K_{triticale}$ and $K_{ryegrass}$), and aggressiveness (AG) indicated significant effects for all triticale cultivars when competing with ryegrass for plant height (PH), leaf area (LA), and shoot dry mass (SDM), except for the cultivar BRS Minotauro, which showed no significant effect on LA in the presence of the weed (Table 6). The crop showed RC > 1, $K_{triticale} > K_{ryegrass}$, and AG > 0 in all situations, except for BRS Minotauro, which presented RC < 1, $K_{triticale} < K_{ryegrass}$, and AG < 0 for LA. However, this was not significant for at least two indices in the presence of the weed. It is worth noting that, to be considered significant, at least two indices must show significant differences according to the *t*-test (BIANCHI et al. 2006) between triticale cultivars and their competitors. The exception was the cultivar BRS Minotauro competing with ryegrass for LA, where no competitive differences were observed. In the other scenarios, the species were not equivalent in terms of competitiveness, with the crop being more competitive. Similarly, YAMAUTI et al. (2011) also reported that triticale was more competitive than turnip, showing faster growth and development.

The growth of turnip surpassed that of the triticale cultivars according to the RC index (< 1), with the competitor's relative dominance (K) higher than that of the crop, and negative AG values, indicating that the weed was more competitive than the crop for LA and SDM (Table 4). It is important to highlight that there was no significant effect on at least two indices for the cultivars Embrapa 53 and BRS Resoluto regarding PH, and for BRS Minotauro regarding LA and SDM when competing with turnip. It was also observed that RC > 1, $K_{triticale} > K_{turnip}$, and AG > 0 when the cultivars BRS Ulisses and BRS Minotauro competed with turnip for PH. This probably occurred because the crop exhibited greater stem elongation (etiolation) in search of light under competition. Meanwhile, turnip tends to expand laterally to occupy space and dominate the environment, forming larger plants with a greater leaf area, larger canopy, higher biomass accumulation, and greater seed production capacity, even under competition with the crop (SOUZA & VELINI 1997). Similar results were also observed when barley, wheat, and triticale competed with ryegrass and turnip (YAMAUTI et al. 2011, LAMEGO et al. 2013, COSTA & RIZZARDI 2015, GALON et al. 2017, PIES et al. 2019).

Table 5. Physiological responses of triticale cultivars subjected to interference from the competitor turnip (*Raphanus raphanistrum*), expressed as intercellular CO_2 concentration (Ci, µmol mol^{-1}), stomatal conductance (g_S, mol m^{-2} s^{-1}), transpiration (E, mol m^{-2} s^{-1}), photosynthetic rate (A, µmol m^{-2} s^{-1}), carboxylation efficiency (CE, mol m^{-2} s^{-1}), and water use efficiency (WUE, mol mol^{-1}). UFFS, Erechim, RS.

Plant proportions Triticale/Turnip	Physiological traits					
	Ci	g_S	*E*	*A*	CE	WUE
	BRS Ulisses					
100:0 (C)	366.38	0.37	2.41	6.58	0.02	2.13
75:25	374.17	0.35	3.00	4.20*	0.01	1.40*
50:50	344.71	0.36	3.67	7.26	0.02	2.02
25:75	354.66	0.35	2.86	6.34	0.01	1.62
C.V (%)	4.70	10.30	37.10	22.10	45.60	22.60
	Turnip					
0:100 (C)	339.69	0.57	4.46	10.52	0.04	2.75
25:75	324.23	0.54	3.99	13.29	0.04	3.37
50:50	336.34	0.59	4.08	11.88	0.03	2.83
75:25	339.79	0.56	2.89*	12.05	0.04	3.82*
C.V (%)	3.10	10.00	10.30	16.90	35.90	17.6
	BRS Minotauro					
100:0 (C)	325.54	0.34	4.2	10.05	0.03	2.09
75:25	337.64	0.32	3.73	6.72	0.03	1.81
50:50	289.62*	0.31	4.09	13.06	0.04	3.12*
25:75	332.54	0.30	4.10	9.20	0.03	1.77
C.V (%)	5.60	12.40	11.00	35.90	55.10	25.10
	Turnip					
0:100 (C)	385.10	0.56	2.67	4.36	0.01	2.42
25:75	366.50	0.52	2.44	9.39*	0.02	3.62
50:50	387.34	0.49	1.99*	6.01	0.01	2.86
75:25	395.04	0.41*	2.13*	4.00	0.01	1.78
C.V (%)	3.60	12.70	10.40	29.40	47.7	30.20
	Embrapa 53					
100:0 (C)	339.50	0.33	3.99	6.00	0.02	1.49
75:25	346.88	0.38	4.04	6.42	0.03	1.62
50:50	333.75	0.40	4.56*	7.56	0.03	1.61
25:75	349.94	0.44*	4.69*	6.82	0.03	1.98
C.V (%)	6.30	11.00	5.90	29.30	63.30	30.00
	Turnip					
0:100 (C)	354.50	0.51	3.35	6.37	0.02	2.99
25:75	366.83	0.50	3.29	8.38	0.02	1.97
50:50	340.75	0.48	3.18	11.07*	0.03	3.76
75:25	359.25	0.59	3.27	11.87*	0.03*	3.66
C.V (%)	7.90	14.50	7.40	27.80	37.60	29.50
	BRS Resoluto					
100:0 (C)	357.08	0.45	2.71	8.27	0.03	2.96
75:25	356.42	0.41	3.35*	8.32	0.02	2.45
50:50	351.67	0.40	3.60*	5.61*	0.02	2.07*
25:75	364.50	0.42	3.66*	5.92	0.02	2.03*
C.V (%)	6.10	8.50	6.20	22.30	47.60	23.00
	Turnip					
0:100 (C)	292.84	0.17	2.42	8.46	0.03	3.23
25:75	345.42*	0.41*	3.68*	11.55*	0.04	3.03
50:50	399.56*	0.40*	3.52*	1.21*	0.00*	0.75*
75:25	305.55	0.44*	3.45*	14.45*	0.05*	4.10
C.V (%)	9.10	17.70	12.50	20.70	20.30	28.30

* Mean differs from the control (C) according to Dunnett's test ($p<0.05$).

The joint analysis of the data (Figures 2 to 4 and Tables 2 to 6) generally demonstrates that competition from ryegrass and/or turnip has negative effects on the triticale cultivars BRS Ulisses, Embrapa 53, and BRS Resoluto. In other words, the

weeds show highly competitive ability relative to the crop, given their capacity to survive under adverse conditions and use environmental resources—such as water, light, and nutrients—more efficiently (JASTRZĘBSKA et al. 2023, KUMAR et al. 2025). The rusticity of weed species is also associated with the absence of genetic improvement compared to triticale, particularly turnip, which caused greater damage to the crop than ryegrass. Triticale is a hybrid resulting from a cross between wheat and rye, incorporating alleles from both species to improve adaptation, yield, and grain quality (JASTRZĘBSKA et al. 2023). However, this may lead the crop to exhibit lower competitive ability when infested by ryegrass and/or turnip.

Table 6. Competitiveness indices for morphological variables between triticale cultivars (x *Triticosecale* Wittmack) and the weed species ryegrass (*Lolium multiflorum*) and turnip (*Raphanus raphanistrum*), competing at equal plant proportions (50:50), expressed by relative competitiveness (RC), relative clustering coefficient (K), and aggressiveness (AG). UFFS, Erechim, RS.

Variables	CR	Kx (triticale)	Ky (competidor)	AG
		Plant height		
BRS Ulisses x ryegrass	1.460± 0.025*	0.867± 0.038*	0.466± 0.009	0.146± 0.008*
BRS Minotauro x ryegrass	1.408± 0.040*	1.095± 0.040*	0.592± 0.019	0.151± 0.012*
Embrapa 53 x ryegrass	1.540± 0.122*	0.929± 0.026*	0.472± 0.050	0.163± 0.023*
BRS Resoluto x ryegrass	1.475± 0.048*	1.141± 0.048*	0.570± 0.035	0.170± 0.012*
BRS Ulisses x turnip	1.375± 0.063*	1.006± 0.021*	0.582± 0.041	0.135± 0.018*
BRS Minotauro x turnip	1.443 ± 0.102*	1.007 ± 0.019*	0.554 ± 0.066	0.149 ± 0.026*
Embrapa 53 x turnip	1.121± 0.053	0.901± 0.022	0.756± 0.088	0.047± 0.022
BRS Resoluto x turnip	1.004± 0.022	1.060± 0.051	1.050 ± 0.042	0.002± 0.011
		Leaf area		
BRS Ulisses x ryegrass	6.897± 0.773*	1.029± 0.085*	0.082± 0.008	0.429± 0.023*
BRS Minotauro x ryegrass	0.977± 0.075	0.196± 0.025	0.199± 0.013	-0.003± 0.012
Embrapa 53 x ryegrass	6.523± 0.582*	0.927± 0.056*	0.082± 0.008	0.404± 0.012*
BRS Resoluto x ryegrass	4.033± 0.141*	0.382± 0.028*	0.074± 0.005	0.207± 0.011*
BRS Ulisses x turnip	0.516± 0.043*	0.203± 0.029*	0.483± 0.057	-0.155± 0.019*
BRS Minotauro x turnip	0.969 ± 0.084	0.439 ± 0.043	0.464 ± 0.039	-0.012 ± 0.026
Embrapa 53 x turnip	0.392± 0.063*	0.229± 0.018*	1.035± 0.180	-0.31± 0.056*
BRS Resoluto x turnip	0.305± 0.052*	0.158± 0.031*	0.802± 0.105	-0.306± 0.030*
		Shoot dry mass		
BRS Ulisses x ryegrass	4.966± 0.616*	0.572± 0.088*	0.081± 0.011	0.283± 0.033*
BRS Minotauro x ryegrass	2.680± 0.429*	0.478± 0.031*	0.150± 0.025	0.194± 0.027*
Embrapa 53 x ryegrass	14.102± 1.502*	0.602± 0.030*	0.028± 0.004	0.347± 0.011*
BRS Resoluto x ryegrass	4.687± 0.647*	0.638± 0.043*	0.096±0.014	0.301± 0.019*
BRS Ulisses x turnip	0.767± 0.017*	0.249± 0.013*	0.351± 0.012	-0.060± 0.004*
BRS Minotauro x turnip	0.751 ± 0.087	0.281 ± 0.028*	0.425 ± 0.046	-0.078 ± 0.031
Embrapa 53 x turnip	0.307 ± 0.034*	0.187 ± 0.033*	1.041 ± 0.152	-0.346 ± 0.024*
BRS Resoluto x turnip	0.415± 0.055*	0.183± 0.028*	0.588± 0.031	-0.217± 0.021*

***** Significant difference according to the *t*-test ($p<0.05$). Kx and Ky are the relative clustering coefficient of the triticale cultivars and the competitor's ryegrass and turnip, respectively.

Desse Thus, understanding the dynamics and competitive abilities when crops and weeds coexist in the same community is crucial for decision-making regarding the timing of weed control. In the case of triticale, there are few studies evaluating its competition with weed species, especially ryegrass and turnip, which produce a large number of seeds, are widely distributed across fields, exhibit high competitive ability, and are resistant to EPSPS, ACCase, and ALS-inhibiting herbicides (ryegrass) and

ALS-inhibiting herbicides (turnip) (MARIO et al. 2024, HEAP 2025), herbicides commonly used for chemical control of winter weeds in southern Brazil.

CONCLUSION

There is an equivalence in competition mechanisms and resource demand among triticale cultivars in the presence of ryegrass and turnip.

The triticale cultivars (BRS Ulisses, Embrapa 53, and BRS Resoluto) exhibit similar competitive ability for environmental resources when associated with ryegrass and turnip.

The physiological variables of triticale cultivars were negatively affected as the density of ryegrass and turnip plants increased in the mixtures.

The observed differences in the behavior of RC, Kx/Ky, and AG indices for PH, LA, and SDM indicate variation in the competitive ability of triticale cultivars against weeds. Generally, the crop showed greater relative growth in the presence of ryegrass and lower growth when infested with turnip.

Interspecific competition causes greater negative impacts on the morphophysiological variables of species than intraspecific competition.

Triticale and the weed species ryegrass and turnip essentially compete for the same environmental resources.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, and formal analysis**, Leandro Galon, Tailana Iager and Janaíne Oliveira Toso**; software and validation**, Gismael Francisco Perin, Rodrigo José Tonin and Germani Concenço;** investigation**, Janaíne Oliveira Toso, Maico André Michelon Bagnara and Leandro Galon**; resources and data curation**, Tailana Iager, Janaíne Oliveira Toso and Gismael Francisco Perin**; writing-original draft preparation**, Janaíne Oliveira Toso, Maico André Michelon Bagnara and Rodrigo José Tonin**; writing-review and editing**, Leandro Galon, Germani Concenço and Gismael Francisco Perin**; visualization**, Gismael Francisco Perin, Rodrigo José Tonin and Janaíne Oliveira Toso**; supervision, **Janaíne Oliveira Toso, Leandro Galon and Rodrigo José Tonin**; project administration, **Leandro Galon, Gismael Francisco Perin and Rodrigo José Tonin**; funding acquisition, **Leandro Galon and Gismael Francisco Perin**. All authors have read and agreed to the published version of the manuscript.

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INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable for studies not involving humans or animals.

INFORMED CONSENT STATEMENT

Not applicable because this study did not involve humans.

DATA AVAILABILITY STATEMENT

The data can be made available under request.

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CONFLICTS OF INTEREST

To the best of our knowledge, the named authors have no conflict of interest, financial or otherwise.

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