Agronomic traits of white oat treated with the growth regulator trinexapac-ethyl

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ABSTRACT

The growth and yield performance of white oat cultivars may vary in response to doses of trinexapac-ethyl (TE) growth regulator. The objective of the work was to evaluate the lodging and productive performance of white oat cultivars under different doses of trinexapac-ethyl growth regulator. The experiments were carried out in a randomized complete block design with four replications, in a 4 x 2 factorial scheme, with four doses of trinexapac-ethyl (0, 50, 100 and 150 g ha^{-1}) applied in the phenological stage between the 1st visible stalk node and the 2nd perceptible node in two white oat cultivars (URS Altiva and URS Corona). The following were evaluated: plant height, panicle length, panicles per m^2, spikelets per panicle, grains per spikelet, number of grains per panicle, thousand grain weight, plant lodging and grain yield. The application of trinexapac-ethyl at doses 100 and 150 g ha^{-1} reduces plant height and panicle components: length, number of spikelets and grains per panicle of the two cultivars. TE doses above 100 g ha^{-1} provide a significant reduction in lodging with an increase in the number of panicles per m^2 and in grain yield for the two white oat cultivars.

Keywords: *Avena sativa* L.; growth regulator; productivity; yield components.

INTRODUCTION

Within the production system in southern Brazil and in part of the Southeast and Midwest, white oat (*Avena sativa* L.) is cultivated for grain production and, in addition, straw left on the ground cover favors the implementation of summer harvests in succession, especially in a system of no-tillage (Ceccon *et al.*, 2004).

The occurrence of lodging is quite common in oat cultivation, in the flowering stage may compromise productivity, as it reduces the photosynthetic area exposed to sunlight. In addition, although this event occurs during the maturation phase, the proximity of panicles to the soil exposes them to higher humidity conditions, which normally leads to losses in both yield and grain quality. Another harmful effect of lodging, regardless of which stage it occurs, is the difficulty it imposes on the harvesting operation (Penckowski *et al.*, 2009).

An alternative to avoid problems caused by lodging without compromising grain yield is the application of growth regulators, which are chemicals that have gained importance in improving the productive efficiency of cultivated species (Bazzo *et al.*, 2019). Among the growth regulators used in winter cereals, otrinexapac-ethyl (TE) stands out, which acts to reduce internode elongation, increase stem diameter, change leaf architecture and reduce plant lodging.

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TE inhibit the enzyme 3β-hydroxylase, drastically reducing the level of active gibberellic acid (GA_1), resulting in an increase in its immediate biosynthetic precursor GA_{20} (Davies, 1987). The reduction in the level of GA_1, which acts on internode elongation, is responsible for plant growth inhibition (Rademacher, 2000). In some cereals such as wheat, rice and barley (Koch *et al.*, 2017a; Arf *et al.*, 2012; Swoish *et al.*, 2021), the use of this growth regulator has been shown to be effective in reducing lodging, even in cultivation systems with intensive use of fertilizers. However, these effects are dependent on the genotype, the doses of TE application and the interaction of these factors with the environment.

Zagonel & Fernandes (2007), studying the effect of trinexapac-ethyl on wheat, showed that both the dose and the timing of application of the growth regulator can be specific for each cultivar, especially when applied to genotypes with high susceptibility to lodging. The same authors mention that the application of trinexapac-ethyl is indicated for wheat when the first and second noticeable nodes appear at a dose of 100 g of TE ha^{-1}. However, this recommendation is very broad and does not take into account the peculiar characteristics of each cultivar, which may respond differently in relation to the dose of the product.

The use of growth regulators may be an alternative to minimize the negative effects of plant lodging and favor the yield components and productivity of white oat, as has been reported for other cereals (Murcia, 2016). Commonly, due to lack of specific studies, the recommended doses of trinexapac-ethyl application for wheat are extrapolated to white oat cultivation. In addition, in other cereals whose use of the growth regulator is already consolidated, the responses to application doses of the product vary according to the genotype and growing environment. Thus, it is expected that for white oats, specific recommendations are also needed according to genotype, environment and management.

This study aimed to evaluate the lodging and productive performance of white oat cultivars under different doses of trinexapac-ethyl growth regulator.

MATERIAL AND METHODS

The experiment was carried out in two agricultural seasons, following the recommended periods according to the climatic zoning of the region for the cultivation of the winter crop in the years 2019 and 2020 at the Experimental Station of the Instituto de Desenvolvimento Rural do Paraná - IDR-PARANÁ, located in the municipality of Londrina-PR (geographical coordinates: 23° 23’ S and 51° 11’ W and altitude 545 m). The soil is classified as Eutroferric Red Latosol (Embrapa, 2018). The climate is of the Cfa type, described as humid subtropical, with an average minimum temperature in the coldest month of 0 to -3 °C, and an average maximum in the hottest month of 22 °C, according to Köpen classification. The maximum and minimum temperatures and rainfall recorded during the periods of conducting the experiments are shown in Figure 1.

The chemical characteristics of the soil at a depth of 0-20 cm were determined before the installation of the experiments. In the 2019 harvest, the following values were obtained: pH ($CaCl_2$) 5.00; 5.21 $cmol_c$ dm^{-3} of H + Al; 5.31 $cmol_c$ dm^{-3} of Ca^{2+}; 0.98 $cmol_c$ dm^{-3} of Mg^{2+}; 0.59 $cmol_c$ dm^{-3} de K^+; 29.33 mg dm^{-3} of P and 16.98 g dm^{-3} of organic matter; in the harvest 2020: pH ($CaCl_2$) 4.85; 5.96 $cmol_c$ dm^{-3} of H + Al; 5.76 $cmol_c dm^{-3}$ of Ca^{2+}; 0.65 $cmol_c$ dm^{-3} of Mg^{2+}; 0.61 $cmol_c dm^{-3}$ of K^+; 31.09 mg dm^{-3} of P and 15.92 g dm^{-3} of organic matter.

Sowing was carried out in a mechanized way in the no-tillage system in succession to soybean cultivation, in both harvests. In the 2019 harvest, oats were sown on May 3rd, with emergence and harvest recorded on May 14th and August 28th, respectively. In the 2020 harvest, oats were sown on April 17th, with emergence and harvest recorded on April 25th and August 11th, respectively.

The base fertilization consisted of the application of 200 kg ha^{-1} of the 10-30-10 formula. The nitrogen topdressing fertilization was carried out with 54 kg ha^{-1} of N, divided into two applications, 27 kg ha^{-1} ten days after seedling emergence, and 27 kg ha^{-1} five days after the first application, distributed manually. The other cultivation treatments were carried out in accordance with the technical recommendations for oat culture.

Each experimental unit consisted of 6 lines of 5m in length, spaced 0.17m apart, and with a density of 300 viable seeds m^2, considering the 4 central lines as useful area.

The experimental design adopted was a randomized block design with four replications, in a 4 x 2 factorial scheme, with four doses of trinexapac-ethyl and two white oat cultivars (URS Altiva and URS Corona). The evaluated doses were: 0, 50, 100 and 150 g a. i ha^{-1}, using the commercial product Moddus®. The application of do-trinexapac-ethyl was carried out in the phenological stage, which comprises the 1st node of the visible stalk and the 2nd node of the perceptible. The evaluated grain oat genotypes have different heights, cycles and levels of tolerance to lodging. Cultivar URS Altiva was launched in 2015 by the Federal University of Rio Grande do Sul – UFRGS, has an early cycle (110 to 135 days), moderate resistance to lodging and tall plants (110 to 140 cm). The URS Corona was launched in 2010 by UFRGS, exhibits medium cycle, moderate susceptibility to lodging and high height.

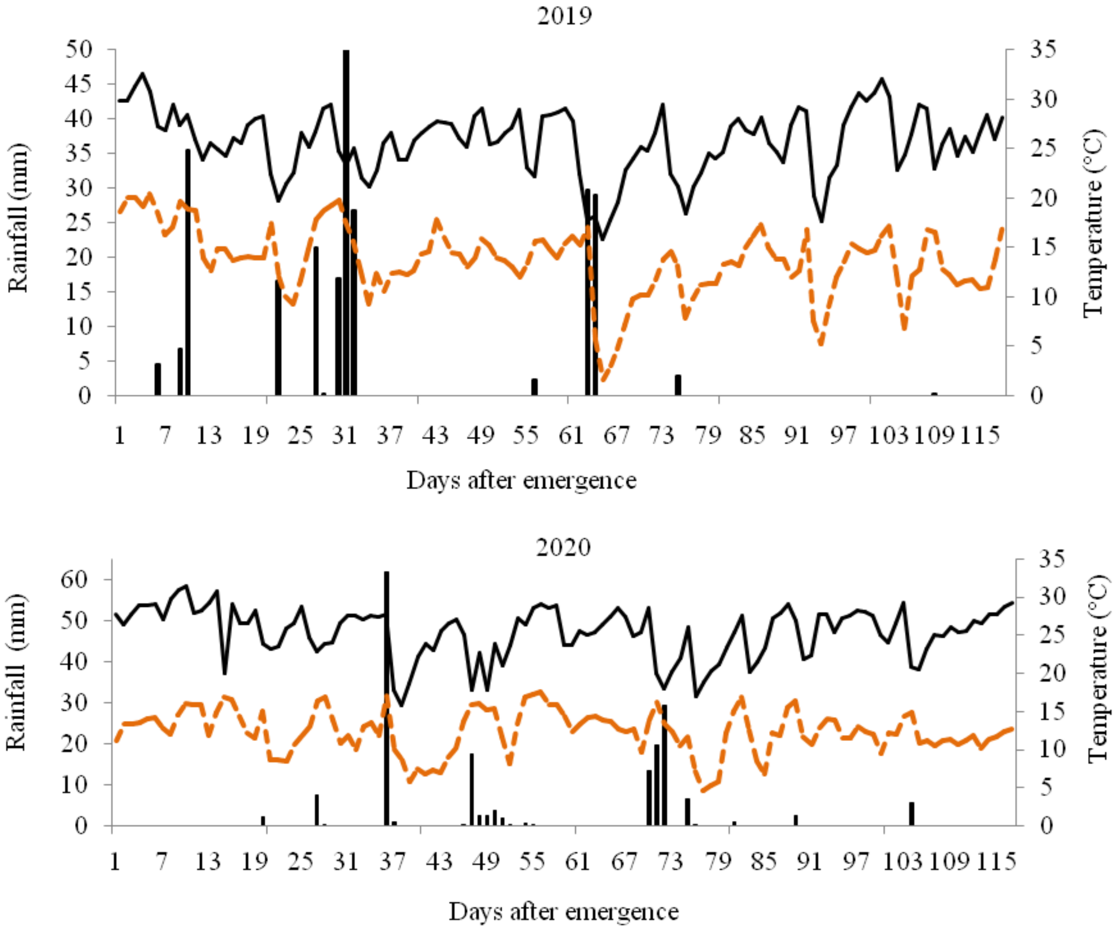


Figure 1: Daily average temperature and rainfall data (mm) for the periods of conduction of the experiments in Londrina-PR, in the 2019 and 2020 harvests. Bar is the Rainfall (mm): Solid line is the Maximum temperature: Dashed line is the Minimum temperature.

The application of the regulator was made using a costal spray at a constant pressure of 30 lb in.$^{-2}$, pressurized by compressed CO_2, equipped with two tips with flat jet nozzles XR 110-020, with a spray volume proportional to 200 L ha^{-1}.

The harvest was carried out after the grains reached harvest maturity, a stage characterized by hardening of the caryopsis, plants with a dry appearance and grains with moisture below 20%. The following agronomic characteristics and production components were evaluated in the useful area of the plots:

Lodging: was obtained through visual observations, during the maturation phase of the plants, attributing grades from 0 (no lodging) to 100% (total lodging of the plot), considering as lodging the plants that were at an inclination equal to or less than 45 degrees in relation to the ground.

Plant height: determined from ground level to panicle tip, with average results expressed in cm; the measurements were carried out on five plants taken at random, at the time of grain filling.

Panicle length (PL): determined from the panicle insertion point to the panicle tip, with mean results expressed in cm; the measurements were carried out on panicles of five plants taken at random, at the time of grain filling.

Number of panicles per m^2 (P/m^2): determined by counting the number of panicles in 1.0 m^2 of each plot.

Number of spikelets per panicle (SPP): performed by manually counting the spikelets of 10 panicles randomly collected in each plot.

Number of grains per spikelet (GPSt): performed by manually counting the spikelets grains from 10 panicles randomly collected in each plot.

Number of grains per panicle (GPP): performed by removing the grains from ten panicles randomly collected in the plot and, after their complete separation, they were counted manually.

Thousand grain weight (TGW): obtained by counting and weighing eight repetitions of 100 grains per plot. The mean of these values was multiplied by 10 to obtain the value of the TGW.

Grain yield (GY): was determined by harvesting the grains of plants contained in the useful area of the plot. After mechanical threshing, the grains were weighed and the data transformed into kg ha^{-1} and corrected to 13% moisture.

Data were subjected to analysis of normality and homogeneity of errors and, subsequently, to analysis of variance. The means were compared by the conclusive F test for the cultivar factor and submitted to regression analysis up to 2nd degree for the regulator doses, at 5% probability. All statistical analyses were performed with the aid of the Genes computer program (Cruz, 2013).

RESULTS AND DISCUSSION

URS Corona and URS Altiva cultivars, in the 2019 harvest, showed significant interaction between genotypes and TE doses for the variables GPP, Plant height, TGW and Lodging; isolated effect of genotypes and TE doses for PL, SPP, number of panicles per unit area and GY, except for the variable GPSt, which showed an isolated effect only for genotype. In the 2020 harvest, there was a significant interaction between genotypes and doses of TE for the variables SPP, GPP, Plant height and number of panicles per unit area; isolated effect of genotypes and TE doses for the Panicle length and Lodging variables. As seen in the 2019 harvest, the GPSt variable showed only an isolated effect of the genotype. On the other hand, the GY and TGW variables were not significantly affected by genotypes, TE doses, or the interaction between these factors (Table 1).

Table 1: Values of the mean square of the analysis of variance and estimate of the coefficients of variation (CV) for nine characteristics evaluated considering the white oat genotypes URS Corona and URS Altiva, and doses of trinexapac-ethyl. Londrina-PR, 2019 and 2020 harvests

Year	Variables	Mean squares					CV	Mean
		Block	Genotype (G)	Dose (D)	D x G	Residue	(%)	
2019	PL	0.048	20,801**	9,578**	0.677^{ns}	0.334	3.39	17.01
	SPP	1,447	140,281**	71,864**	1,197^{ns}	1,376	3.66	32.09
	GPSt	0.002	1.28**	0.008^{ns}	0.003^{ns}	0.006	3.63	2.18
	GPP	2,041	3612.5**	142,208**	22,083**	2,875	2.37	71.56
	Plant height	4,114	1391.281**	2978.031**	376447**	8,138	2.49	114.17
	P/M²	20,281	258781**	7270.031**	122,114^{ns}	41,305	2.08	308.78
	GY	6025.6	192665.2*	551221.3**	85888.8^{ns}	34242.2	5.03	3677.59
	TGW	1.74	42.32**	1337^{ns}	40,722**	1182	3.33	32.68
	lodging	9,335	27132.8**	868.9**	871.7**	3324	6.22	29.32
2020	PL	3.02	67.28**	40196**	0813^{ns}	1,305	6.87	16.63
	SPP	2.25	518.42**	124.24**	39.74**	6931	12.93	20.35
	GPSt	3	0.02**	0.01^{ns}	0,002^{ns}	4	3.21	2.04
	GPP	29708	2016.1**	360.4**	227.1**	31565	13.28	42.31
	Plant height	12.86	536.28**	884.53**	69.78**	11436	3.47	97.53
	P/M²	413.86	330281.2**	25677.6**	5614.2**	945959	6.54	470.47
	GY	111997.6	24808.7^{ns}	45480.0^{ns}	15753.1^{ns}	83138.75	6.5	4463.97
	TGM	1765	2881^{ns}	2124^{ns}	6776^{ns}	5271	7.07	32.47
	lodging	66145	3202.01**	833.28*	544.61^{ns}	185.51	96.66	14.09

*/**: significant at 5 and 1% probability by the F test, respectively; ns: not significant;
Degrees of freedom: 3 (block); 3 (dose); 1 (genotype); 3 (D x G); 21 (residue).
Variables: PL: panicle length (cm); SPP: number of spikelets per panicle; GPSt: number of grains per spikelet; GPP: number of grains per panicle; Plant height (cm); P/M²: number of panicles per m²; GY: grain yield (kg ha-1); TGW: thousand grain weight (grams); Lodging (%).

With the exception of plant lodging, all other characteristics evaluated for the cultivars under study in the two growing harvests presented a coefficient of variation lower than 13.28%, indicating adequate experimental precision (Table 1).

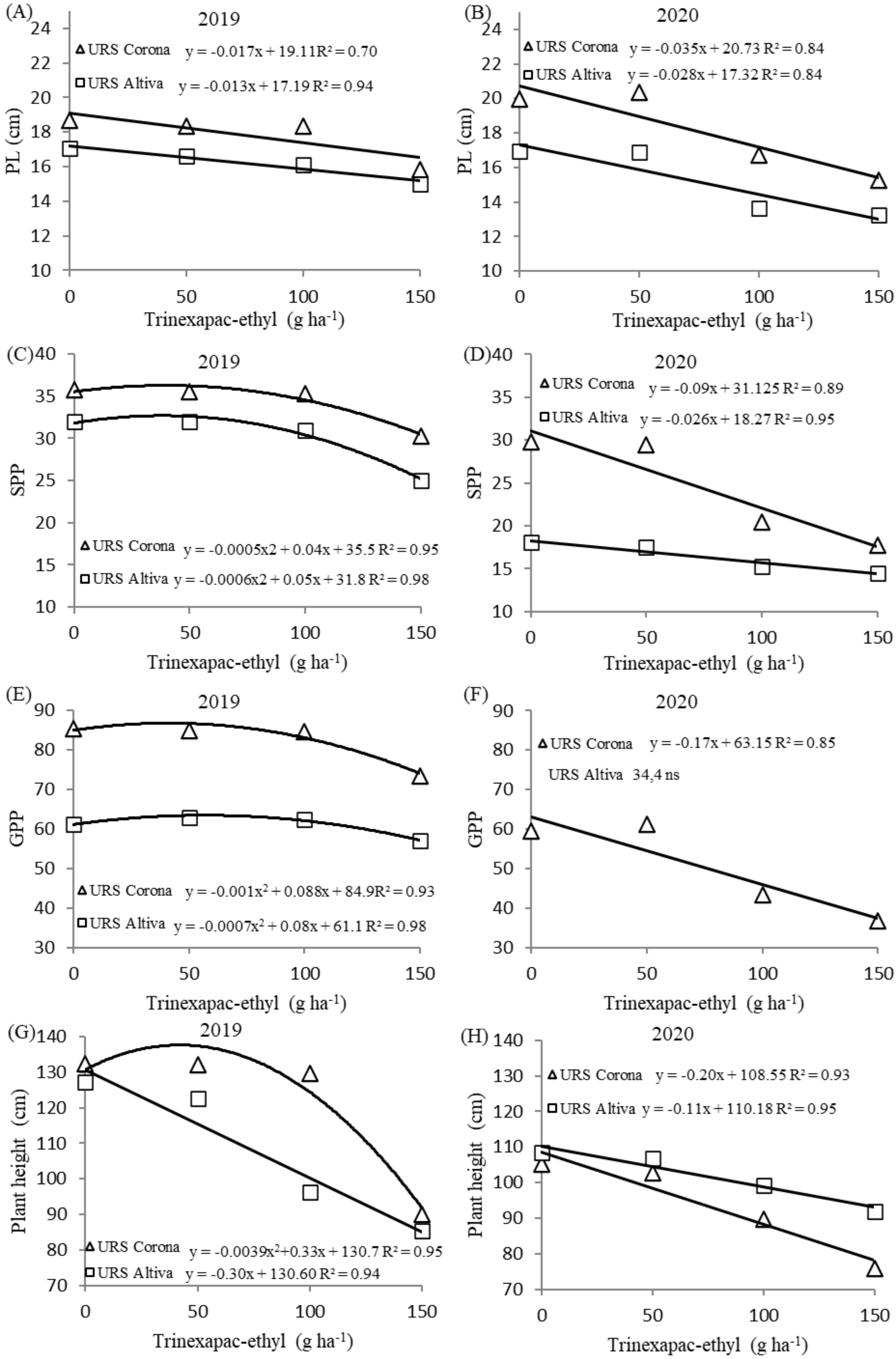
The PL of the URS Corona and URS Altiva cultivars, in the 2019 and 2020 harvests (Table 2 and Figures 2A; B), was adjusted to a decreasing linear equation with the increment of the applied doses of trinexapac-ethyl applied. In addition, URS Corona cultivar showed greater panicle length (PL) compared to URS Altiva cultivar in all doses of TE tested, except for the dose 150 g ha^{-1}, in 2019. Alvarez *et al.* (2007), investigating the influence of doses and times of application of trinexapac-ethyl on yield components in upland rice, mention that the decrease in panicle size may be related to the stage of application of the product, which occurs during the differentiation of the floral primordium, which may interfere with the initial processes of formation of this structure, which involve constant cell multiplication, which is the probable cause of the reduction in panicle length.

Table 2: Mean values of characteristics evaluated in white oat URS Corona, URS Altiva cultivars in different doses of trinexapac-ethyl growth regulator. Londrina-PR, 2019 and 2020 harvests

Variable/[1]	Cultivar	2019 Harvest				2020 Harvest			
		Trinexapac-ethyl (g ha^{-1})				Trinexapac-ethyl (g ha^{-1})			
		0	50	100	150	0	50	100	150
PL (cm)	URS Corona	18.7 a	18.4 a	18.4 a	15.8 a	19.9 a	20.3 a	16.7 a	15.2 a
	URS Altiva	17.1 b	16.6 b	16.1 b	15.0 a	16.9 b	16.8 b	13.6 b	13.2 b
SPP	URS Corona	35.0 a	35.5 a	35.2 a	30.2 a	29.7 a	29.5 a	20.5 a	17.7 a
	URS Altiva	32.0 b	32.0 b	31.0 b	25.0 b	18.1 b	17.5 b	15.3 b	14.4 a
GPSt	URS Corona	2.37 a	2.40 a	2.45 a	2.32 a	2.01 a	2.07 a	2.01 a	2.07 a
	URS Altiva	1.97 b	2.00 b	2.00 b	1.97 b	1.97 a	2.05 a	2.02 a	2.01 a
GPP	URS Corona	85.5 a	85.0 a	84.7 a	73.5 a	59.5 a	61.2 a	43.5 a	36.7 a
	URS Altiva	61.2 b	63.0 b	62.5 b	57.0 b	35.5 b	35.7 b	33.0 b	33.2 a
Plant height	URS Corona	132.5 a	132.0 a	129.7 a	90.0 a	105.2 a	102.7 a	89.7 b	76.0 b
	URS Altiva	127.2 b	122.5 b	96.2 b	85.5 b	108.5 a	106.7 a	99.2 a	92.0 a
P/M^2	URS Corona	294.2 a	297.2 a	303.7 a	351.2 a	345.2 b	341.5 b	378.0 b	410.7 b
	URS Altiva	289.5 a	285.2 b	292.7 b	356.2 a	495.2 a	507.2 a	633.0 a	652.7 a
GY (kg ha^{-1})	URS Corona	3336 b	3327 b	3641 a	4094 a	4479 a	4386 a	4500 a	4378 a
	URS Altiva	3675 a	3644 a	3690 a	4010 a	4572 a	4335 a	4526 a	4533 a
TGW (g)	URS Corona	29.9 b	30.17 b	30.5 b	35.5 a	32.3 a	33.1 a	33.1 a	30.2 a
	URS Altiva	35.1 a	34.75 a	34.4 a	31.1 b	32.5 a	32.1 a	33.1 a	33.4 a
Lodging (%)	URS Corona	74.2 a	76.0 a	51.5 a	32.0 a	23.7 a	45.0 a	26.7 a	0.81 a
	URS Altiva	0.17 b	0.20 b	0.20 b	0.22 b	9.27 a	5.32 b	1.57 b	0.17 a

Means followed by the same lowercase letter in the column do not differ by Tukey's test ($P < 0.05$).
/[1]Variable: PL: panicle length (cm); SPP: number of spikelets per panicle; GPSt: number of grains per spikelet; GPP: number of grains per panicle; Plant height (cm); P/M^2: number of panicles per m^2; GY: grain yield (kg ha^{-1}); TGW: thousand grain weight (grams); Lodging (%).

It was found that the variable SPP of the URS Corona and URS Altiva cultivars in the 2019 harvest year, the quadratic function was adjusted in response to the doses of the TE growth regulator (Table 2 and Figure 2C). For the URS Corona the maximum point (36.3) was obtained at the estimated dose of 40.0 g ha^{-1}, while for the URS Altiva the maximum point (32.8) was obtained at the estimated dose of 41.7 g ha^{-1}. In the 2020 harvest, the number of SPP was adjusted to a decreasing linear equation with the increment of the doses of trinexapac-ethyl applied to the two cultivars (Table 2 and Figure 2D). It appears that with the use of increasing doses of the growth regulator, there was a reduction in the number of SPP in the two agricultural years.


(A)
2019
URS Corona y = -0.017x + 19.11R² = 0.70
URS Altiva y = -0.013x + 17.19 R² = 0.94
PL (cm)
Trinexapac-ethyl (g ha-1)
(B)
2020
URS Corona y = -0.035x + 20.73 R² = 0.84
URS Altiva y = -0.028x + 17.32 R² = 0.84
PL (cm)
Trinexapac-ethyl (g ha-1)
(C)
2019
URS Corona y = -0.0005x2 + 0.04x + 35.5 R² = 0.95
URS Altiva y = -0.0006x2 + 0.05x + 31.8 R² = 0.98
SPP
Trinexapac-ethyl (g ha-1)
(D)
2020
URS Corona y = -0.09x + 31.125 R² = 0.89
URS Altiva y = -0.026x + 18.27 R² = 0.95
SPP
Trinexapac-ethyl (g ha-1)
(E)
2019
URS Corona y = -0.001x² + 0.088x + 84.9R² = 0.93
URS Altiva y = -0.0007x² + 0.08x + 61.1 R² = 0.98
GPP
Trinexapac-ethyl (g ha-1)
(F)
2020
URS Corona y = -0.17x + 63.15 R² = 0.85
URS Altiva 34,4 ns
GPP
Trinexapac-ethyl (g ha-1)
(G)
2019
URS Corona y = -0.0039x²+0.33x + 130.7 R² = 0.95
URS Altiva y = -0.30x + 130.60 R² = 0.94
Plant height (cm)
Trinexapac-ethyl (g ha-1)
(H)
2020
URS Corona y = -0.20x + 108.55 R² = 0.93
URS Altiva y = -0.11x + 110.18 R² = 0.95
Plant height (cm)
Trinexapac-ethyl (g ha-1)

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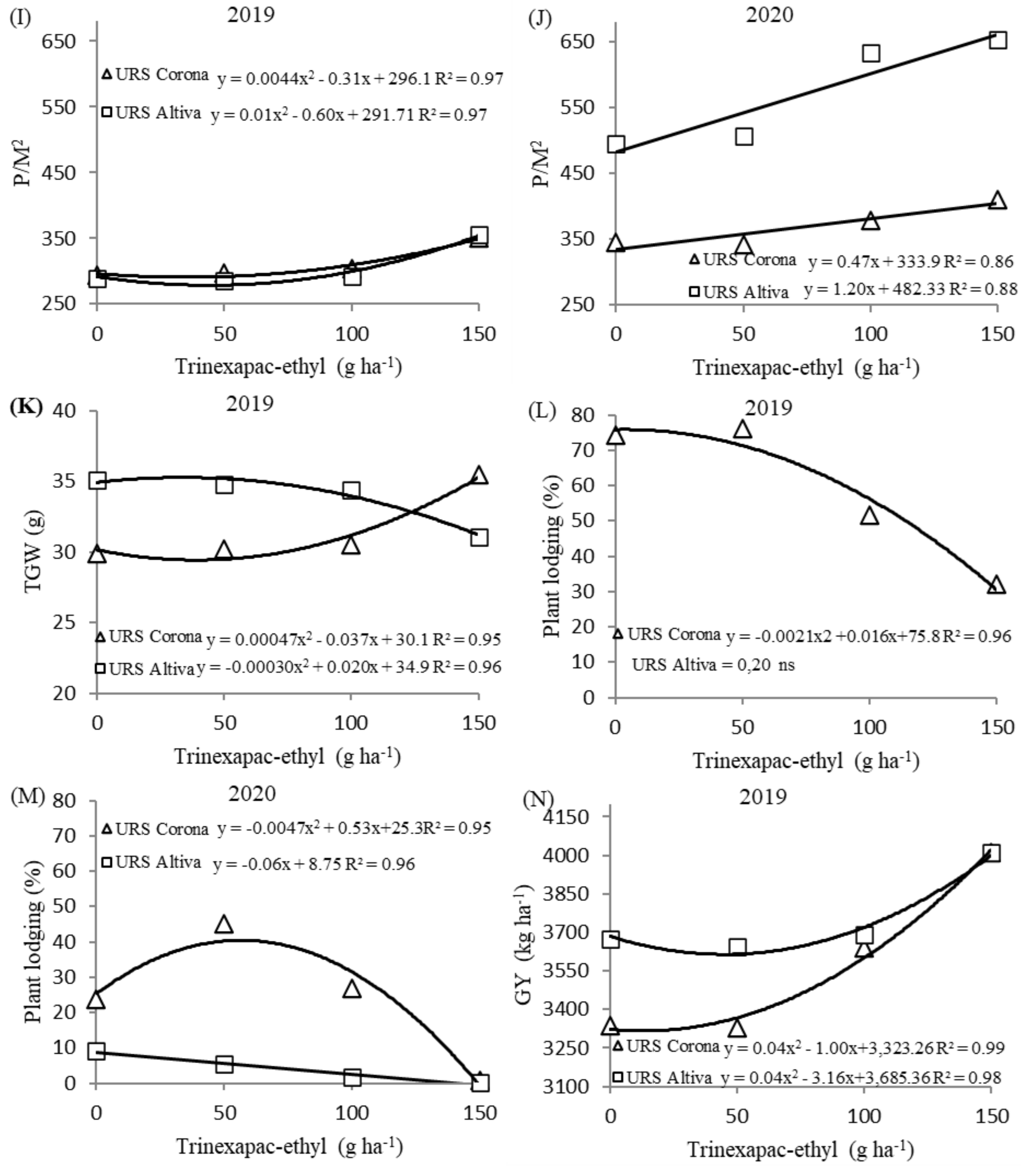

Figure 2: PL: panicle length; SPP: number of spikelets per panicle; GPP: number of grains per panicle; Plant height; P/M^2: number of panicles per m^2; GY: grain yield; TGW: thousand grain weight; Plant lodging as a function of URS Corona and URS Altiva cultivars and application of trinexapac-ethyl growth regulator at different doses. Londrina-PR, 2019 and 2020 harvests. The p values are in Table 1.

Likewise, the URS Corona and URS Altiva cultivars in the 2019 harvest year adjusted to the quadratic function in response to the use of TE for the GPP variable (Table 2 and Figure 2E). For the URS Corona the maximum point (86.83) was obtained at the estimated dose of 44.0 g ha^{-1}, while for the URS Altiva the maximum point (63.38) was obtained at the estimated dose of 57.1 g ha^{-1}. On the other hand, in the 2020 harvest, the URS Corona adjusted to a decreasing linear equation with the increase in TE doses (Table 2 and Figure 2F). This fact is certainly related to the lower PL obtained in the same treatments. Similar results are reported by Guerreiro & Oliveira (2012), who, in studies with white oats, observed a reduction in the number of grains per panicle as a result of increasing doses of trinexapac-ethyl.

Note that for the variable plant height in the 2019 harvest, the URS Corona cultivar adjusted to a quadratic function in response to the use of four doses of TE, where the maximum point (136.32 cm) was obtained in the dose estimated at 42.3 g ha^{-1}. As for the URS Altiva, the adjustment of the equation was linear and decreasing as a result of the increase in TE doses (Table 2 and Figure 2G). However, in the 2020 harvest, the cultivars URS Corona and URS Altiva were adjusted to a decreasing linear equation with the increment of the applied doses of trinexapac-ethyl (Table 2 and Figure 2H). It can be noted that, regardless of the TE doses, the cultivar URS Corona has greater height compared to URS Altiva (Table 2). Kaspary *et al.* (2015), studying TE doses in white oat cultivars, also observed a similar behavior with the increase in trinexapac-ethyl doses, with a reduction of up to 60% in plant height at the dose of 150 g ha^{-1}. The effect of TE was also verified in corn hybrids in similar studies conducted by Sangoi *et al.* (2020), where they reported a reduction in plant height, in line with what was verified by Leolato *et al.* (2017) and Fagherazzi *et al.* (2018) who also found an influence on the reduction of the height of maize plants, especially in the vegetative stages of crop development.

The result obtained is also due to the adequate time of application of the regulator, during the differentiation of the panicle primordium, acting directly in the elongation stage of the stalk. Results of plant height reduction were also reported in studies with rice (Arf *et al.*, 2012), wheat (Koch *et al.*, 2017a), fescue (Chastain *et al.*, 2015), barley (Swoish *et al.*, 2021) and white oat (Hawerroth *et al.*, 2015), demonstrating the effectiveness of the product in reducing plant height in cereals.

Alvarez *et al.* (2007) mention that the decrease in panicle length, due to the application of TE, results in a greater balance of photoassimilates in the entire plant, which can activate the basal buds and cause the plant to till later and thus increase the number of tillers and the formation of new panicles. This statement corroborates the results obtained in this study in the 2019 and 2020 harvests, in which a decrease in panicle length and an increase in the number of panicles per m^2 (P/m^2) with the application of TE were observed (Table 2).

It was found that the variable the number of panicles per unit area of the URS Corona and URS Altiva cultivars in the 2019 harvest adjusted to the quadratic function in response to the TE doses (Table 2 and Figure 2I). For URS Corona and URS Altiva, the minimum points (290.63) and (282.71) were obtained at the estimated doses of 35.2 and 30.0 g ha^{-1}, respectively. In the 2020 harvest, the number of panicles per unit area was adjusted to a linear increasing equation with the increment of the doses of trinexapac-ethyl applied to the two cultivars (Table 2 and Figure 2J). It can be seen that with the use of increasing doses of the growth regulator, there was an increase in the number of panicles per unit area. On the other hand, regardless of the harvests and doses, the cultivar URS Altiva presented a higher number of panicles per m^2 than URS Corona. Bazzo *et al.* (2019), studying the effect of trinexapac-ethyl at a dose of 100 g ha^{-1}, in different white oat cultivars, observed an increase in the number of panicles per m^2. In this context, Zagonel *et al.* (2002) emphasize that plants with smaller height and more compact present better direction of photoassimilates, increasing the number of reproductive structures per square meter, resulting in higher final productivity.

The behavior observed in this study for the characteristic the number of panicles per unit area can be explained by the fact that the application of TE results in the reduction of plant height of the two cultivars studied, which probably provided more favorable conditions for the development of fertile tillers, and, consequently, a greater number of panicles per m^2. It is noteworthy that the increase in the number of panicles per m^2 due to the application of the growth regulator may have contributed to the reduction in the number of spikelets per panicle and the number of grains per panicle, due to the competition of fertile tillers by photoassimilates.

The TGW of the URS Altiva cultivar was negatively affected in the 2019 harvest by the application of TE (Table 2 and Figure 2K). Note that the dose of 150 g of TE ha^{-1} provided a reduction of 11.14% in TGW, compared to the dose of 0 g ha^{-1}. The lower grain filling observed at higher doses of trinexapac-ethyl may be due to the greater number of panicles per m^2 (Table 2). Bazzo *et al.* (2019), observed that trinexapac-ethyl caused a reduction in TGW in oat. Martins *et al.* (2021), in studies on the effects of TE in upland rice cultivars, verified that doses above 75 g ha^{-1} cause a reduction in the thousand grain weight, associated with the application period. Kaspary *et al.* (2015) reported that the use of 150 g of TE ha^{-1} interfered in the thousand grain weight of white oat cultivars. Zagonel *et al.* (2002) working with different wheat cultivars and N doses, verified a negative influence of the regulator on the thousand grain weight, regardless of the cultivar. The reduction in the thousand grain weight indicates smaller amounts of stored reserves, which may influence seed germination and vigor. Generally, seeds that have greater vigor can germinate and emerge more quickly under adverse conditions (Vieira & Carvalho, 1994).

On the other hand, it is possible to observe in this study that the thousand grain weight (TGW) of the URS Corona cultivar was positively affected in the 2019 season by the application of TE (Table 2 and Figure 2K). Note that at the dose of 150 g ha^{-1}, the TGW was 35.5 g; on the other hand, at a dose of 0 g ha^{-1} the mean TGW was only 30.1 g. This behavior can be explained by the fact that in the 2019 harvest, lodging occurred more significantly for the URS Corona cultivar (Table 2 and Figure 2L), reaching 75.8% in the lower doses of TE, thus placing the grains in conditions more favorable for weight loss, due to their greater exposure to soil moisture. This demonstrates that TE indirectly, by reducing plant lodging, contributes so that the TGW characteristic is not drastically reduced by the exposure of panicles to the soil. Koch *et al.* (2017b), working with different wheat cultivars, verified a positive influence of the regulator on the thousand grain weight, vigor and starch contents in seeds.

It appears that there was no significant difference for the URS Altiva cultivar in the 2019 harvest for the lodging variable, however, for the URS Corona there was a quadratic adjustment in response to the doses of the growth regulator TE, where the maximum point (75.8%) was obtained at the estimated dose of 3.80 g ha^{-1} (Table 2 and Figure 2L). In addition, in the 2020 harvest, the URS Corona cultivar was adjusted to the quadratic function, where the maximum point (40.24%) was obtained at the estimated dose of 56.4 g ha^{-1}. On the other hand, the URS Adjusted the decreasing linear function as a result of the increase in TE doses (Table 2 and Figure 2M). A reason that is probably related to the reduction in plant height, as observed in this study. Bazzo *et al.* (2019) studying TE and N doses in white oat cultivars observed that TE was efficient in reducing the percentage of lodging.

Regarding the grain yield of the URS Corona and URS Altiva cultivars for the 2019 harvest (Table 2 and Figure 2N), the TE positively influenced this characteristic, adjusting to a quadratic function. For the URS Corona and URS Altiva, the minimum points (3317.01 kg ha^{-1}) (3622.95 kg ha^{-1}) were obtained at the estimated doses of 12.5 and 39.5 g ha^{-1}, respectively. that at the dose of 150 g ha^{-1} there was an increase of 22.72% and 9.12% for the cultivars URS Corona and URS Altiva. For the 2020 harvest (Table 1) there was no significant difference for this characteristic. Bazzo *et al.* (2019) observed results that corroborate those found in this study, where for the white oat IPR Afrodite cultivar, the use of TE generated an increase in grain yield and the number of panicles per unit area, with the number of panicles per m^2 probably being the characteristic that most influenced the increase in yield. These results are in line with those observed in this study, where P/m^2 had a clear influence on the grain yield of URS Corona and URS Altiva cultivars. Marco Junior *et al.* (2013), working with different wheat doses and cultivars, concluded that trinexapac-ethyl increases the number of panicles per unit area and wheat yield at doses 75 g ha^{-1} and 150 g ha^{-1}. On the other hand, Martins *et al.* (2021) studying the effect of TE application, reported a reduction in yield in rice harvest from the dose of 75 g ha^{-1}. However, for wheat, TE may positively affect the yield variable, increasing it or not, reducing it in relation to controls (Knott *et al.*, 2016; Swoish *et al.*, 2021).

Analyzing the results, the use of TE reduced the lodging of URS Corona and URS Altiva cultivars without harming grain yield. In addition, it appears that the increase in plant lodging did not affect the grain yield of the genotypes analyzed. It is noteworthy that, as this is an experimental area, mechanized harvesting was carried out carefully, which substantially reduced the losses that could have been caused by lodging.

The variation between genotypes found in this study for the variables was also reported by Subedi *et al.* (2021), where they evaluated the effects of TE on the agronomic characters of winter cereal species, reporting that although the effects were verified in all cultivars of the species used in the study, there were variations between genotypes for the same variable, as highlighted by plant height, number of panicle per unit area; such occurrence was justified due to the intrinsic characteristics of each genotype, such as height and yield potential. The justification adopted by the authors can be applied to this research, considering the different development patterns of plants of the URS Corona and URS Altiva cultivars, characteristics which are predetermined by the genotype, considering that variations were found, in averages, in the responses of the cultivars for the evaluated variables.

CONCLUSION

The application of trinexapac-ethyl at doses 100 and 150 g ha^{-1} reduces plant height and length, spikelet number and number of grains per panicle of URS Corona and URS Altiva cultivars.

TE doses above 100 g ha^{-1} caused a significant reduction in lodging, with a parallel increase in the number of panicle per unit area and in grain yield for the two white oat cultivars.

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