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Research Article

Yielding performance of wheat cultivars subjected to different management techniques

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Abstract

Wheat (*Triticum aestivum* L.) is one of the most cultivated and consumed crops worldwide, playing a crucial role in food security and global trade. In Brazil, more than 85% of national wheat production is concentrated in the southern region, where the choice of cultivar and management practices directly affect crop performance. This study aimed to evaluate the productive performance of 14 wheat cultivars subjected to two different management techniques: chemical and chemical + biological. The experiment was conducted at the Experimental Farm of the Universidade Regional do Noroeste do Estado do Rio Grande do Sul (Unijuí), in 2024, using an incomplete factorial block design. Agronomic traits, pest and disease incidence, and the interaction between treatments and genotypes were assessed. The results indicated that chemical management resulted in greater plant height, number of leaves, ear length, and number of grains per ear, while chemical + biological management promoted a higher number of spikelets per ear. The cultivars TBIO PONTEIRO and ORS SOBERANO excelled in spikelet formation, while TBIO CAPAZ, TBIO TRUNFO, and TBIO TALISMÃ showed a higher number of grains per ear. These findings highlight the importance of cultivar selection and integrated management strategies to optimize wheat yield under different environmental conditions.

Keywords: *Triticum aestivum* L., phytosanitary control, agronomic variables, sustainability, interaction, genotypes.

Introduction

Wheat (*Triticum aestivum* L.) belonging to the Poaceae family, subfamily Pooideae, is one of the most cultivated and consumed agricultural crops in the world, being an important commodity (Vergütz et al., 2024). In Brazil, the southern region of the country holds more than 85% of cereal production, being characterized as an important cradle for the development of research and testing of cultivars (Companhia Nacional de Abastecimento [CONAB], 2024). Cereal plays a fundamental role in human and animal nutrition, containing important components, such as minerals, proteins, vitamins and carbohydrates (Khalid, Hameed, & Tahir, 2023), and can be used to make bread, pasta, cakes and cookies (Reynolds & Braun, 2022). In animal feed, wheat can be used as forage, grain and feed (Mori & Icnaczak, 2011).

Wheat is an autogamous annual species, with C3 metabolism, and the wheat cultivars grown in Brazil have a spring habit, insensitive to photoperiod (Rodrigues, 2022). The crop has thin, flat and long leaves, fasciculated roots that can reach up to 1.5m deep, and erect culms with 5 to 7 nodes (Gregório, 2023). Its inflorescence is a compound ear, formed by 15 to 20 spikelets, each containing 2 to 3 grains (Lins, 2021). The grain is a caryopsis, oval in shape and rounded at the ends, composed of the pericarp, endosperm and germ (Lins, 2021). The wheat cycle varies according to the bioclimatic group and the genetic component of the cultivars, with an average range of 100 to 160 days (Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA], 2016). The best temperatures for crop development are between 20 and 25ºC, and for tillering, between 15 and 20ºC (Borém & Scheeren, 2015).

According to data released by the National Supply Company (CONAB, 2024), the volume of Brazilian grain production is expected to reach 322.53 million tons in the 2024/2025 harvest. However, a large part of the reduction in wheat yield is due to attacks by insect pests and diseases (Lau et al., 2020). In southern Brazil, which is the main cereal producing region, the main diseases that can affect the crop include: Fusarium head blight (*Gibberella zeae*), blast brusone (*Pyricularia oryzae*), leaf rust (*Puccinia triticina*), stem rust (*Puccinia graminis* f. sp. *tritici*), powdery mildew (*Blumeria graminis* f. sp. *tritici*), yellow spot (*Drechslera tritici-repentis*) and brown spot (*Bipolaris sorokiniana*) (Maciel et al., 2020).

In addition to diseases, several pests affect wheat, such as caterpillars (*Spodoptera frugiperda, Mythimna sequax* and *Mythimna adultera*), grub (*Diloboderus abderus and Phyllophaga triticophaga*), aphids (*Schizaphis graminum, Rhopalosiphum padi, Metopolophium dirhodum, Sitobion avenae* and *Sipha maydis*) bed bugs (*Dichelops melacanthus, Nezara viridula* and *Thyanta perditor*) and borers (*Elasmopalpus lignosellus, Diatraea saccharalis*) (Salvadori et al., 2022).

Due to adversities, the application of bioinputs emerges as a sustainable alternative, using beneficial microorganisms to control pests and to improve the efficiency of nutrient use by plants (EMBRAPA, 2022). When compared to pesticides, biological pesticides have greater selectivity, reduced chemical residues, better agronomic performance and lower toxic effects on human health and the environment (Berro et al., 2024). In this sense, studies demonstrate that the combination of chemical and biological products has increased nutritional efficiency, balanced plant physiology and improved pest and disease management (Bonissoni, 2020).

In addition to management, wheat productivity results from interactions between the genotype and the environment, which influence production components, such as the number of grains per ear and grain weight. The choice of cultivar plays a fundamental role in this context, as it determines the productive potential, technological quality and reaction to biotic and abiotic stresses (CONAB, 2017). Therefore, the objective of this study is to characterize the agronomic performance of wheat cultivars recommended for the Southern Region of Brazil, subjected to different management techniques, emphasizing those that have the greatest potential for genetic resilience against diseases and insect pests.

Materials and Methods

The work was carried out at the Escola Fazenda of the Universidade Regional do Noroeste do Estado do Rio Grande do Sul (Unijuí), located in the municipality of Augusto Pestana, Rio Grande do Sul, Brazil, in the second half of 2024. According to Köppen, the local climate is characterized as Cfa, that is, humid subtropical (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013). The soil in the experimental area is classified as a typical dystroferric latosol, according to the SiBCS (Brazilian Soil Classification System), with a deep profile, well drained, with a dark red color.

The results of the soil analysis are presented in Table 1. The area has an average organic matter (2.6%), class 2 clay (53%) and a high CEC pH7.0 (22.9 cmolc/dm³). The pH of 4.8 is outside the recommended value for the culture (6.0). The level of phosphorus found is very high. The potassium and calcium contents are high. Additionally, micronutrients such as zinc, manganese and copper are at very high levels. The sulfur content is medium. Soil acidity is one of the biggest limitations to obtaining good yields in wheat crops. In this sense, acidity in the presence of toxic aluminum can cause significant damage to root growth and wheat production (Marschner, 2012).

Table 1. Chemical and physical analysis of the soil, from the place where the experiment was carried out.

Clay (%)	pH	Index SMP	P (mg/dm³)[1]	K (mg/dm³)	OM (%)	Al (cmolc/dm³)
53	4.8	4.9	45.5	213	2.6	1
Ca (cmolc/dm³)	CEC ph_7 (cmolc/dm³)	H + Al (cmolc/dm³)	S (mg/dm³)	Zn (mg/gm³)	Cu (mg/dm³)	Mn (mg/dm³)
4.9	22.9	15.4	4.5	4.4	9	47.7

[1]P: phosphorus; K: potassium; MO: organic matter; Al: aluminum; Ca: calcium; S: sulfur; Zn: zinc; Cu: copper; Mn: manganese.

Sowing was carried out on May 21, 2024, in a direct cultivation system, using a seeder-fertilizer, using 120 kg ha^{-1} of NPK 5-20-20, employing a seed density of 150 kg ha^{-1}. After 48 days, top dressing was applied with Monoammonium Phosphate (MAP) (50 kg ha^{-1}), Potassium Chloride (50 kg ha^{-1}) and Urea (100 kg ha^{-1}). The experiment was conducted in an incomplete block design with factorial, using 14 cultivars (TBIO CALIBRE, TBIO AUDAZ, TBIO TRUNFO, TBIO TALISMÃ, TBIO CAPAZ, TBIO FUSÃO, TBIO TITAN, TBIO MOTRIZ, TBIO PONTEIRO, ORS FALCÃO, ORS FEROZ, ORS GLADIADOR, ORS PREMIUM, ORS SOBERANO) (Table 2) and two treatments (Chemical and Chemical + Biological). Each experimental unit was 3.20 m wide × 150 m long, totaling 480 m² per cultivar.

The 14 cultivars (Table 2) were chosen through different breeders, in accordance with recommendations for the southern region of the country, considering that each cultivar has different levels of tolerance for different diseases and pests.

Phytosanitary management was divided into two areas for evaluation. In the chemical area, the first C treatment arried out was at the end of tillering, using Nativo fungicide (500 ml ha^{-1}) together with mineral oil (300 ml ha^{-1}) and pH reducer (30 ml ha^{-1}). The second application took place during the stretching phase, aiming to eliminate the weed population, using the herbicide 2.4 D (1.5 L ha^{-1}) and the pH reducer (50 ml ha^{-1}). At the end of the stretching phase, a third application was carried out, using, again, the same products used in the first. At the heading stage, the last application was carried out, with the fungicide Nativo (600 ml ha^{-1}) and the pH reducer

(30 ml ha^{-1}) (Figure 1). In the area that had biological and chemical tests, the same procedures were carried out as in the chemical area. However, at the beginning of heading, Tríppel (microbiological fungicide; 1L ha^{-1}), Rootland (organic fertilizer; 1L ha^{-1}), Assertive (microbiological insecticide; 1.5 L ha^{-1}), CT Green (citronella-based foliar fertilizer; 200ml/ha), *Azospirillum* (inoculant, growth promoter; 2 L ha^{-1}), *Bacillus Pumilus* (microbiological fungicide; 2 L ha^{-1}) and *Megaterium* (inoculant, phosphorus solubilizer; 2 L ha^{-1}) (Figure 2) were used.

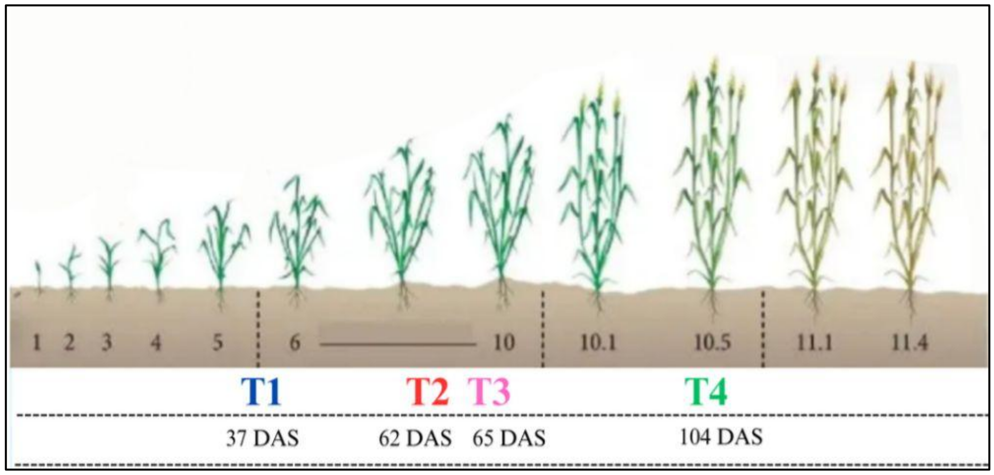

Figure 1. Product applied, dose and date of application, defined for phytosanitary treatment of the area with chemical treatment. T1 - Nativo (500 ml ha^{1}) + pH reducer (30 ml ha^{1}); T2 - 2.4 D (1.5 L ha^{1}) + pH reducer (50 ml ha^{-1}); T3 - Nativo (500 ml ha^{-1}) + Mineral oil (300 ml ha^{1}) + pH reducer (30 ml ha^{-1}); T4 - Nativo (600 ml ha^{1}) + pH reducer (30 ml ha^{1}).
Source: Own authorship, 2024.

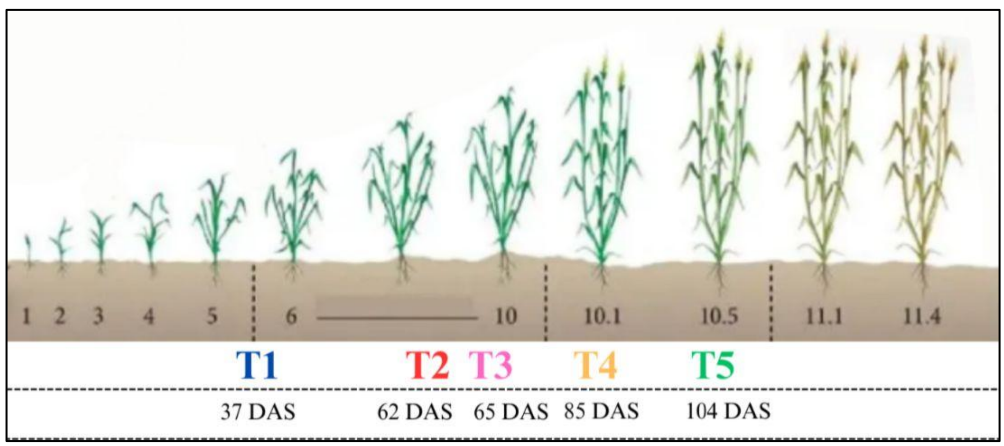

Figure 2. Product applied, dose and date of application, defined for phytosanitary treatment of the area with chemical + biological treatment. T1 - Nativo (500 ml ha^{-1}) + pH reducer (30 ml ha^{-1}); T2 - 2.4 D (1.5 L ha^{-1}) + pH reducer (50 ml ha^{-1}); T3 - Nativo (500 ml ha^{-1}) + Mineral oil (300 ml ha^{1}) + pH reducer (30 ml ha^{1}); T4 -Tríppel (1 L ha^{1}) + Rootland (1 L ha^{-1}) + Assertive (1.5 L ha^{-1}) + CT Green (200 ml ha^{1}) + Azospirillum (2 L ha^{-1}) + Bacillus Pumilus (2 L ha^{1}) + Megaterium (2 L ha^{-1}); T5 - Nativo (600 ml ha^{1}) + pH reducer (30 ml ha^{1}).
Source: Own authorship, 2024.

Pre-harvest and harvest assessments were carried out. In pre-harvest evaluations, in the grain-filling phase, in each treatment, 10 points were analyzed. At each point, a plant was randomly collected and analyzed, considering quantitative variables, such as: height (PH); number of tillers (NT); leaf width (LW); leaf length (LL); ear length

(EL); number of spikelets per ear (NSE) and number of grains per ear (NGE). The invasive species present in 1 m² (*Lolium multiflorum, Conyza spp, Raphanus raphanistrum*) and plant stands, in 2 and 5 m, were also quantified, aiming to correct the plant population.

Furthermore, soil-related variables were analyzed, such as compaction level (CL); straw volume (SV); soil coverage (SC); fertility (FER); plantability (PLA); emergency (EME); rootlets (RL) and volume (RSV), aggressiveness (RSA) and depth (RSD) of the root system. For these measurements, the criteria of 0 for a little and 10 for a lot were used.

Table 2. Cultivar with classification, cycle and level of tolerance to the main diseases.

CULTIVAR	Classification	Cycle	*Drechslera tritici-repentis*	*Blumeria graminis* f.sp. *tritici*	*Puccinia triticina*
TBIO Calibre	Bread/Improver	Superprecocious	INT[1]	INT	MT
TBIO Audaz	Improver	Precocious	MT	MS	MT
TBIO Trunfo	Bread	Precocious	INT	INT	MT
TBIO Talismã	Improver	Precocious	MT	INT	MT
TBIO Capaz	Bread/Whitener	Superprecocious	MT	MT	MT
TBIO Fusão	Improver	Precocious	MT	MT	MT
TBIO Titan	Bread/ Improver	Medium	MT	MT	MT
TBIO Motriz	Bread/Improver	Medium/Late	MT	INT	MT
TBIO Ponteiro	Bread	Late	INT	T	MS
ORS Falcão	Improver	Superprecocious	MT	MT	MT
ORS Feroz	Improver	Precocious	MT	MT	MT
ORS Gladiador	Bread	Medium	MT	MT	MT
ORS Premium	Improver/Whitener	Medium/ Precocious	MT	MT	MT
ORS Soberano	Improver	Medium	MT	MT	MT

[1]MS: moderately susceptible; INT: intermediate; MT: moderately tolerant; T: tolerant; *Drechslera tritici-repentis* = yellow spot; *Blumeria graminis* f.sp. *tritici* = powdery mildew; *Puccinia triticina* = leaf rust.

Regarding pests and diseases, analyzes were carried out on the quantification of aphids (*Sitobion avenae*), cutworm (*Agrotis ipsilon*), fall armyworm (*Spodoptera* sp.), grubs (*Diloboderus abderus*), yellow spot (*Drechslera tritici-repentis*), brown spot (*Bipolaris sorokiniana*), leaf rust (*Puccinia triticina*), stem rust (*Puccinia graminis* f.sp. *tritici*) and powdery mildew (*Blumeria graminis* f.sp. *tritici*). For these measurements, visual notes were also used, with the criteria being 0 for little and 10 for a lot.

In harvest evaluations, in each trial, 50 plants were collected and, subsequently, in the laboratory, the following variables were analyzed: plant height (PH); insertion height of the ear (IHE); ear length (EL); number of spikelets (NS, n); number of grains (NG); grain weight per ear (GWE); thousand grains weight (TGW) and harvest index (HI).

The set of data obtained was subjected to the process of identifying and removing outliers. Next, the assumptions of the statistical model were verified, based on the tests of normality of errors, homogeneity of variance and independence of errors, by Shapiro-Wilk, Bartlett and Durbin-Watson, respectively. With the assumptions met, analysis of variance was carried out to verify the effects of treatment levels and different cultivars, as well as their interaction, on the quantitative characters evaluated in the pre-harvest and harvest phases, at 5% probability using the F test. Upon finding a significant effect, the simple and main effects of each variation factor were broken down using the Tukey mean comparison test, at 5% probability. For qualitative variables, descriptive analysis was carried out, using the average of each variable. The analyzes were carried out using the R software (Shimizu, Marubayashi, & Gonçalves, 2023; R Core Team, 2023). In Table 3 is presented the commercial classification of wheat.

Table 3. Commercial classification of wheat.

Class	Gluten strength (minimum value expressed in 10^{-4} J)	Stability (time expressed in minutes)	Number of falls (minimum value, expressed in seconds)
Improver	300	14	250
Bread	220	10	220
Domestic	160	6	220
Basic	100	3	200
Other uses	Any	Any	Any

Source: Cunha and Caierão (2023).

Results and Discussion

During the culture cycle, the temperature fluctuated between -1.22 and 32.51°C (Table 4). According to Borém and Scheeren (2015), the ideal range for wheat development is between 15 and 25°C. The months of September and October remained within this range (Figure 3). However, the thermal variations observed may have negatively impacted yield. According to Fietz, Sousa, and Urchei (2005), mean daily temperatures above 18.5°C can reduce wheat productivity by up to 11.3%, reaching 32.3% when it exceeds 25°C. Associated with this, according to Scheeren, Cunha, Quadros and Martins (2000), from the elongation stage onwards, very low temperatures, with the formation of strong frosts, may cause "burning" of leaves and "strangulation" of the wheat stalk.

In relation to precipitation, it was analyzed that the months of June and October had the highest precipitation, being 195.12 mm and 192.72 mm, respectively. The month with the lowest rainfall was July, with 67.14 mm. Thus, during the cycle, a total of 776.3 mm was recorded. According to Doorenbos and Kassam (1979) wheat needs 450 to 600 mm, depending on the climate and the duration of the cycle. Due to this, it can be seen that the precipitation levels did not differ greatly from those recommended for the crop. Although the total precipitation meets the crop's requirements, its poor distribution during the cycle, especially in critical phases such as tillering and maturation, may have contributed to the observed losses (Canziani & Guimarães, 2009).

Table 4. Stage with respective duration and observed temperatures.

Stage	Mean temp. (ºC) [1]	Maximum temp. (ºC)	Minimum temp. (ºC)
Germination	12.84	26.84	4.22
Tillering	18.17	27.51	6.38
Elongation	12.94	26.01	-1.22
Tasseling	13.83	25.85	1.75
Maturation	16.26	32.51	-0.77

[1]Temp: Temperature.
Source: Own authorship, 2024.

According to Raddatz, Follmann, Santos, Pereira and Rosa (2023), with a base temperature of 5°C, 1192.7 degree-days were needed for the wheat cycle to be completed. In the experiment, a thermal sum of 1366.88°C was observed, taking into account a base temperature of 5°C. In the month of September there was the highest sum (Figure 4), accounting for 411.19 degree days. Considering the different phenological phases, 69.42 degree-days were needed from emergence to the beginning of tillering, 437.04 degree-days from the beginning of tillering to flowering and 860.43 degree-days from flowering to maturation.

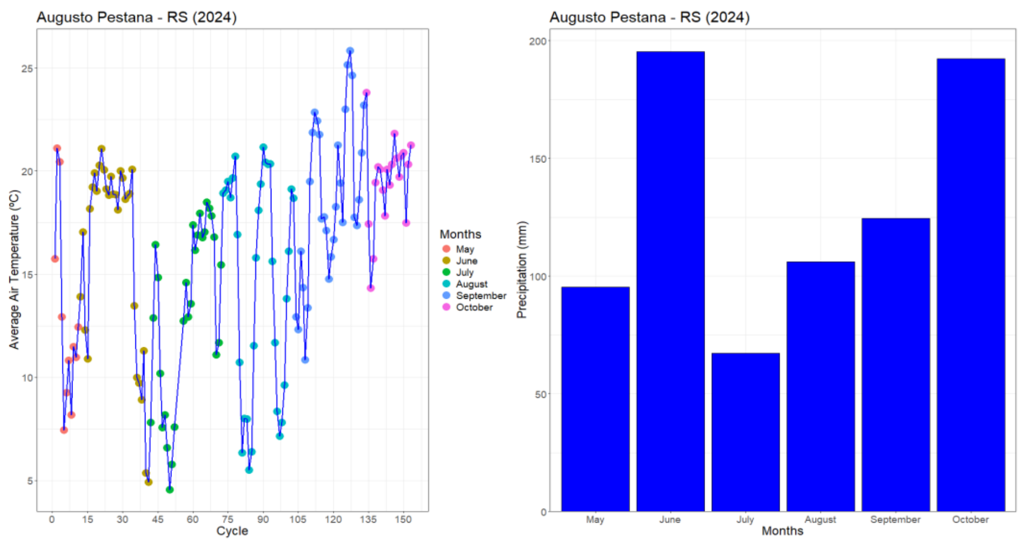

Figure 3. Graph of temperature and precipitation variations depending on post-emergence days. **Source:** Own authorship, 2024.

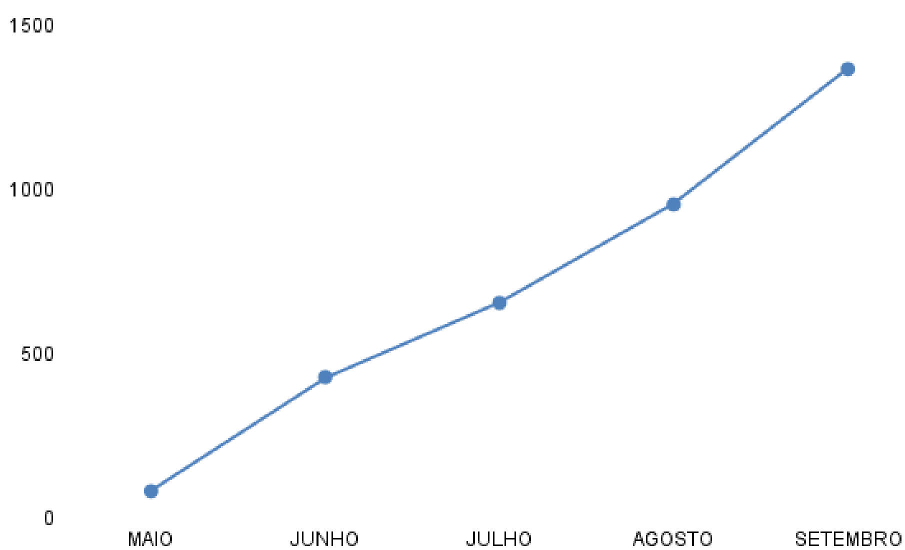

Figure 4. Graph of thermal sum as a function of months.
Source: Own authorship, 2024.

When observing the descriptive analysis of disease incidence (Table 5), it can be seen that the cultivar with the highest incidence of *Drechslera tritici-repentis* was TBIO CAPAZ, however, the cultivar TBIO AUDAZ was the least affected by the disease. For *Bipolaris sorokiniana*, the highest incidence was observed in the cultivar TBIO CALIBRE and the lowest in the cultivars TBIO MOTRIZ and TBIO TITAN.

For *Puccinia triticina*, there was a higher occurrence in the cultivar TBIO CALIBRE and lower in the cultivars ORS GLADIADOR, ORS PREMIUM and TBIO MOTRIZ. For *Puccinia graminis* f.sp. *tritici* there was a higher incidence in the cultivar ORS SOBERANO and lower in the cultivars TBIO AUDAZ, ORS PREMIUM, TBIO TALISMÃ, TBIO TITAN and TBIO TRUNFO. *Blumeria graminis* f.sp. *tritici* was present only in the cultivars TBIO TALISMÃ, TBIO TITAN and TBIO TRUNFO. According to Kumar and Kukreja (2024), around 15 to 20% of losses in wheat production are attributed to fungal and bacterial diseases and insect pest attacks.

Table 5. Summary of the descriptive analysis of the average incidence of diseases in the evaluated wheat cultivars.

CULTIVAR	*Drechslera tritici-repentis*[1]	*Bipolaris sorokiniana*	*Puccinia triticina*	*Puccinia graminis* f.sp. *tritici*	*Blumeria graminis* f.sp. *tritici*
TBIO Audaz	2.10	1.05	0.15	0.00	0.00
TBIO Calibre	3.95	3.30	2.10	0.50	0.00
TBIO Capaz	5.05	2.45	0.35	2.40	0.00
ORS Falcão	3.25	1.95	0.05	2.60	0.00
ORS Feroz	3.35	1.35	0.40	3.65	0.00
TBIO Fusão	3.85	1.40	0.05	0.35	0.00
ORS Gladiador	3.95	2.60	0.00	4.40	0.00
TBIO Motriz	2.75	0.90	0.00	0.10	0.00
TBIO Ponteiro	4.20	1.05	0.2	1.15	0.00
ORS Premium	4.25	1.60	0.00	0.00	0.00
ORS Soberano	2.95	1.60	0.10	5.00	0.00
TBIO Talismã	3.55	2.30	0.60	0.00	0.20
TBIO Titan	3.25	0.90	0.25	0.00	0.05
TBIO Trunfo	4.55	1.45	0.25	0.00	1.55

[1]*Drechslera tritici-repentis* = yellow spot; *Bipolaris sorokiniana* = brown spot; *Puccinia triticina* = leaf rust; *Puccinia graminis* f.sp. *tritici* = stem rust; *Blumeria graminis* f.sp. *tritici* = powdery mildew.

Through the data contained in Table 6, with regard to insect pests, it can be seen that both *Agrotis ipsilon* and *Diloboderus abderus* were absent in all tested cultivars. *Spodoptera* sp. it was also absent in the vast majority of cultivars, except for TBIO AUDAZ. *Sitobion avenae* had a higher occurrence in the ORS FEROZ cultivar. On the other hand, TBIO AUDAZ and ORS PREMIUM did not show the presence of the pest. According to EMBRAPA (2005), one of the pests that can cause the most damage to wheat is the aphid, an insect capable of weakening the plant and transmitting diseases that reduce production.

Regarding invasives, those that showed the highest occurrence were: *Lolium multiflorum, Conyza bonariensis* and *Raphanus raphanistrum*. According to Agostinetto, Vargas, Gazziero and Silva (2015), the losses caused by weeds in wheat yield may be due to competition, the effect of allelopathy or indirectly, reducing the quality of the harvested product. In this sense, in the experiment, numerous invasive plants were observed, responsible for reducing the final quality of wheat, due to competition.

Table 7 demonstrates the descriptive analysis of the performance of each cultivar. Therefore, for the variable compaction level (CL), the highest number was observed in the ORS FALCÃO cultivar (7.65). On the other hand, the lowest value was found in the TBIO TRUNFO cultivar (5.15). According to Machado (2003), soil compaction can cause a drop of up to 60% in plant productivity. For straw volume (SV), the highest value was identified in the cultivar ORS GLADIADOR (5.05) and the lowest in TBIO TALISMÃ (1.15). For soil cover (SC), the highest value was seen in TBIO CALIBRE (3.55) and the lowest in TBIO TALISMÃ (1.15). Soil coverage becomes important as it minimizes the "splash" effect, reducing erosion and nutrient loss (Verdum, Vieira,

& Caneppele, 2016).

Table 6. Summary of the descriptive analysis of the average number of invasive plants and insect pests in the evaluated wheat cultivars.

CULTIVAR	Invasive	*Lolium multiflorum*[1]	*Raphanus raphanistrum*	*Conyza bonariensis*	*Sitobion avenae*	*Agrotis ipsilon*	*Diloboderus abderus*	*Spodoptera* frugiperda
TBIO Audaz	5.20	1.30	0.05	0.15	0.00	0.00	0.00	0.15
TBIO Calibre	17.20	0.50	0.20	2.10	0.50	0.00	0.00	0.00
TBIO Capaz	18.30	5.60	0.45	0.35	2.40	0.00	0.00	0.00
ORS Falcão	2.50	1.70	0.10	0.05	2.60	0.00	0.00	0.00
ORS Feroz	4.30	1.15	0.05	0.40	3.65	0.00	0.00	0.00
TBIO Fusão	4.80	0.10	0.10	0.05	0.35	0.00	0.00	0.00
ORS Gladiador	4.20	1.75	0.00	0.00	4.40	0.00	0.00	0.00
TBIO Motriz	5.40	1.85	0.00	0.00	0.10	0.00	0.00	0.00
TBIO Ponteiro	4.10	0.05	0.00	0.20	1.15	0.00	0.00	0.00
ORS Premium	5.10	3.35	0.00	0.00	0.00	0.00	0.00	0.00
ORS Soberano	6.20	3.80	0.00	0.10	5.00	0.00	0.00	0.00
TBIO Talismã	9.70	1.80	0.05	0.05	0.70	0.00	0.00	0.00
TBIO Titan	6.65	1.45	0.05	0.00	0.10	0.00	0.00	0.00
TBIO Trunfo	5.05	1.50	0.20	0.25	0.35	0.00	0.00	0.00

[1]*Lolium multiflorum* = ryegrass; *Raphanus raphanistrum* = turnip; *Conyza bonariensis* = horseweed; *Sitobion avenae* = ear aphid; *Agrotis ipsilon* = screwworm; *Diloboderus abderus* = pasture grub; *Spodoptera frugiperda* = fall armyworm.

Table 7. Summary of the descriptive analysis of the performance of each cultivar related to agronomic characters.

CULTIVAR	CL (un.)[1]	SV (un.)	SC (un.)	FER (un.)	PLA (un.)	EME (un.)	RSD (un.)	RSV (un.)	RSA (un.)	RL (un.)
TBIO Audaz	6.40	2.00	2.00	8.00	7.90	8.00	3.25	3.45	3.30	2.20
TBIO Calibre	6.10	3.40	3.55	8.45	8.85	8.50	4.70	4.70	4.25	3.85
TBIO Capaz	5.60	2.95	2.45	7.75	8.55	8.55	7.50	5.30	5.35	5.05
ORS Falcão	7.65	2.00	2.00	8.00	8.00	8.00	2.05	2.10	1.65	1.60
ORS Feroz	7.25	2.00	2.00	8.00	8.00	8.00	2.80	2.85	2.55	2.40
TBIO Fusão	6.75	2.10	1.80	7.55	7.95	9.00	3.85	4.25	3.80	3.45
ORS Gladiador	7.20	5.05	2.00	4.50	8.00	8.00	5.15	2.65	3.00	2.70
TBIO Motriz	6.90	2.05	2.05	9.00	9.00	9.00	3.65	4.10	3.55	3.50
TBIO Ponteiro	6.65	3.10	3.10	8.00	7.60	8.00	4.60	3.90	3.60	3.35
ORS Premium	7.25	1.90	1.90	8.00	8.00	8.00	2.65	2.45	2.20	2.35
ORS Soberano	7.25	1.40	1.40	7.00	7.75	7.75	2.20	2.45	2.25	2.40
TBIO Talismã	6.15	1.15	1.15	8.30	7.50	8.50	3.50	3.85	3.60	3.75
TBIO Titan	6.80	2.25	2.30	8.00	8.50	8.50	4.15	4.35	5.45	3.20
TBIO Trunfo	5.15	2.65	2.65	9.00	8.20	8.50	4.45	4.10	4.35	4.75

[1]CL = compression level; SV = straw volume; SC = soil cover; FER = fertility; PLA = plantability; EME = emergency; RSD = root system depth; RSV = root system volume; RSA = root system aggressiveness; RL = rootlets.

For fertility (FER), the highest value was observed in TBIO TRUNFO (9) and the lowest in ORS GLADIADOR (4.5). For root system depth (RSD), the highest value was found in TBIO CAPAZ (7.5) and the lowest in ORS FALCÃO (2.05). For root system volume (VSR), the highest value was observed in TBIO CALIBRE (4.7) and the lowest in ORS FALCÃO (2.1). For root system aggressiveness (RSA), TBIO TITAN (5.45) presented higher values and ORS FALCÃO (1.65) lower ones. For rootlets (RL), TBIO CAPAZ (5.05) demonstrated higher values and TBIO AUDAZ (2.2) lower values. According to Cunha and Caierão (2023), successful implementation requires an accurate diagnosis of soil conditions. It is essential to analyze the presence of physical restrictions that may limit root growth and the occurrence of variations in chemical properties that indicate soil fertility. According to the analysis previously carried out, it was noticed that the local conditions were not ideal for wheat cultivation, making root development difficult.

For plantability (PLA), the highest value was found in the cultivar TBIO MOTRIZ (9) and the lowest in TBIO TALISMÃ. For emergence (EME), the highest value was observed in the cultivars TBIO FUSÃO (9) and TBIO MOTRIZ (9). On the other hand, the lowest value was found in the ORS SOBERANO cultivar (7.75). Plantability is related to the quality of the vertical distribution of seeds in the sowing furrow, and horizontally to the variation in distance between seeds in the row. The uniformity of plant distribution will provide a well-established crop, with low competitiveness between the crop of interest (Martin et al., 2022).

Regarding the descriptive analysis for the treatment effect, contained in Table 8, it can be seen that, for the variables leaf width (LW), number of tillers (NT), straw volume (SV), fertility (FER) and plantability (PLA), the C+B treatment obtained higher averages. For the variables compaction level (CL), soil cover (SC), emergence (EME), root system depth (RSD), root system volume (RSV), root system aggressiveness (RSA) and rootlets (RL), C treatment obtained higher averages.

Table 8. Summary of the descriptive analysis for the treatment effect on agronomic traits.

Treatment	LW (cm) [1]	NT (un.)	CL (un.)	SV (un.)	SC (un.)	FER (un.)	PLA (un.)	EME (un.)	RSD (un.)	RSV (un.)	RSA (un.)	RL (un.)
Chemical + Biological	1.40	1.17	6.63	2.05	2.06	8.08	8.21	8.29	3.29	3.31	2.98	2.88
Chemical	1.34	0.992	6.67	2.01	2.27	5.57	8.05	8.33	4.49	3.9	4.01	4.49

[1]LW = leaf width; NT = number of tillers; CL = compression level; SV = straw volume; SC = soil cover; FER = fertility; PLA = plantability; EME = emergency; RSD = root system depth; RSV = root system volume; RSA = root system aggressiveness; RL = rootlets.

Leaf width plays a fundamental role in wheat yield. The wider the leaves, the greater the total leaf area, which means a greater ability to intercept sunlight. This interception of light is essential for the photosynthesis process, which, in turn, provides the nutrients necessary for the growth and development of the plant, including the formation of ears (Cunha & Caierão, 2023). Furthermore, the tiller emission process in wheat cultivation is extremely important for productivity, as the number and their development influence the total leaf area, which directly affects final production (Valério et al., 2009).

The analysis of variance, with pre-harvest data, contained in Table 9, demonstrated that, for the variables plant height (PH), leaf length (LL) and number of spikelets per ear (NSE) there was a significant effect for the cultivar variation factor. For the variable ear length (EL), none of the sources of variation caused a significant effect. For variable leaf width (LW), treatment and cultivar demonstrated a significant effect. As for the variables number of leaves (NL) and number of grains per ear (NGE), there was a significant effect for the sources of cultivar variation (C) and the interaction between treatment and cultivar (T×C). It is worth mentioning that the coefficient of variation (CV) ranged from 8.70 to 17.77, demonstrating the good precision of the data.

Large crops with a long life cycle tend to significantly reduce the quantity and quality of photosynthetically active radiation incident on weeds, compromising their photosynthetic rate and, consequently, their potential to compete with the main crop (Fleck, Balbinot-Junior, Agostinetto, & Rizzardi, 2003). 78% of plant height variation is genetic in origin (Freitas et al., 2020). For this reason, it can be concluded that plant height is a factor that is directly related to the genetics of the cultivar.

On the other hand, the analysis of variance with harvest data, present in Table 10, demonstrated that, for the variables plant height (PH), insertion height of the ear (IHE) and ear length (EL) there was a significant effect for the source of variation treatment. Furthermore, for all variables there was a significant effect for the sources of cultivar variation (C) and the interaction between treatment and cultivar (T×C). It is noteworthy that the coefficient of variation (CV) ranged from 7.64 to 20.31, also demonstrating the good precision of the data.

Table 9. Summary of variance analysis for traits of with pre-harvest data.

FV[1]	DF	MS						
		PH (cm^3)	EL (cm)	LW (cm)	LL (cm)	NSE (un.)	NL (un.)	NGE (un.)
TREATMENT (T)	1	85.7	1.35	0.23*	28.91	9.6	0.02	77.18
CULTIVAR (C)	13	522.73*	2.02	0.37*	58.53*	19.36*	5.16*	175.60*
T × C	13	60.69	0.83	0.05	10.62	7.69*	1.04*	131.79*
Error	23	42.65	1.27	0.04	12.97	3.83	0.39	42.78
Mean	-	75.08	7.7258	1.37	22.72	12.12	3.71	36.81
CV (%)	-	8.7	14.59	14.28	15.85	16.15	16.84	17.77

[1]FV = factor of variation; DF = degree of freedom; MS = mean square; CV = coefficient of variation; PH = plant height; EL = ear length; LW = leaf width; LL = leaf length; NSE = number of spikelets per ear; NF = number of leaves; NGE = number of grains per ear.

*Significant using the Tukey test at 5% error probability.

Table 10. Summary of variance analysis for traits of agronomic interest.

FV[1]	DF	MS			
		PH (cm^3)	IHE (cm)	EL (cm)	NSE (cm)
TREATMENT (T)	1	627.39*	725.04*	6.53*	0.41
CULTIVAR (C)	13	3184.53*	2994.76*	34.07*	182.29*
T × C	13	292.49*	243.99*	19.53*	57.37*
Error	1363	29.1	26.29	1.5	4.91
Mean	-	70.6	64.06	6.54	10.91
CV (%)	-	7.64	8,00	18.77	20.31

[1]FV = factor of variation; DF = degree of freedom; MS = mean square; CV = coefficient of variation; PH = plant height; IHE = insertion height of the ear; EL = ear length; NSE = number of spikelets per ear.*Significant using the Tukey test at 5% error probability.

Regarding the interaction of cultivar and treatment on the variable number of spikelets per ear (NSE) (Table 11), it is identified that, regardless of the treatment, the majority of cultivars did not differ statistically from each other, except TBIO FUSÃO and TBIO TITAN, in which the C+B treatment obtained higher averages (12.67; 12.80) in relation to the C treatment. High temperatures, during the crop cycle, promote a reduction in the root development and the number of productive tillers, compromising the differentiation of spikelets and flowers (Pimentel et al., 2015). Due to this, the number of spikelets may have been reduced, considering the high temperatures observed during the crop cycle.

When the C+B treatment for the different cultivars is taken into account, most of them did not differ statistically from each other, except for the cultivars TBIO CAPAZ and ORS PREMIUM, which obtained lower averages of 14.67 and 10.60. In relation to C treatment, the higher average was found in the cultivar ORS GLADIADOR, which did not differ statistically from TBIO AUDAZ, TBIO CAPAZ, ORS FALCÃO, TBIO PONTEIRO, TBIO SOBERANO, TBIO TALISMÃ and TBIO TRUNFO. On the other hand, the lower average was found in TBIO TITAN (9.89), which did not differ statistically from TBIO AUDAZ, TBIO CALIBRE, ORS FALCÃO, ORS FEROZ, ORS FUSÃO, TBIO MOTRIZ, TBIO PONTEIRO, ORS PREMIUM, ORS SOBERANO, TBIO TITAN and TBIO TRUNFO.

Regarding the interaction of cultivar and treatment on the variable leaf number (LN), present in Table 11, it is identified that, regardless of the treatment, the majority of cultivars did not differ statistically from each other, except for the cultivar TBIO PONTEIRO, with a higher average for C treatment (4.33) and lower for C+B (3.60). ORS SOBERANO and TBIO TITAN also differed, having higher means in the C+B treatment (4.00; 3.80) and lower means in the C treatment (3.33; 3.22).

Table 11. Summary of the interaction between treatment × cultivar on the variables number of spikelets per ear (NSE), number of leaves (NL) and number of grains per ear (NGE).

CULTIVAR	Treatment Chemical + Biological			Treatment Chemical		
	NSE	NL	NGE	NSE	NL	NGE
TBIO Audaz	12.10 aABC[1]	4.10 aAB	37.20 aAB	12.70 aABC	4.50 aAB	41.60 aAB
TBIO Calibre	11.11 aBC	3.78 aABC	35.90 aAB	11.00 aBC	3.70 aBCDE	33.60 aABC
TBIO Capaz	14.67 aA	4.22 aAB	43.30 aA	13.00 aAB	3.60 bBCDE	35.50 bABC
ORS Falcão	12.80 aABC	3.00 aCD	38.00 aAB	12.70 aABC	3.40 aCDEF	37.20 aABC
ORS Feroz	10.70 aBC	3.00 aCD	34.50 aAB	10.60 aBC	2.60 aF	34.80 aABC
TBIO Fusão	12.67 aABC	3.89 aABC	39.90 aA	10.75 bBC	4.25 aABCD	31.40 bBC
ORS Gladiador	11.80 bABC	2.80 aD	35.10 bAB	14.10 aA	3.20 aEF	43.40 aA
TBIO Motriz	12.80 aABC	4.30 aA	38.40 aAB	10.89 aBC	4.33 aABC	32.80 aBC
TBIO Ponteiro	13.60 aAB	3.60 bABCD	35.30 aAB	12.56 aABC	4.33 aABC	37.40 aABC
ORS Premium	10.60 aC	3.30 aBCD	29.30 aB	10.78 aBC	3.11 aEF	32.00 aBC
ORS Soberano	11.90 aABC	4.00 aAB	35.30 aAB	11.30 aABC	3.33 bDEF	33.90 aABC
TBIO Talismã	12.67 aABC	4.22 aAB	41.30 aA	13.30 aAB	4.70 aA	43.20 aA
TBIO Titan	12.80 aABC	3.80 aABC	39.80 aA	9.89 bC	3.22 bDEF	29.60 bC
TBIO Trunfo	13.11 aABC	4.00 aAB	41.00 aA	12.89 aABC	3.89 aABCDE	39.20 aABC

[1]Means followed by the same capital letter for the same cultivar and variable do not differ, statistically according to the Tukey test at 5% error probability. Means followed by the same lowercase letter for the same cultivar and variable do not differ statistically according to the Tukey Test at 5% error probability.

When analyzing the cultivars subjected to the same treatment (C+B), it can be seen that the highest average was found in TBIO MOTRIZ (4.30), which did not differ statistically from TBIO AUDAZ, TBIO CALIBRE, TBIO CAPAZ, TBIO FUSÃO, TBIO PONTEIRO, ORS SOBERANO, TBIO TALISMÃ, TBIO TITAN and TBIO TRUNFO. Furthermore, the lower average observed in ORS GLADIADOR (2.80) did not differ from the averages found in ORS FALCÃO, ORS FEROZ, TBIO PONTEIRO ORS PREMIUM.

For C treatment, the highest average was found in the cultivar TBIO TALISMÃ (4.70), which was not statistically different from TBIO AUDAZ, TBIO FUSÃO, TBIO MOTRIZ, TBIO PONTEIRO and TBIO TRUNFO. The lowest average was found in the cultivar ORS FEROZ (2.60), which did not differ statistically from ORS FALCÃO, ORS GLADIADOR, ORS PREMIUM, ORS SOBERANO and TBIO FUSÃO. According to Walter, Streck, Rosa, Alberto and Oliveira (2009) the duration of the vegetative phase in wheat is directly related to the final number of leaves.

Regarding the interaction of cultivar and treatment on the variable number of grains per ear (NGE), contained in Table 11, it is identified that, regardless of the treatment, the majority of cultivars did not differ statistically from each other, except for TBIO FUSÃO, ORS GLADIADOR and TBIO TITAN. ORS GLADIADOR obtained a higher mean with the C treatment (43.4) and a lower mean with the C+B treatment (35.1), unlike TBIO FUSÃO and TBIO TITAN, in which the higher means were obtained with the C+B treatment (39.9; 39.8) and lower means with the C (31.4; 29.6).

For the C+B treatment, the highest averages were for the cultivars TBIO CAPAZ (43.3), TBIO FUSÃO (39.9), TBIO TALISMÃ (41.3), TBIO TITAN (39.8) and TBIO TRUNFO (41.00). The lowest average was observed in ORS PREMIUM (29.3). For C treatment, the highest averages were found in the cultivars ORS GLADIADOR and TBIO TALISMÃ, being 43.4 and 43.2, respectively. The lowest average was found in TBIO TITAN (29.6). According to Vesohoski, Marchioro, Franco and Cantelle (2011), as the number of spikelets per ear increases, there is an increase in the same proportion in the number of grains per spikelet and also the number of grains per ear. From this perspective, cultivars that presented a greater number of spikelets will possibly present a greater number of grains and, consequently, a greater yield.

Regarding the variable plant height (PH), contained in Table 12, considering the C+B treatment, the highest average was found in the cultivar TBIO PONTEIRO (84.5 cm) and the lowest averages in the cultivars TBIO MOTRIZ (63.3 cm) and ORS FALCÃO (61.3 cm). However, when subjected to C treatment, the higher averages were found in the cultivars TBIO PONTEIRO (84 cm) and TBIO TRUNFO (83.8 cm). The lowest average was observed in the ORS GLADIADOR cultivar (60.9 cm). When comparing the same cultivar subjected to different treatments, it was possible to see that the C+B treatment obtained higher averages for the cultivars ORS FEROZ (71.2 cm) and ORS GLADIADOR (64.4 cm). In contrast, C treatment obtained higher averages for the cultivars TBIO CALIBRE (72.3 cm), ORS FALCÃO (69.8 cm), TBIO MOTRIZ (67 cm), ORS SOBERANO (71.9 cm), TBIO TITAN (73.7 cm) and TBIO TRUNFO (83.8 cm). The other cultivars did not differ statistically from each other.

For the variable insertion height of ear (IHE), present in Table 12, considering the C+B treatment, the upper mean was found in TBIO PONTEIRO (77.1 cm) and the lower in TBIO CAPAZ (63 cm), which did not differ statistically from ORS FALCÃO, ORS GLADIADOR and TBIO MOTRIZ. However, when subjected to C treatment, the higher averages were found in the cultivars TBIO PONTEIRO (77.4 cm) and TBIO TRUNFO (76.5 cm). The lowest average was observed in ORS GLADIADOR (55 cm). When we compare the same cultivar subjected to different treatments, it is possible to see that the C+B treatment obtained higher averages for the cultivars ORS FEROZ (64.1 cm), TBIO FUSÃO (67.7 cm) and ORS GLADIADOR (57.5 cm). In contrast, the C treatment obtained higher averages for the cultivars TBIO CALIBRE (66.7 cm), ORS FALCÃO (61.9 cm), TBIO MOTRIZ (60.9 cm), ORS PREMIUM (64.8 cm) and ORS SOBERANO (64.9 cm). It is worth noting that the other cultivars did not differ statistically from each other.

For the variable ear length (EL), contained in Table 12, considering the C+B treatment, the highest averages were found in the cultivars TBIO CAPAZ (7.54 cm) and ORS FEROZ (7.40 cm). The lowest average was observed in the cultivar TBIO CALIBRE (5.44 cm). However, when subjected to C treatment, the upper average was found in ORS SOBERANO (7.80 cm) and the lower ones in TBIO AUDAZ (5.68 cm), ORS GLADIADOR (5.92 cm), TBIO MOTRIZ (5.80 cm) and TBIO TALISMÃ (5.35 cm). When we compare the same cultivar subjected to different treatments, it is possible to see that the C+B treatment obtained higher averages for the cultivars TBIO CAPAZ (7.54 cm), ORS GLADIADOR (6.84 cm), TBIO MOTRIZ (6.32 cm), ORS PREMIUM (6.88 cm) and TBIO TALISMÃ (6.04 cm). In contrast, the C treatment obtained higher averages for the cultivars TBIO CALIBRE (6.13 cm), ORS FALCÃO

(7.30 cm), TBIO FUSÃO (7.33 cm), ORS SOBERANO (7.80 cm), TBIO TITAN (7.56 cm) and TBIO TRUNFO (6.80 cm). It is noteworthy that the other cultivars did not differ statistically from each other. In this sense, in a study carried out by Silva et al. 2015, it was concluded that, according to the wheat cultivar, there are differences in ear length. In this way, it can be seen that from cultivar to cultivar, in the experiment, there were significant differences in relation to the measurement of the ear length.

Table 12. Summary of the interaction between treatment × cultivar on the variables plant height (PH), insertion height of the ear (IHE), ear length (EL) and number of spikelets (NS).

CULTIVAR	TREATMENT							
	Chemical + Biological				Chemical			
	PH	IHE	EL	NSE	PH	IHE	EL	NSE
TBIO Audaz	67.20 aEF[1]	61.50 aD	5.52 aFG	10.16 aCD	65.70 aF	59.90 aF	5.68 aD	10.58 aDE
TBIO Calibre	70.0 bCDE	64.20 bD	5.44 bG	10.16 bCD	72.30 aBC	66.70 aB	6.13 aCD	11.08 aCDE
TBIO Capaz	69.80 aCDE	63.00 aCDEF	7.54 aA	11.70 bAB	70.50 aBCDE	63.40 aBCDE	6.96 bB	13.58 aAB
ORS Falcão	61.30 bG	56.80 bE	5.94 bEFG	11.72 aAB	69.80 aCDE	61.90 aD	7.30 aAB	9.68 bEF
ORS Feroz	71.20 aCD	64.10 aD	7.40 aA	9.26 aD	68.50 bDEF	61.30 bEF	6.98 aAB	8.02 bG
TBIO Fusão	73.10 aBC	67.70 aBC	5.76 bEFG	11.82 bAB	71.50 aBCD	65.60 bBC	7.33 aAB	13.16 aAB
ORS Gladiador	64.40 aFG	57.50 aE	6.84 aABCD	10.66 bBCD	60.90 bG	55.00 bG	5.92 bD	12.42 aABC
TBIO Motriz	63.30 bG	56.50 bE	6.32 aCDEF	10.12 aCD	67.00 aEF	60.90 aEF	5.80 bD	8.88 bFG
TBIO Ponteiro	84.50 aA	77.10 aA	7.32 aAB	12.32 bA	84.00 aA	77.40 aA	6.84 aBC	13.84 aA
ORS Premium	69.00 aDE	62.30 bD	6.88 aABC	10.50 aBCD	71.10 aBCD	64.80 aBCD	6.03 bCD	10.30 aDEF
ORS Soberano	69.70 bCDE	62.80 bD	6.51 bBCDE	12.32 aA	71.90 aBCD	64.90 aBCD	7.80 aA	11.58 aCD
TBIO Talismã	67.20 aEF	61.00 aD	6.04 aDEFG	10.02 aCD	67.20 aEF	61.60 aDEF	5.35 bD	7.78 bG
TBIO Titan	71.20 bCD	64.30 aCD	6.78 bABCD	10.36 bBCD	73.70 aB	66.30 aBC	7.56 aAB	12.14 aBC
TBIO Trunfo	75.30 bB	69.10 bB	6.28 bCDEF	11.42 aABC	83.80 aA	76.50 aA	6.80 ABC	9.98 bEF

[1]Means followed by the same capital letter for the same cultivar and variable do not differ, statistically according to the Tukey test at 5% error probability. Means followed by the same lowercase letter for the same cultivar and variable do not differ statistically according to the Tukey Test at 5% error probability.

Regarding the variable number of spikelets per ear (NSE), present in Table 12, considering the C+B treatment, the higher averages were found in the cultivars TBIO PONTEIRO (12.32) and ORS SOBERANO (12.32). The lowest average was observed in the cultivar ORS FEROZ (9.26). In contrast, C treatment obtained a higher average for the cultivar TBIO PONTEIRO (13.84) and lower for the cultivars ORS FEROZ (8.02) and TBIO TALISMÃ (7.78). When we compare the same cultivar subjected to different treatments, it is possible to see that the C+B treatment obtained higher averages for the cultivars ORS FALCÃO (11.72), ORS FEROZ (9.26), TBIO MOTRIZ (10.12), TBIO TALISMÃ (10.02) and TBIO TRUNFO (11.42). On the other hand, C treatment obtained higher averages for the cultivars TBIO CALIBRE (11.08), TBIO CAPAZ (13.58), TBIO FUSÃO (13.16), ORS GLADIADOR (12.42), TBIO PONTEIRO (13.84) and TBIO TITAN (12.14). The other cultivars did not differ statistically from each other.

Regarding the mean comparison test for the effect of cultivar on agronomic characters (Table 13), it can be observed that, for the variable plant height (PH), the cultivars TBIO PONTEIRO and TBIO TRUNFO presented the highest means, not statistically different from each other, these being 86.15 cm and 83.44 cm, respectively. The cultivars ORS PREMIUM, ORS FEROZ, ORS FALCÃO and ORS GLADIADOR obtained the lowest averages, these being 72.94 cm, 71.60 cm, 69.60 cm and 66.00 cm, also not differing statistically from each other. According to Biotrigo Genética, both the TBIO PONTEIRO and TBIO TRUNFO cultivars are medium/tall in height. Furthermore, according to OR Genética, the cultivars ORS PREMIUM, ORS FEROZ, ORS FALCÃO and ORS GLADIADOR are short in height. Thus, the experiment confirmed the size characteristics inherent to the genotype of the cultivars.

Table 13. Summary of the mean comparison test for the effect of cultivar on agronomic traits.

Cultivar	PH (cm) [1]	LW (cm)	LL (cm)
TBIO Ponteiro	86.15 a[2]	1.32 cde	20.71 bc
TBIO Trunfo	83.44 ab	1.35 bcde	23.16 abc
TBIO Talismã	78.89 bc	1.19 e	22.55 abc
TBIO Fusão	77.97 bcd	1.23 bcde	21.68 bc
TBIO Calibre	75.84 cde	1.31 cde	24.16 ab
TBIO Titan	75.47 cde	1.51 abc	21.00 bc
TBIO Audaz	75.15 cde	1.23 de	19.70 c
TBIO Capaz	73.44 cde	1.42 bcd	23.09 abc
ORS Soberano	73.21 cde	1.31 cde	22.53 abc
TBIO Motriz	73.15 cde	1.35 bcde	21.58 bc
ORS Premium	72.94 cdef	1.55 ab	26.47 a
ORS Feroz	71.60 def	1.40 bcde	23.05 abc
ORS Falcão	69.60 ef	1.29 de	24.55 ab
ORS Gladiador	66.00 f	1.69 a	23.75 ab

[1]PH = plant height; LW = leaf width; LL = leaf length.
[2]Means followed by the same lowercase letter do not differ statistically according to the Tukey Test at a 5% error probability.

For the variable leaf width (LW), the highest averages were obtained by the cultivars ORS GLADIADOR, ORS PREMIUM and TBIO TITAN, which did not differ statistically from each other, measuring, respectively, 1.69 cm, 1.55 cm and 1.51 cm. The lower averages were obtained in the cultivars ORS FEROZ (1.40 cm), TBIO MOTRIZ (1.35cm), TBIO FUSÃO (1.32 cm), TBIO FUSÃO (1.23 cm), TBIO PONTEIRO (1.32 cm), TBIO CALIBRE (1.31 cm), ORS SOBERANO (1.31 cm), ORS FALCÃO (1.29 cm), TBIO AUDAZ (1.23 cm) and TBIO TALISMÃ (1.19 cm).

The variable leaf length (LL) presented higher averages in the cultivars ORS PREMIUM (26.47 cm), ORS FALCÃO (24.55 cm), TBIO CALIBRE (24.16 cm), ORS GLADIADOR (23.75 cm), TBIO TRUNFO (23.16 cm), TBIO CAPAZ (23.09 cm), TBIO TALISMÃ (22.55 cm) and ORS SOBERANO (22.53 cm). On the other hand, the lowest average was found in the cultivar TBIO AUDAZ (19.70 cm).

Based on Pearson's linear correlation analysis for characters of agronomic interest, both in the area with chemical treatment and in the area subjected to chemical + biological treatment, (Figure 5 and 6), it was found that there is a high correlation (r=0.60 to 0.95) between the grain weight per ear (GWE) and the number of grains (NG). Furthermore, insertion height of the ear (IHE) is highly correlated with plant height (PH), considering that the closer the absolute value of this coefficient is to 1, the stronger the linear relationship between the two variables (Sousa, 2019). Therefore, the existing correlations were similar in both treatments. The other variables did not show a significant correlation.

For chemical treatment, there was a correlation of 0.88 between the grain weight per ear and the number of grains. Therefore, it can be concluded that the grains/ear weight influences the total number of grains and vice versa. Insertion height of the ear and plant height showed a correlation of 0.97, demonstrating a high magnitude and linear relationship. Treatment with chemicals + biologicals demonstrated a correlation of 0.87 between the grain weight per ear and the number of grains. Furthermore, ear insertion height and plant height showed a correlation of 0.97.

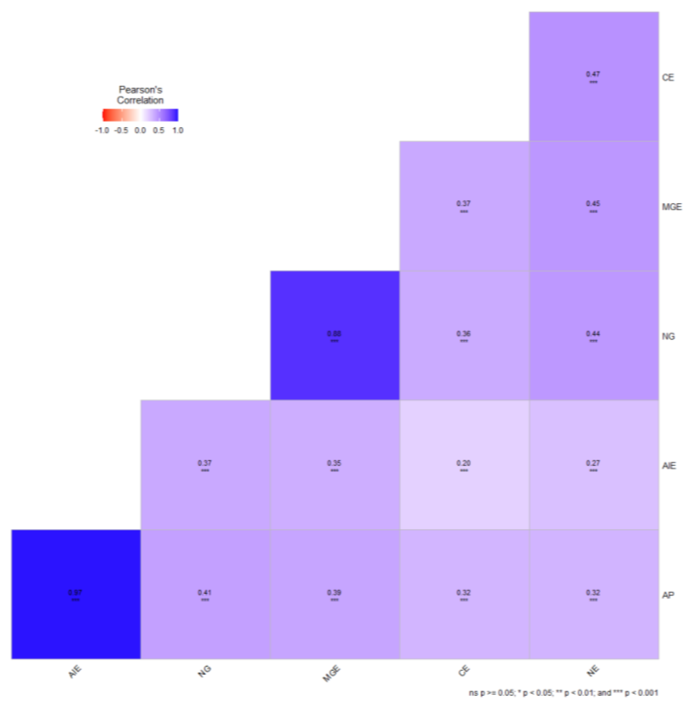

Figure 5. Significant Pearson linear correlation coefficient at 5% probability using the t test for characters of agronomic interest in the area with chemical treatment. EL = ear length; GWE = grain weight per ear; NG = number of grains; IHE = insertion height of the ear; PH = plant height.

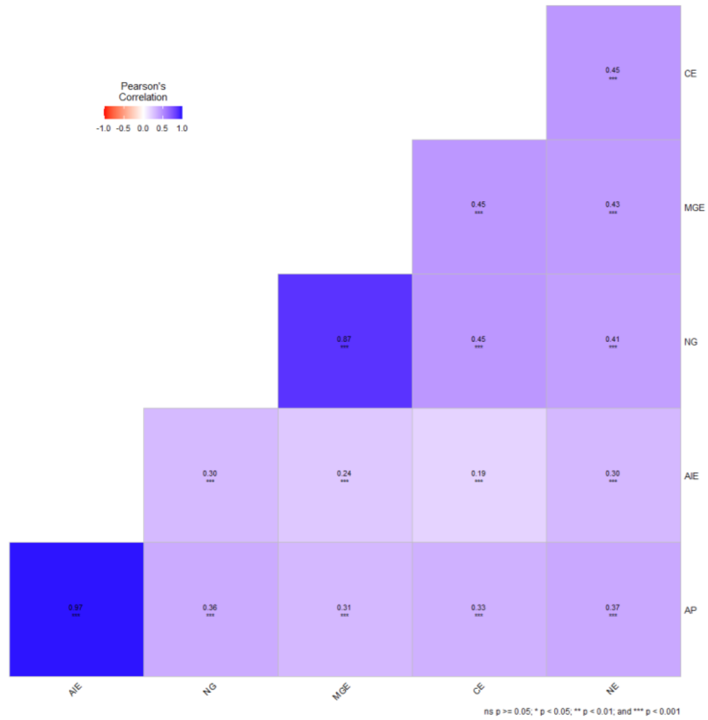

Figure 6. Significant Pearson linear correlation coefficient at 5% probability using the t test for characters of agronomic interest in the area with chemical + biological treatment. EL = ear length; GWE = grain weight per ear; NG = number of grains; IHE = insertion height of the ear; PH = plant height.

The analysis of main components (Figure 7) of the area with chemical treatment, obtained in the study, allowed explaining 80.6% of the total variability of the information (Dim1: 62.7%; Dim2: 17.9%). The variables with the greatest contribution were plant height (PH) and insertion height of the ear (IHE), with a value greater than 18%. The intermediate ones, which were average, were the grain weight per ear (GWE), the number of grains (NG) and the number of spikelets (NS). It was found that the variable with the lowest contribution was ear length (EL).

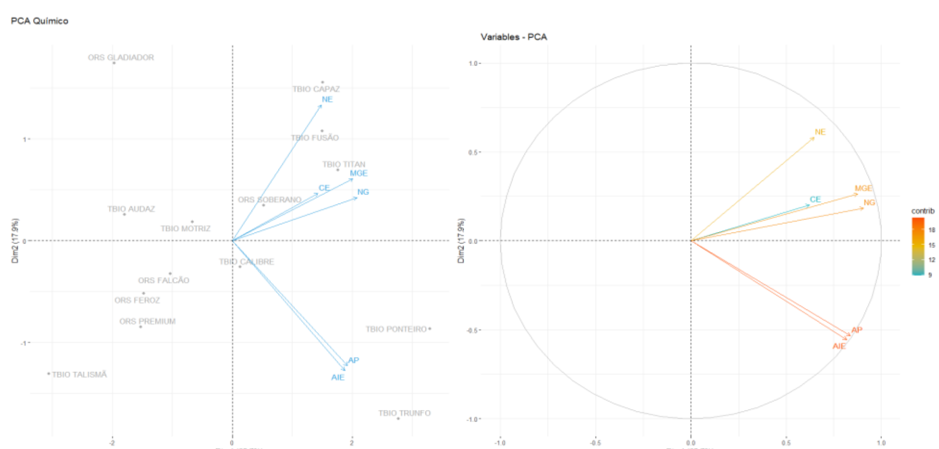

Figure 7. Main components (Biplot) of the area with chemical treatment, to explain the variables plant height, insertion height of the ear, number of spikelets, grain weight per ear, ear length and number of grains. PH = plant height; IHE = insertion height of the ear; NS = number of spikelets; GWE = grain weight per ear; EL = ear length; NG = number of grains.

PCA Biplot made it possible to identify relationships between cultivars and the expression of certain characters. In this way, it was verified that the cultivar TBIO CALIBRE presented proximity to the variables plant height and insertion height of the ear. The cultivars TBIO TITAN and ORS SOBERANO approached the variables ear length, grain weight per ear and number of grains. On the other hand, the cultivars TBIO CAPAZ, TBIO FUSÃO and ORS SOBERANO demonstrated similarity in the variable number of spikelets.

On the other hand, the analysis of main components (Figure 8) of the area with chemical + biological treatment, obtained in the study, allowed explaining 79.6% of the total variability of the information (Dim1: 54.8%; Dim2: 24.8%). The variables with the greatest contribution were plant height (PH), insertion height of the year (IHE), grain weight per ear (GWE) and number of grains (NG), with a value greater than 20%. The intermediate variable was ear length (EL). It was found that the variable with the lowest contribution was the number of spikelets (NS).

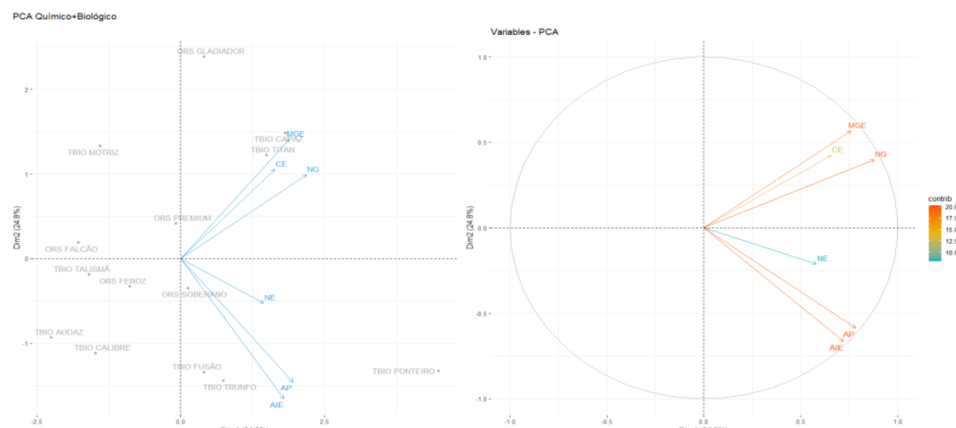

Figure 8. Main components (Biplot) of the chemical + biological area, to explain the variables plant height, insertion height of the ear, number of spikelets, grain weight per ear, ear length and number of grains. PH = plant height; IHE = insertion height of the ear; NS = number of spikelets; GWE = grain weight per ear; EL = ear length; NG = number of grains.

PCA Biplot made it possible to identify relationships between cultivars and the expression of certain characters. In this way, it was observed that the cultivars ORS SOBERANO, TBIO FUSÃO and TBIO TRUNFO presented greater proximity of the variables plant height and ear insertion height. The ORS SOBERANO cultivar also approached the variable number of spikelets. The cultivars TBIO CAPAZ, TBIO TITAN and ORS PREMIUM approached the variables number of grains, ear length and grain weight per ear.

Conclusions

Regarding yield components, it can be concluded that the cultivars TBIO PONTEIRO and ORS SOBERANO, in combination with biological and chemical management, presented a greater number of spikelets. TBIO CAPAZ, TBIO TRUNFO, TBIO AUDAZ, ORS GLADIADOR and TBIO TALISMÃ demonstrated a greater number of grains per ear. The cultivar with the highest number of leaves was TBIO PONTEIRO. With regard to diseases, the lowest occurrence was seen in the cultivars TBIO AUDAZ, TBIO TITAN, ORS GLADIADOR, ORS PREMIUM, TBIO MOTRIZ, TBIO TALISMÃ and TBIO TRUNFO.

Considering insect pests, the ORS FEROZ cultivar was the most susceptible to the occurrence of *Sitobion avenae*. It should be noted that the chemical treatment presented higher averages for the variables plant height, insertion height of the ear, number of leaves, ear length and number of grains per ear. The chemical + biological treatment provided a greater number of spikelets per ear. The cultivar with the best performance in chemical management was ORS GLADIADOR. In chemical + biological management, TBIO CAPAZ demonstrated superiority.

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References

Agostinetto, D., Vargas, L., Gazziero, D. L. P., & Silva, A. A. (2015). *Manejo de plantas daninhas*. In: Sediyama, T., Silva, F., & Borém, A. Soja: do plantio à colheita. Cap. 11, p. 234-*255*. Viçosa, MG: Editora UFV. Available in: http://www.alice.cnptia.embrapa.br/alice/handle/doc/1022693

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Gonçalves, J. L. M., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, *22*(6), 711–728. https://doi.org/10.1127/0941-2948/2013/0507

Berro, M. L. C., Schmitt, M., Fipke, G. M., Fernandes, A. A., Martins, M. B., & Pinho, R. S. C. (2024). Agronomic efficiency of the use of bioinputs in wheat cultivation. *Pedagogical Notebook Journal*, *21*(10), e9865. https://doi.org/10.54033/cadpedv21n10-367

Bonissoni, K. (2020). Manejo integrado com químicos e biológicos contribui para sucesso na lavoura. *Revista Cultivar*. Pelotas, RS: Grupo Cultivar de Publicações Ltda. Available in: https://revistacultivar.com.br/noticias/manejo-integrado-com-quimicos-e-biologicos-contribui-para-sucesso-na-lavoura

Borém, A., & Scheeren, P. L. (2015). *Botânica, morfologia e descrição fenotípica*. In: Borém, A.; Scheeren, P. L. Trigo: do plantio à colheita. p. 35-55. Viçosa, MG: Editora UFV.

Canziani, J. R., & Guimarães, V. D. A. (2009). *O trigo no Brasil e no mundo: cadeia de produção, transformação e comercialização*. In: Gilberto Rocca da Cunha (Ed.). Oficina sobre trigo no Brasil: bases para a construção de uma nova triticultura. p. 29-72. Passo Fundo, RS: Embrapa Trigo.

CONAB - Companhia nacional de abastecimento. (2017). *A cultura do trigo*. Brasília, DF: CONAB. Available in: https://www.conab.gov.br/uploads/arquivos/17_04_25_11_40_00_a_cultura_do_trigo_versao_digital_final.pdf

CONAB - Companhia nacional de abastecimento. (2024). *Brasil deve produzir 299,27 milhões de toneladas de grãos na safra 2023/2024.* Brasília, DF: CONAB. Available in: https://antigo.conab.gov.br/ultimas-noticias/5615-brasil-deve-produzir-299-27-milhoes-de-toneladas-de-graos-na-safra-2023-2024

Cunha, G. R., & Caierão, E. (2023). *Informações técnicas para trigo e triticale: safra 2023*. Passo Fundo, RS: Embrapa Trigo (CNPT). Available in: https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1153536/1/InformacoesTecnicasTrigoTriticale-Safra2023.pdf

Doorenbos, J., & Kassan, A. H. (1979). *FAO Irrigation and Drainage Paper 33 - Yield response to water.* Rome, It: FAO.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. (2005). *O produtor deve ficar atento ao controle dos pulgões do trigo*. Brasília, DF: EMBRAPA. Available in: https://www.embrapa.br/en/busca-de-noticias/-/noticia/17982667/o-produtor-deve-ficar-atento-ao-controle-dos-pulgoes-do-trigo-

EMBRAPA Empresa Brasileira de Pesquisa Agropecuária. Embrapa trigo. (2016). *Perguntas e respostas sobre trigo.* Brasília, DF*:* Embrapa. Available in: https://www.bibliotecaagptea.org.br/agricultura/culturas_anuais/livros/500%20PERGUNTAS%20E%20RESPOSTAS%20SOBRE%20TRIGO%20EMBRAPA.pdf#page=16

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária (2022). *Bioinsumos para o trigo*. Brasília, DF: Embrapa. Available in: https://www.embrapa.br/busca-de-noticias/-/noticia/76917656/bioinsumos-para-o-trigo

Fietz, C. R., Sousa, P. G., & Urchei, M. A. (2005). Análise da época de semeadura para trigo na região de Dourados, MS. *Revista Brasileira de Agrometeorologia*, *13*(1), 59-63.

Fleck, N. G., Balbinot-Junior, A. A., Agostinetto, D., & Rizzardi, M. A. (2003). Velocidade de estabelecimento em cultivares de arroz irrigado como característica para aumentar a habilidade competitiva com plantas concorrentes. *Rural Science*, *33*(4), 635-640. https://doi.org/10.1590/S0103-84782003000400007

Freitas, D. S., Lima, G. W., Paiva, M., Ribeiro, H. Q., Roberto, G. F., & Nardino, M. (2020). Parâmetros genéticos para caracteres de altura de plantas e resistência a doenças em linhagens do Programa Trigo-UFV. Campinas, SP: Galoá Science. Available in: https://proceedings.science/sigm/xi-sigm/trabalhos/parametros-geneticos-para-caracteres-de-altura-de-plantas-e-resistencia-a-doenca?lang=pt-br

Gregório, D. F. S. (2023). *Controle de infestantes em pré e pós-emergência na cultura do trigo mole* (*Triticum aestivum* L.). Dissertação de Mestrado. Évora, Portugal: Universidade de Évora. Available in: https://dspace.uevora.pt/rdpc/bitstream/10174/34933/1/Mestrado-Engenharia_Agronomica-Daniel_Filipe_Sousa_Gregorio.pdf

Khalid, A., Hameed, A., & Tahir, M. F. (2023). Wheat quality: A review on chemical composition, nutritional attributes, grain anatomy, types, classification, and function of seed storage proteins in bread making quality. Frontiers in Nutrition, *10*. https://doi.org/10.3389/fnut.2023.1053196

Kumar, D., & Kukreja, V. (2024). Image segmentation, classification and recognition methods for wheat diseases: systematic review of two decades of literature. *Computers and Electronics in Agriculture*, *221*, 109005. DOI: https://doi.org/10.1016/j.compag.2024.109005

Lau, D., Sbalcheiro, C. C., Martins, F. C., Santana, F., Maciel, J. L. N., Fernandes, J. M. C., Costamilan, L. M., Lima, M. I. P. M., Kuhnem, P., & Casa, R. T. (2020). *Principais doenças do trigo no sul do Brasil: diagnóstico e manejo*. Comunicado Técnico Online 375. Passo Fundo, RS: Embrapa Trigo.

Lins, É. G. C. (2021). *Influência da etapa de purificação das sêmolas nas características físico-químicas e reológicas de farinhas de trigo*. Trabalho de Conclusão de Curso (Bacharelado em Engenharia de Alimentos). Fortaleza, CE: Centro de Ciências Agrárias, Universidade Federal do Ceará.

Machado, P. L. O. A. (2003). Compactação do solo e crescimento de plantas: Como identificar, evitar e remediar. Rio de Janeiro, RJ: Embrapa Solos. Available in: http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/338323

Maciel, J. L. N., Sbalcheiro, C. C., Lau, D., Santana, F. M., Costamilan, L. M., & Lima, M. I. P. M. (2020). *Doenças da cultura do trigo no Brasil.* Passo Fundo, RS: Embrapa Trigo. Available in: https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/1122395/1/Artigo-pronto-publicado-em-abril-de-2020.pdf

Marschner, P. (2012). *Marschner's mineral nutrition of higher plants*. (3rd ed.). New York: Academic Press.

Martin, T. N., Burg, G. M., Cunha, V. S., Pinho, M. A. B., Pires, J. L. F., & Vey, R. T. (2022). *Tecnologias Aplicadas para o Manejo Rentável e Eficiente da Cultura da Soja*. Instituto Brasileiro de Informação em Ciência e Tecnologia. Santa Maria, RS: Editora GR.

Mori, C., & Icnaczak, J. C. (2011). *Aspectos econômicos do complexo agroindustrial do trigo*. Passo Fundo, RS: Embrapa Trigo.

Pimentel, A., Rocha, J. R. A. S. C., Souza, M. A., Ribeiro, G., Silva, C. R., & Oliveira, I. C. M. (2015). Characterization of heat tolerance in wheat cultivars and effects on production components. *Revista Ceres, 62*(2), 191-198. https://doi.org/10.1590/0034-737X201562020009

R Core Team. (2023). *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing.

Raddatz, R. I., Follmann, D., Santos, E., Pereira, A., & Rosa, G. (2023). Desenvolvimento vegetativo e reprodutivo, associado a emissão de folhas em cultivares de trigo. *Centro Científico Conhecer – Jandaia-GO*, *20*(44), 135. https://doi.org/10.18677/EnciBio_2023B9

Reynolds, M. P., & Braun, H. J. (2022). *Wheat Improvement: Food Security in a Changing Climate*. Springer Nature. Available in: https://link.springer.com/book/10.1007/978-3-030-90673-3

Rodrigues, M. A. (2022). Estatísticas agrícolas: o que nos mostram e o que nos escondem. Instituto Politécnico de Bragança. Available in: http://hdl.handle.net/10198/26973

Salvadori, J. R., Marsaro-Júnior, A. L., Milan, C. S. S., Lau, D., Engel, E., Pasini, M. P. B., & Pereira, P. R. V. S. (2022). *Pragas da cultura do trigo*. Passo Fundo, RS: Embrapa Trigo. Available in: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/243709/1/Documentos-200-online-VFinal-ODS.pdf

Scheeren, P. L., Cunha, G. R., Quadros, F. J. S. & Martins, L. F. (2000). *Trigo do Plantio à Colheita: Botânica, Morfologia e Descrição Fenotípica.* Passo Fundo, RS: Embrapa Trigo (CNPT). Available at: <https://ainfo.cnptia.embrapa.br/>

Shimizu, G. D., Marubayashi, R. Y. P., & Gonçalves, L. S. A. (2023). *AgroR: Estatística Experimental e Gráficos para Ciências Agrárias.* Londrina, PR: UEL. Available in: https://agronomiar.github.io/AgroR_package/index.html, https://fisher.uel.br/AgroR_shiny, https://fisher.uel.br/AgroR_shiny.pt

Silva, J. D., Arenhardt, E. G., Kruger, C. A. M. B., Lucchese, O. A., Metz, M., & Marolli, A. (2015). A expressão dos componentes de produtividade do trigo pela classe tecnológica e aproveitamento do nitrogênio. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *19*(1), 27-33. https://doi.org/10.1590/1807-1929/agriambi.v19n1p27-33

Sousa, A. (2019). *Coeficiente de correlação de Pearson e coeficiente de correlação de Spearman. O que medem e em que situações devem ser utilizados.* Açores, Portugal: Gráfica Açoreana, Lda. Available in: http://hdl.handle.net/10400.3/5365

Valério, I. P., Carvalho, F. I. F., Oliveira, A. C., Benin, G., Souza, V. Q., Machado, A. A., Bertan, I., Busato, C. C., Silveira, G., & Fonseca, D. A. R. (2009). Seeding density in wheat genotypes as a function of tillering potential. *Scientia Agricola*, *66*(1), 28-39. https://doi.org/10.1590/S0103-90162009000100000

Verdum, R., Vieira, C. L., & Caneppelle, J. C. G. (2016). *Métodos e técnicas para o controle da erosão e conservação do solo*. Porto Alegre, RS: IGEO/UFRGS.

Vergütz, L. F., Tiemann, L. A. R., Foletto, M., Bohrz, I. G., Vieira, G. D. M., Casanova, C. L., Cossul, V., & Ludwig, R. L. (2024). Seed and foliar inoculation with Azospirillum brasilense associated with nitrogen topdressing rates in wheat crop. Chap. 4. São José dos Pinhais, PR: Seven Editora - Agricultural and Biological Sciences: Foundations and Applications. Available in: https://doi.org/10.56238/sevened2024.023-004

Vesohoski, F., Marchioro, V. S., Franco, F. A., & Cantelle, A. (2011). Componentes do rendimento de grãos em trigo e seus efeitos diretos e indiretos na produtividade. *Revista Ceres*, *58*(3), 337-341. https://doi.org/10.1590/S0034-737X2011000300014

Walter, L. C., Streck, N. A., Rosa, H. T., Alberto, C. M., & Oliveira, F. B. (2009). Desenvolvimento vegetativo e reprodutivo de cultivares de trigo e sua associação com a emissão de folhas. *Ciência Rural*, *39*(8), 2320-2326. https://doi.org/10.1590/S0103-84782009005000169