

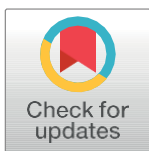
Applicability of ozone on the morphological productive and grain quality performance of wheat

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Abstract

Wheat (*Triticum aestivum* L.) cultivation in Brazil's subtropical climate is generally affected by heavy rainfall during the reproductive period, up to harvest, causing significant economic losses and, most importantly, compromising grain quality due to mycotoxin infection by the fungus *Fusarium*. Seeking to reduce toxins in wheat grains, this study evaluated the effects of ozone application and phosphate fertilization on morphological and productive performance. The following treatments were applied to the TBIO Trunfo cultivar: T1 – ozone on the seed + phosphate at sowing; T2 – phosphate only at sowing; T3 – control; T4 – ozone only on the seed. The occurrence of pests and weeds in the plots, plant diseases, and morphological and productive characteristics were evaluated. In the analysis of the interaction between factors, the application of phosphate at sowing along with ozone on the seeds favored the increase in grain yield characteristics and vegetative development of the plants, with a lower incidence of diseases.

Keywords: New technologies; sanitization; saturated atmosphere; innovative techniques; sustainability; flour-derived products; sowing times.

Introduction

Wheat (*Triticum aestivum* L.) is of great economic importance, being one of the main agricultural commodities and one of the three most consumed cereals worldwide, after corn and rice, second only to corn in production (Segatto et al., 2022; Silva et al., 2025). This cereal is widely used in the manufacture of flour-derived products, making it an essential food in the world diet (Pimentel et al., 2021). Furthermore, it is used in beer production and animal feed, both as grains and in rations, or as forage for grazing, haymaking, pre-dried forage, and silage (Stas et al., 2024). For the 2024 wheat crop in Brazil, the total sown area was 3,058.7 thousand hectares, resulting in an average productivity of 2,579 kg ha⁻¹ and a production of 7,889.3 thousand tons. The Southern region accounted for approximately 86% of the national total, with 2,146,400 hectares cultivated and an average productivity of 3,080 kg ha⁻¹ (Companhia Nacional de Abastecimento [CONAB], 2025).

Wheat cultivars grown in Brazil are mostly spring-growing, insensitive to photoperiod, and have C3 metabolism, characteristics that confer broad adaptability to different sowing times and environmental conditions (Feng et al., 2014; Girolomoni et al., 2017). Historical lodging problems, common in tall genotypes, have been significantly reduced with the incorporation of dwarfing genes (Rht), resulting in semi-dwarf cultivars with higher harvest index and significant yield gains in favorable environments (Stevenson, Villoria, Byerlee, Kelley, & Maredia, 2013). Despite these advances, biotic stresses remain among the main limiting factors for the crop, particularly diseases such as rusts, powdery mildew, Fusarium head blight, blast, and barley yellow dwarf virus (BYDV), which compromise yield stability and grain quality (Savary et al., 2019). Furthermore, weed interference represents a critical factor in yield reduction and increased production costs due to competition for resources (Savić et al., 2025). Given this scenario, wheat breeding programs have prioritized resistance to biotic stresses and tolerance to abiotic stresses, aiming for greater productive stability in contrasting environments (Tester & Langridge, 2010).

In recent years, there has been increasing concern about contamination by mycotoxins, toxic secondary metabolites produced mainly by fungi of the genera *Aspergillus*, *Penicillium*, and *Fusarium*, due to the associated health risks and economic losses (Eskola et al., 2020). In cereals such as wheat, fungal infections occur predominantly in the field and can worsen during storage when environmental conditions favor the germination and multiplication of fungi, resulting in grain deterioration and mycotoxin synthesis (Mannaa & Kim, 2017). Among the main mycotoxins associated with wheat are deoxynivalenol (DON), aflatoxins, ochratoxin A (OTA), and zearalenone (ZEA), whose maximum limits are regulated by international agencies due to the impacts on food safety and the need to discard contaminated grains and feed, generating significant losses to the production chain (Eskola et al., 2020).

The application of ozone (O₃) has stood out as an alternative for controlling fungi and reducing mycotoxin levels in food, due to its high oxidation potential, penetration capacity, and direct action on the cell wall of microorganisms (Savi, Piacentini, Bittencourt, & Scussel, 2014). Furthermore, ozone dissociates into oxygen, leaving no residue in food. In grain storage, ozone can be applied in gaseous form, being treated as an effective method for pest control, fungal control, and mycotoxin control (Schwaner, Kumar, & Thippareddi, 2025). Considering that most Brazilian soils have low phosphorus availability, the use of natural phosphate is a viable alternative (Ma et al., 2025), and can also enhance the effects of ozone on wheat yield components. Given that ozone is an alternative to reduce contamination by mycotoxin-producing fungi, this study aims to evaluate the effects of ozone application and phosphate fertilization on wheat, in relation to morphological and productive performance, as well as the quality of wheat grains.

Materials and Methods

The study was conducted at Experimental Farm of the Regional University of the Northwest of the State of Rio Grande do Sul (UNIJUÍ), in the municipality of Augusto Pestana-RS, during the 2025 agricultural season. The climate is characterized as humid subtropical (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013). The soil is classified as a typical dystrophic Red Latosol (Santos et al., 2018). A strip-plot design with internal blocks was used, with 6 meters wide by 50 meters long, totaling an area of 1200 m². The wheat cultivar TBIO Trunfo was used in the study, which has an early cycle, medium/tall height, medium tillering potential, is suitable for breadmaking, has a mean thousand-grain weight of 34 g, and stands out for its tolerance to blast and *Fusarium* head blight (Biotrigo Genética, 2024).

Prior to sowing, a soil analysis was performed (Table 1), which showed that the soil is clayey, with good water and nutrient retention, but presents limitations for wheat cultivation, such as low base saturation, acidic pH (5.1), and high aluminum content, which can restrict root growth. In addition, there is a deficiency of phosphorus, potassium, and organic matter, while calcium, sulfur, and micronutrients are at adequate levels. Sowing was carried out in the second half of July using a seed drill. Phytosanitary management was carried out preventively to avoid undesirable biotic effects on the experiment results (Figure 1). The treatments were: T1 – TBIO Trunfo wheat with ozone application associated with phosphate; T2 – TBIO Trunfo wheat with phosphate application; T3 – TBIO Trunfo wheat (control); T4 – TBIO Trunfo wheat with ozone application. Ozone application was carried out pre-sowing of the wheat, through seed treatment, which remained for 15 days in a hermetically sealed environment at a concentration of 50 ppm of ozone, using a compressor for daily renewal of the ozone concentration. Natural rock phosphate (5% P₂O₅) was applied broadcast pre-sowing at a dose of 250 kg ha⁻¹. In all treatments, base fertilization was carried out with the 10-20-20 (N-P-K) formulation, at a dose of 250 kg ha⁻¹.

Table 1. Physicochemical parameters of the soil obtained from soil analysis performed before sowing in the experiment.

Parameter	Result	Classification
Clay	57%	Class 2
pH ¹	5.1	Low
SMP	5.2	Low
Phosphorus	<3.0 mg dm ⁻³	Very low
Potassium	60 mg dm ⁻³	Low
Organic matter	2.0%	Low
Aluminum	0.5 cmol _c dm ⁻³	High
Calcium	4.2 cmol _c dm ⁻³	High
Magnesium	1.9 cmol _c dm ⁻³	High
Ca/Mg Ratio	2.2	
CEC pH 7.0	17.1 cmol _c dm ⁻³	High
CEC effective	6.7 cmol _c dm ⁻³	
Copper	12.0 mg dm ⁻³	High
Zinc	2.1 mg dm ⁻³	High
Manganese	76.7 mg dm ⁻³	High
Sulfur	5.6 mg dm ⁻³	High
V value	36.2%	Very low
m value	7.8%	Low

¹pH – Hydrogen ion potential; SMP - Shoemaker, McLean and Pratt method for estimating liming requirements; CEC - Cation Exchange Capacity; V value: base saturation; m value: aluminum saturation.

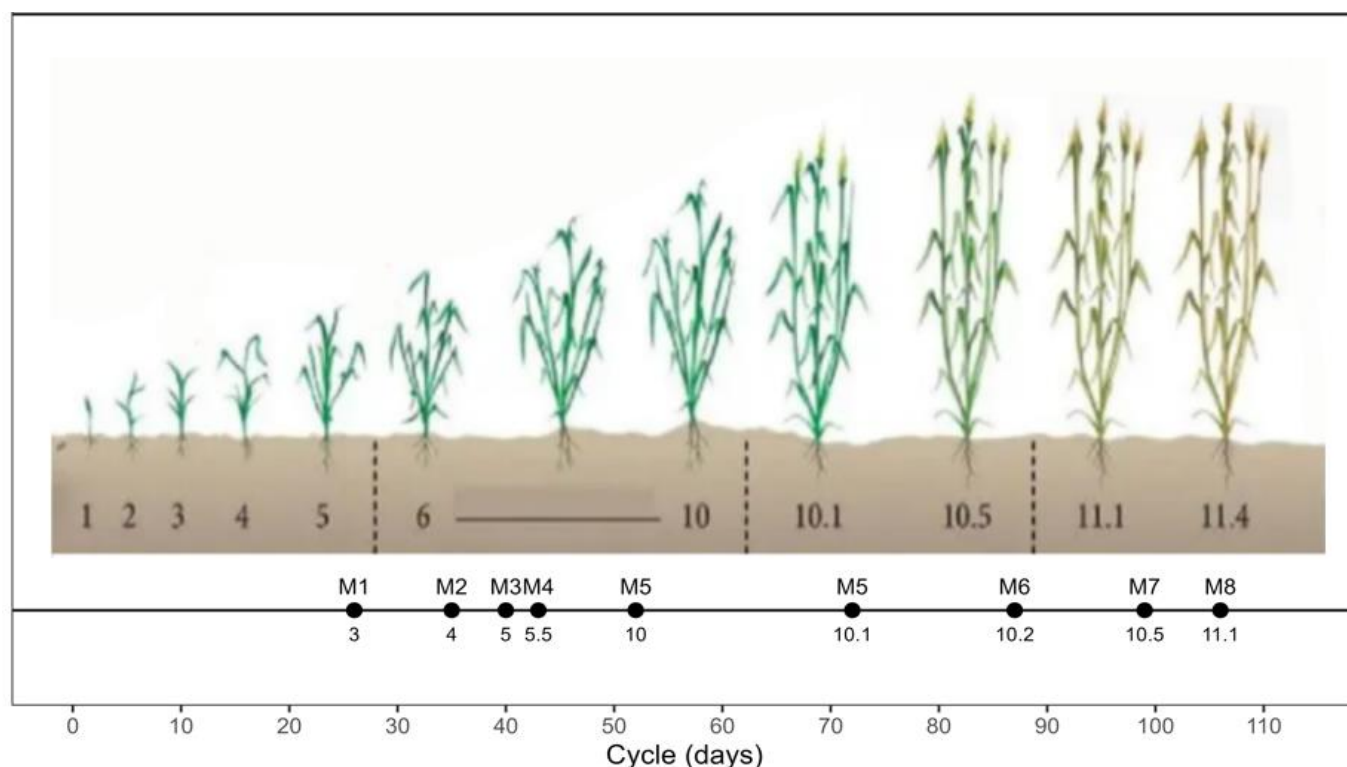


Figure 1. Positioning of management practices used in the wheat growing cycle in Augusto Pestana – RS, 2025, taking the Feeks and Large (1954) scale as references. M1 - Abacus (250 mL ha⁻¹); M2 - Urea (100 kg ha⁻¹); M3 - 2,4D (1.2 L ha⁻¹); M4 - Cypress (500 mL ha⁻¹) + Sperto (100 g ha⁻¹); M5 - Nativo (1 L ha⁻¹); M6 - Tebuconazole (0.75 L ha⁻¹); M7 - Nativo (150 mL ha⁻¹); M8 - Finale (1.5 L ha⁻¹).

Penetrometry was performed at depths 5, 10, and 15 cm using a digital penetrometer, with results expressed in kPa. The percentage of weed presence of *Conyza bonariensis*, *Raphanus raphanistrum*, *Ageratum conyzoides*, *Sida* spp, *Commelina benghalensis*, *Solanum americanum*, *Amaranthus* spp., *Digitaria insularis*, *Avena* spp., *Sorghum bicolor* and *Lolium multiflorum* was also evaluated. The percentage of incidence of insect pests *Melanoplus sanguinipes* e *Rhopalosiphum padi*), as well as the pathogens *Bipolaris sorokiniana*, *Puccinia triticea*, *Drechslera tritici*, *Fusarium graminearum*, *Gaeumannomyces* and *Pyricularia oryzae*, was determined. The field variables evaluated were: PH: plant height (cm); EIH: ear insertion height (cm); RSA: root system aggressiveness; SD: stem diameter (mm); FLL: flag leaf length (mm); FLW: flag leaf width (mm); EL: ear length (cm); EW: ear weight (g); NRN: number of rachis nodes; NSE: number of spikelets per ear; NIS: number of infertile spikelets; NGE: number of grains per ear; GWE: grain weight per ear (g); TGW: thousand grain weight (g); HW: hectoliter weight (g dm⁻³); GY: grain yield (kg ha⁻¹); TILL: tillering; NFT: number of fertile tillers. Mean air temperature (in °C), relative air humidity (in %), and precipitation (in mm) data were extracted from the NASA POWER platform ([NASA POWER, 2025](#)), using the coordinates and duration of the wheat cycle in the experiment.

The data were subjected to the assumptions of normality of errors, homogeneity of variances, and independence of errors using the Shapiro-Wilk, Bartlett, and Durbin-Watson tests, respectively. Subsequently, an analysis of variance was performed to verify the effects of the treatments and their interactions on the quantitative characteristics evaluated in the pre-harvest and harvest phases, at a 5% probability level using the F-test. Upon finding a significant effect, the simple and main effects of each variation factor were decomposed using Tukey's mean comparison test, at a 5% probability level. A descriptive analysis was performed for the qualitative variables, using the mean of each

variable. Complementarily, principal component analysis (PCA) was employed to identify the associations of the treatments with the evaluated variables and the contribution of each variable. All analyses were performed using the R software (R Core Team, 2025).

Results and Discussion

Throughout the wheat cycle, weather conditions characterized a predominantly mild environment, with mean daily temperatures varying, for much of the period, between 10 and 20 °C, a range close to that considered optimal for wheat development (Figure 2). Recent studies indicate that the crop performs better when temperatures during the vegetative and heading stages remain around 15-20 °C, while values above 30 °C for several consecutive days tend to reduce filling rate, thousand-grain weight, and industrial quality (Khan, Ahmad, Ahmed, & Hussain, 2020). In this context, the absence of prolonged episodes of extreme heat suggests that thermal stress was not a limiting factor for plant performance in the experiment.

Precipitation was distributed throughout the cycle with low to moderate intensity rain events interspersed with dry periods (Figure 2), a typical pattern of rainfed systems in subtropical regions, which generally reduces the risk of water deficit in critical stages such as stem elongation and anthesis. At the same time, relative humidity remained predominantly high, frequently above 75-80% and with several days above 85-90%, indicating the presence of moisture during much of the cycle. This combination of high humidity and mild temperatures is recognized as favorable to the occurrence of wheat foliar diseases, such as leaf rust and blast, reported in different producing regions of Brazil (Aula, Easterly, & Creech, 2023). On the other hand, the good water availability associated with these relative humidity values indicates that the wheat crop had good conditions to express its yield potential (Gandía, Del Monte, Tenorio, & Santín-Montanyá, 2021).

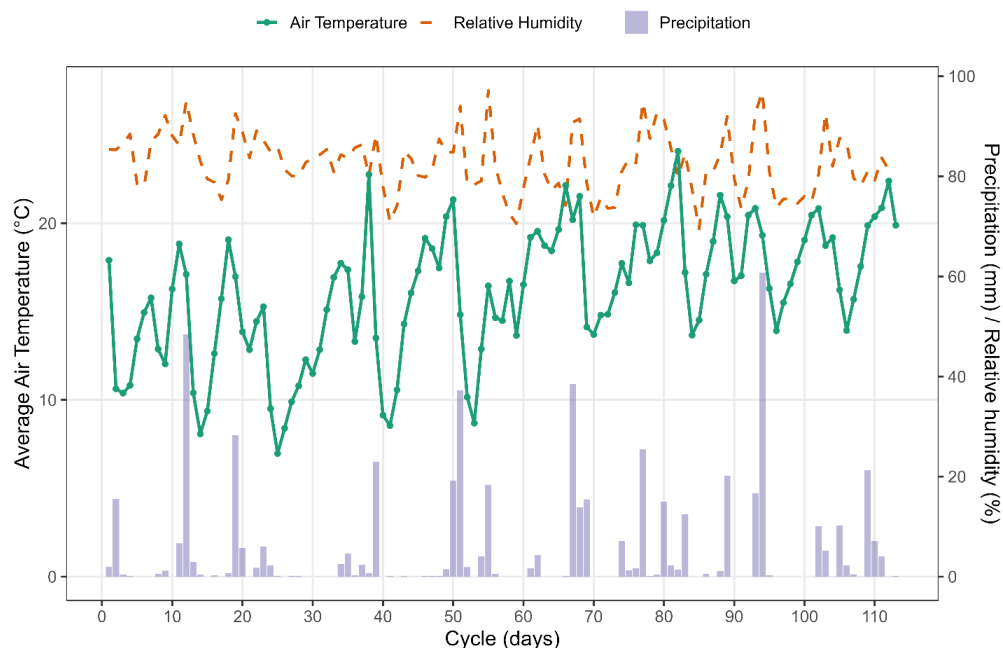


Figure 2. Meteorological conditions of mean air temperature (in °C), relative air humidity (in %) and precipitation (in mm) for the wheat growing cycle in Augusto Pestana - RS, 2025.

The mechanical resistance of the soil showed significant variation among the treatments (Table 2). The Ozone + Phosphate treatment recorded the highest penetration

resistance values, with means of 1405, 2619.25, and 3151.5 kPa at depths of 5, 10, and 15 cm, respectively, while the treatment with Ozone alone showed the lowest means (841.5, 1144.25, and 1454.5 kPa). The species *Lolium multiflorum*, *Avena* spp., and *Sorghum bicolor* were dominant, with means between 52.5% and 61% of the evaluation grid, while *Conyza bonariensis* and *Sida* spp. occurred more frequently in the treatments with phosphate. Among the insects, *Rhopalosiphum padi* showed the highest incidence in the Phosphate (18.25 individuals) and Ozone + Phosphate (14 individuals) treatments, while *Melanoplus sanguinipes* was recorded only in the Ozone treatment (5 individuals). The pathogens *Drechslera tritici* and *Bipolaris sorokiniana* stood out, with incidences ranging from 35.75% to 43% and from 20.85% to 26.57%, respectively. The severity of *Puccinia triticina* was higher in the Ozone treatment (14.4%), while *Fusarium graminearum* showed the highest value in the control (37.66%).

Most of these results reflect the dynamic association between biotic and abiotic factors in the different management practices, without implying direct causal relationships between the treatments and the observed occurrences. However, the lower incidence of *Fusarium graminearum* in the treatments with Ozone (32.33%), Phosphate (28%) and Ozone + Phosphate (20.33%) is a relevant point, possibly indicating the potential of these management practices as seed pre-treatments, corroborating studies that demonstrate the efficiency of ozone in inactivating *Fusarium* in grains (Savi et al., 2014).

Table 2. General description of management variables.

Variables	Ozone + Phosphate	Phosphate	Control	Ozone
Penetrometer 5 cm	1405.00	1838.00	1952.50	841.50
Penetrometer 10 cm	2619.25	2612.50	2466.75	1144.25
Penetrometer 15 cm	3151.50	2958.25	2504.00	1454.50
<i>Conyza bonariensis</i>	7.50	24.00	15.00	15.00
<i>Raphanus raphanistrum</i>	26.50	20.50	15.00	15.00
<i>Ageratum conyzoides</i>	14.00	12.00	0.00	0.00
<i>Sida</i> spp.	15.00	25.00	30.00	30.00
<i>Commelina bbhenbenghalensis</i>	15.00	25.00	30.00	30.00
<i>benghalensis</i>				
<i>Solanum americanum</i>	20.00	0.00	0.00	0.00
<i>Amaranthus</i> spp.	8.00	0.00	0.00	14.00
<i>Digitaria insularis</i>	10.00	5.00	0.00	0.00
<i>Avena</i> spp.	54.00	39.00	44.00	61.00
<i>Sorghum bicolor</i>	47.00	28.00	41.00	42.00
<i>Lolium multiflorum</i>	56.75	60.75	54.00	52.50
<i>Melanoplus sanguinipes</i>	0.00	0.00	0.00	5.00
<i>Rhopalosiphum padi</i>	14.00	18.25	5.25	0.75
<i>Bipolaris sorokiniana</i>	20.85	24.57	23.92	26.57
<i>Puccinia triticina</i>	15.80	10.00	7.40	14.40
<i>Drechslera tritici</i>	41.00	43.00	35.75	37.75
<i>Fusarium graminearum</i>	20.33	28.00	37.66	32.33
<i>Gaeumannomyces graminis</i>	0.00	10.00	25.00	26.50
<i>Pyricularia oryzae</i>	2.50	13.50	19.00	21.50

Analysis of variance revealed that ozone had a significant effect on the variables stem diameter, number of spikelets per spike, flag leaf width, grain yield, and thousand-grain weight, demonstrating its influence on wheat yield components (Table 3). Phosphate exerted significant effects on spike weight and grain weight, suggesting a more specific role in spike components. The phosphate x ozone (PxO) interaction was

significant for the number of rachis nodes in the spike, grain weight, grain yield, and thousand-grain weight, indicating that the ozone response is modulated by phosphate levels in these variables. The coefficients of variation remained within adequate ranges for most variables (up to 15%), demonstrating good precision and experimental consistency.

Table 3. Summary of the analysis of variance for the effects of phosphate (P), ozone (O) and combined phosphate and ozone (PxO) on the variables evaluated in wheat cultivation.

SV ¹	DF	Mean Square									
		PH	EIH	RSA	SD	FLL	FLW	EL	EW	NRN	NSE
P	1	60.06	7.73	0.97	0.01	0.89	0.01	1.31	0.70*	3.24	0.32
O	1	10.56	7.97	0.23	0.32*	6.23	0.13*	0.06	0.00	1	117.36*
Block	3	2.40	10.89	0.69	0.02	1.93	0.02	1.15	0.10	0.57	8.12
PxO	1	60.06	6.15	0.01	0.09	1.69	0.00	2.14	0.12	8.60*	8.8
Residuals	9	21.90	7.88	0.85	0.05	2.14	0.02	1.52	0.03	1.01	10.51
CV (%)	-	5.45	4.03	18.17	8.61	7.33	30.27	15.09	10.24	7.08	8.44

SV	DF	Mean Square						
		NIS	NGE	GWE	TGW	HW	GY	
P	1	7.93	0.01	0.10*	0.23	4.68	1372942.02*	
O	1	5.06	1.39	0.01	10.36*	9.84	343111.13	
Block	3	2.04	10.47	0.01	1.18	30.39	14732.77	
PxO	1	0.12	13.54	0.14*	4.33*	8.12	3044260.96*	
Residuals	9	2.08	5.46	0.06	0.40	29.73	223348.63	
CV (%)	-	24.82	8.040	12.60	2.14	8.06	19.68	

¹SV: Source of variation; DF: degrees of freedom; P: phosphate; O: ozone; PxO: phosphate-ozone interaction; CV: coefficient of variation; PH: plant height (cm); EIH: ear insertion height (cm); RSA: root system aggressiveness; SD: stem diameter (mm); FLL: flag leaf length (mm); FLW: flag leaf width (mm); EL: ear length (cm); EW: ear weight (g); NRN: number of rachis nodes; NSE: number of spikelets per ear; NIS: number of infertile spikelets; NGE: number of grains per ear; GWE: grain weight per ear (g); TGW: thousand grain weight (g); HW: hectoliter weight (g dm⁻³); GY: grain yield (kg ha⁻¹).

The main effects of ozone and phosphate treatments are shown in [Figure 3](#). Ozone application resulted in statistically superior means for stem diameter ([Figure 3A](#)), flag leaf width ([Figure 3B](#)), and number of spikelets per ear ([Figure 3C](#)), with values of 2.77 mm, 0.58 mm, and 41.12 spikelets, respectively. Phosphate application was effective in increasing ear weight ([Figure 3D](#)), with a mean of 1.88 g, while the absence of phosphate resulted in 1.47 g. Studies indicate that ozone can alter growth traits and productive components in plants, influencing spikelet development and inflorescence morphology ([Zhang et al., 2023](#)). Furthermore, the application of phosphate/phosphorus has been shown to promote vegetative growth and yield components in agricultural crops, with an increase in the number of nodes, biomass, and productivity when compared to the absence of phosphorus ([Zhou, Tang, Liu, Huang, & Huang, 2023](#)). Phosphorus acts as a critical nutrient for energy processes, cell division, and development, and its deficiency reduces growth and reproductive structure in different plant species ([Fathi & Afra, 2023](#)).

The analysis of the phosphate × ozone interaction revealed statistically significant differences in the number of rachis nodes in the absence of phosphate, with means of 14.70 nodes under ozone and 12.70 nodes without ozone ([Figure 4A](#)). Grain weight per ear was influenced by ozone application, regardless of the presence of phosphate ([Figure 4B](#)). The interaction indicated that phosphate potentiated ozone, resulting in 0.76 g in the Phosphate + Ozone combination versus 0.41 g without phosphate. In the presence of phosphate, ozone did not alter the thousand-grain weight (29.8 g with ozone vs. 29.3 g without ozone). In the absence of phosphate, ozone increased this variable (31.1 g with

ozone vs. 28.5 g without ozone). Statistically significant differences were observed in the presence of phosphate, with a mean of 2,984 kg ha⁻¹ under ozone versus 2,404 kg ha⁻¹ without ozone (Figure 4D). In the absence of phosphate, the yield was lower and did not differ statistically between ozone conditions, with means of 1,526 kg ha⁻¹ (with ozone) and 2,691 kg ha⁻¹ (without ozone).

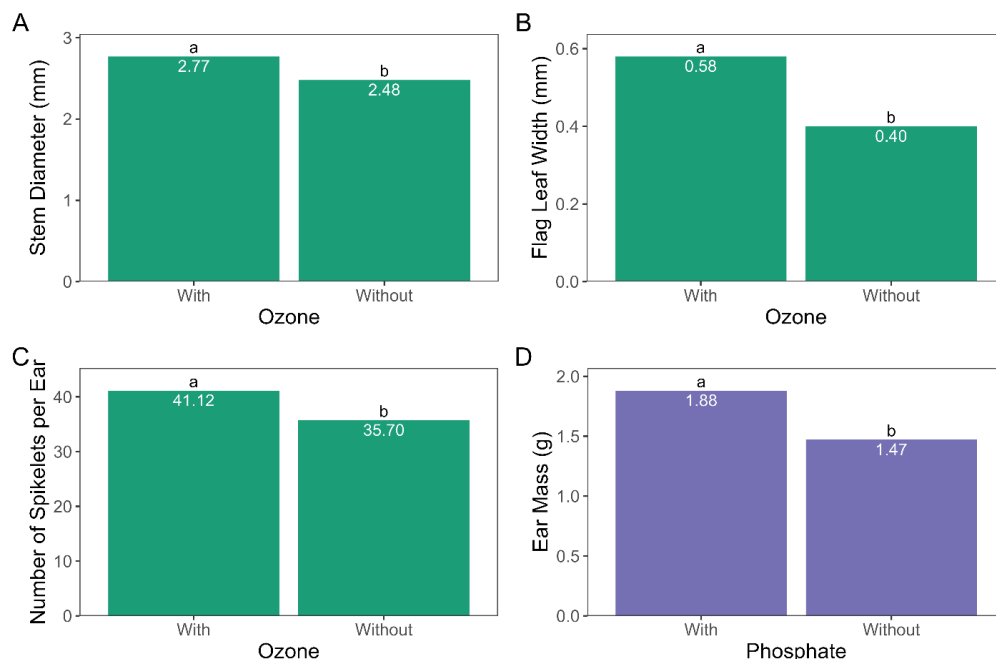


Figure 3. Main effects of treatments with and without ozone on stem diameter (A), flag leaf width (B) and number of spikelets per ear (C), and of treatments with and without phosphate on ear weight (D). Means followed by the same lowercase letter do not differ from each other at 5% probability, by Tukey's test.

The results indicate that the application of ozone as a seed pretreatment modulated morphological and yield components, with responses dependent on phosphate availability. The increased number of rachis nodes in the absence of phosphate under ozone suggests that the ozone-induced effect may stimulate early reproductive development even under limiting nutritional conditions. This is possibly due to physiological adjustments triggered in the initial growth phase, as reported by other crops subjected to seed ozonation (Guzmán-Núñez, Macedo-Cruz, Chávez-Franco, Carrillo-Castañeda, & Rico-Sánchez, 2025).

The greater grain weight per ear in the phosphate + ozone combination indicates that phosphorus potentiated the effects of the pretreatment, corroborating studies that highlight the central role of phosphorus in reproductive development and yield components (Oo et al., 2023; Ma et al., 2025). In turn, the absence of an effect of ozone on the thousand grain weight in the presence of phosphate reinforces that the responses to ozone pretreatment are conditioned by the interaction between initial physiological stimuli and nutritional management throughout the cycle.

The contribution analysis demonstrated that some variables were crucial for separating the treatments, notably the number of spikelets per ear, penetrometer at 5 cm, thousand-grain weight, stem diameter, and *Amaranthus* spp., which showed the highest percentages and clearly exceeded the overall mean contribution (Figure 5). A second group, composed of the variables hectoliter weight, *Puccinia tritricina*, penetrometer at 10 cm, *Melanophus sanguinipes*, flag leaf length, number of infertile spikelets, and grain yield, also showed a relevant contribution. The predominance of variables related to

wheat yield components among the largest contributions reinforces that these parameters were more responsive to the treatments than the isolated biotic components.

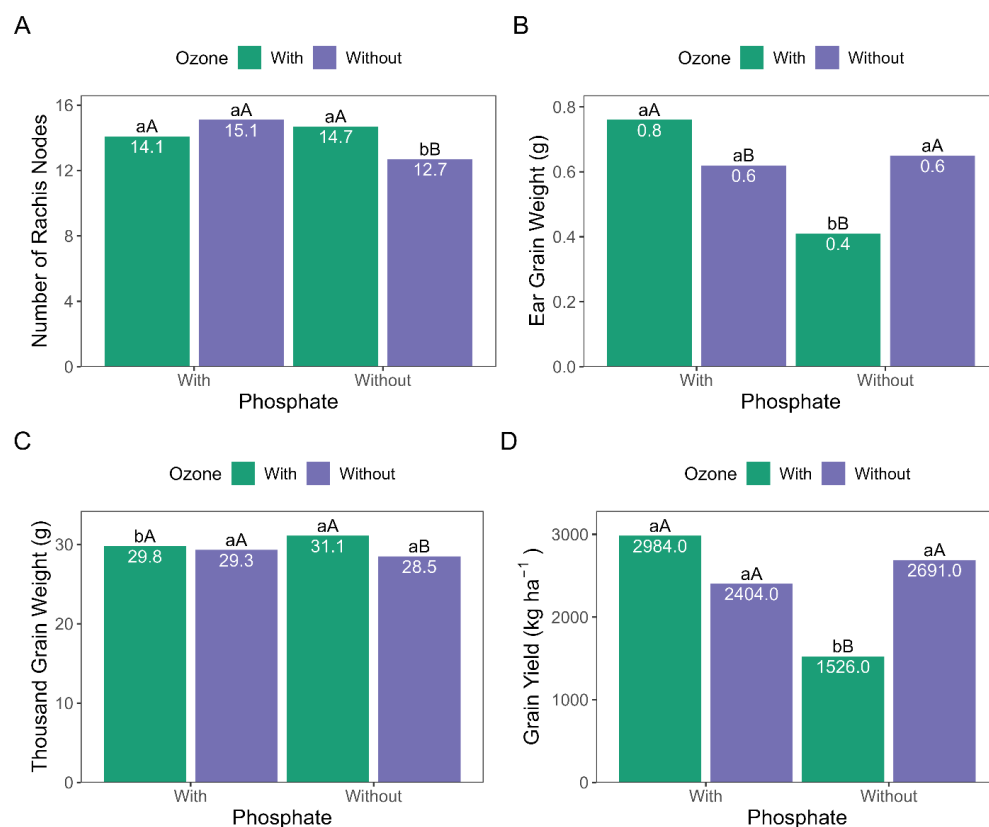


Figure 4. Breakdown of the simple interaction effects between treatments with and without phosphate and ozone on the number of rachis nodes (A), grain weight per ear (B), and thousand-grain weight (C). Means followed by the same lowercase letter do not differ from each other within each phosphate level, while means followed by the same uppercase letter do not differ from each other within each ozone level, by Tukey's test at 5% probability.

Principal component analysis (PCI) explained a total of 21.5% of the data variability (PCI1: 12.2%; PCI2: 9.3%), suggesting high variability among treatments (Figure 6). The Phosphate + No Ozone treatment was positioned in the right quadrant, strongly associated with variables such as *Solanum americanum*, *Raphanus raphanistrum*, and *Ageratum conyzoides*. The No Phosphate + No Ozone treatment was isolated in the lower left quadrant, influenced by *Melanoplus sanguinipes*, flag leaf length, and *Gaeumannomyces graminis*. The Phosphate + Ozone treatment clustered near the center, correlated with *Rhopalosiphum padi*, *Lolium multiflorum*, and penetrometry parameters. The No Ozone + Phosphate treatment was directed towards variables such as stem diameter, hectoliter weight, and incidence of *Puccinia tritricina*. These results confirm that ozone and phosphate modulate, in distinct ways, both attributes related to wheat yield components and the dynamics of biotic components.

The results demonstrate that seed pretreatment with ozone, associated with phosphate management, consistently influences the morphological, productive, and biotic components of wheat, with responses conditioned by the availability of phosphorus in the system. The interaction between phosphate and ozone was mainly reflected in the increase of attributes directly related to yield, in line with the role of phosphorus in the physiological and reproductive processes of plants (Fathi & Afra, 2023; Ma et al., 2025; Zhou et al., 2023). These results indicate that the integration between seed pretreatment

strategies and nutritional management can contribute to optimizing wheat yield performance (Aula et al., 2023). Future studies should focus on evaluating these types of treatments in a larger number of genotypes, with more precise assessments of the effect of ozone on reducing seed pathogens. This could be a practice that will lead to increased seed health and agricultural success.

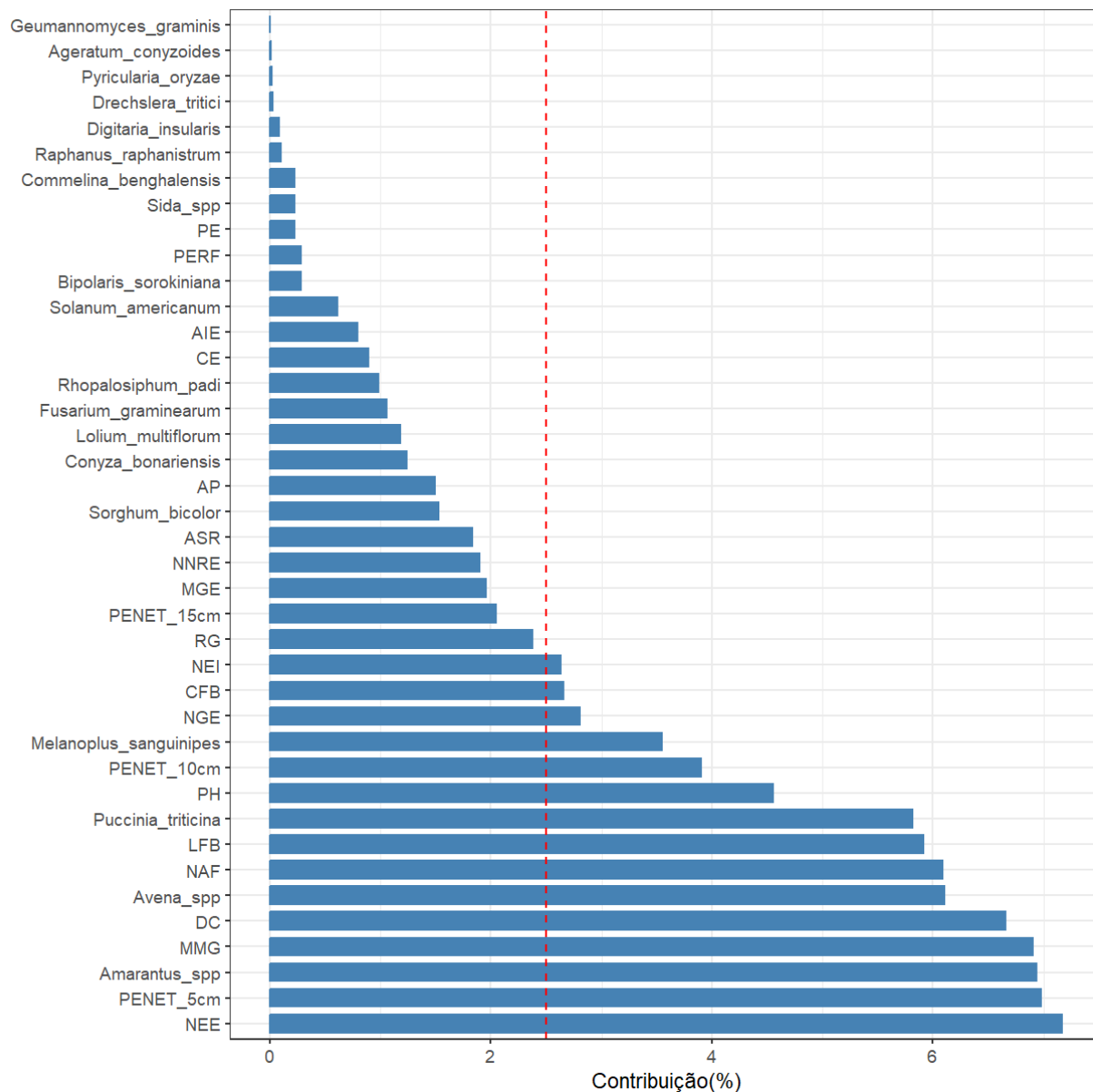
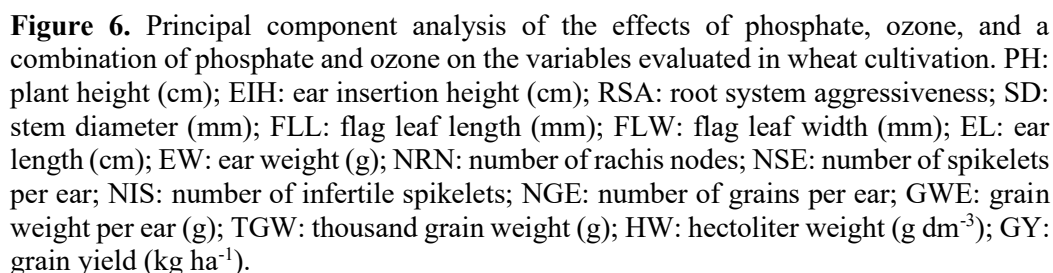


Figure 5. Contribution of variables to the principal component analysis for the effects of phosphate, ozone, and the combined effects of phosphate and ozone on wheat cultivation. PH: plant height (cm); EIH: ear insertion height (cm); RSA: root system aggressiveness; SD: stem diameter (mm); FLL: flag leaf length (mm); FLW: flag leaf width (mm); EL: ear length (cm); EW: ear weight (g); NRN: number of rachis nodes; NSE: number of spikelets per ear; NIS: number of infertile spikelets; NGE: number of grains per ear; GWE: grain weight per ear (g); TGW: thousand grain weight (g); HW: hectoliter weight (g dm^{-3}); GY: grain yield (kg ha^{-1}); TILL: tillering; NFT: number of fertile tillers.



The application of ozone and phosphate fertilization influence the morphological and productive performance, as well as the quality of wheat grains, highlighting the potential of these practices in crop management.

It has been found that the use of ozone in seed pretreatment acts as a physiological modulator, promoting changes in morphological and reproductive components, with intensity dependent on nutritional conditions.

The availability of phosphorus is crucial for the expression of yield components, and the phosphate $\times$ ozone interaction resulted in more consistent responses when the nutrient was present.

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