Trinexapac-ethyl alters the expression of descriptors for identifying white oat cultivars

O trinexapac-ethyl altera a expressão de descritores para identificação de cultivares de aveia-branca

El trinexapac-ethyl altera la expresión de descriptores para la identificación de cultivares de avena blanca

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Abstract
Trinexapac-ethyl reduces lodging in white oat, but its use in seed production fields requires knowledge of its impact on the expression of descriptors, under penalty of compromising the identification of cultivars. In this work, six white oat cultivars of different stature classes (Low: Brisasul and URS Taura; Medium: IPR Artemis; High: URS Altiva, URS Brava and URS 21) were evaluated for the state of expression of descriptors in response to the application of 100 g a.i ha^{-1} of trinexapac-ethyl when the primary stalk had the first visible node and the second perceptible node. Over two years, the experiments were carried out with different rainfall conditions (2017/2018), in a split-plot design, with three replications. The phenotypic variability in response to product application varied according to cultivar and year. Seven out of 23 descriptorschanged the state of expression in response to trinexapac-ethyl, in greater magnitude for plant length, followed by lemma length and panicle branching position, cycle, floral and glume axis lengths, and density of plants panicle. Trinexapac-ethyl reduced plant length, floral axis and glume, anticipated flowering, increased panicle density and lemma length. Regardless of year, the cultivars with the greatest phenotypic stability to the application of trinexapac-ethyl were Brisasul (96%) and Taura (91%), and the least stable was URS Altiva (83%). The stability of the other cultivars was yeardependent, with the greatest change in phenotypic expression in the year of lower water availability.
Keywords: *Avena sativa*; Phenotyping; Phenology; Morphology; Growth regulator.

Resumo
O trinexapac-ethyl reduz o acamamento em aveia-branca, mas seu uso em campos de produção de semente requer o conhecimento do seu impacto sobre a expressão de descritores, sob pena de comprometer a identificação de cultivares. Neste trabalho, seis cultivares de aveia-branca de distinta classe de estatura (Baixa: Brisasul e URS Taura; Média: IPR Artemis; Alta: URS Altiva, URS Brava e URS 21) foram avaliadas quanto ao estado de expressão de descritores em resposta à aplicação de 100 g i.a ha^{-1} de trinexapac-ethyl quando o colmo primário apresentava o primeiro nó visível e o segundo nó perceptível. Os experimentos foram conduzidos em dois anos com distinta condição pluviométrica (2017/2018), em delineamento de parcela subdividida, com três repetições. A variabilidade fenotípica em resposta à aplicação do produto variou conforme a cultivar e o ano. De 23 descritores, sete modificaram o estado de expressão em resposta ao trinexapac-ethyl, em maior magnitude para comprimento de planta, seguido do

comprimento do lema e posição das ramificações na panícula, ciclo, comprimentos de eixo floral e de gluma, e densidade de panícula. O trinexapac-ethyl reduziu comprimento de planta, eixo floral e gluma, antecipou o florescimento, aumentou densidade de panícula e o comprimento do lema. Independentemente de ano, as cultivares com maior estabilidade fenotípica à aplicação do trinexapac-ethyl, foi Brisasul (96%) e Taura (91%), e a menos estável foi URS Altiva (83%). A estabilidade das demais cultivares foi dependente do ano, com maior alteração de expressão fenotípica no ano de menor disponibilidade hídrica.
Palavras-chave: *Avena sativa*; Fenotipagem; Fenologia; Morfologia; Regulador de crescimento.

Resumen
El trinexapac-ethyl reduce el encamado en la avena blanca, pero su uso en los campos de producción de semillas requiere conocer su impacto en la expresión de los descriptores, so pena de comprometer la identificación de los cultivares. En este trabajo, seis cultivares de avena blanca de diferente clase de estatura (Baja: Brisasul y URS Taura; Media: IPR Artemis; Alta: URS Altiva, URS Brava y URS 21) fueron evaluados en cuanto al estado de expresión de los descriptores en respuesta a la aplicación de 100 g i.a ha^{-1} de trinexapac-ethyl cuando el tallo primario presentó el primer nudo visible y el segundo perceptible. Los experimentos se llevaron a cabo en dos años con distintas condiciones de lluvia (2017/2018), en diseño de parcela subdividida, con tres repeticiones. La variabilidad fenotípica en respuesta a la aplicación del producto varió según el cultivar y el año. De los 23 descriptores, siete modificaron el estado de expresión en respuesta al trinexapac-ethyl, en mayor magnitud para la longitud de la planta, seguida de la longitud del lema y la posición de las ramas en la panícula, el ciclo, las longitudes del eje floral y de las glumas, y la densidad de la panícula. Trinexapac-ethyl redujo la longitud de la planta, el eje floral y la gluma, anticipó la floración, aumentó la densidad de la panícula y la longitud de la lemma. Independientemente del año, los cultivares con mayor estabilidad fenotípica a la aplicación de Trinexapac-ethyl, fueron Brisasul (96%) y Taura (91%), y el menos estable fue URS Altiva (83%). La estabilidad de los otros cultivares dependía del año, con un mayor cambio en la expresión fenotípica en el año de menor disponibilidad de agua.
Palabras clave: *Avena sativa*; Fenotipado; Fenología; Morfología; Regulador de crecimiento.

1. Introduction

The production and quality of white oat grains can be limited by several factors, including lodging, which is determined by the action of strong winds and rain. As an alternative to control lodging is the use of growth regulators, which aim to reduce the longitudinal growth of the aerial part without harming productivity.

Among the four types of growth, regulators are trinexapac-ethyl (ethyl cyclopropyl (hydroxy) methylene-3,5-dioxocyclohexanecarboxylate). The compound is part of a group of dioxocyclohexanecarboxylic acids. Its action takes place in the late stages of the gibberellic acid formation, inhibiting the formation of highly active gibberellins from inactive precursors (Rademacher, 2000).

The result is a reduction of internodes elongation, reducing the height of the plants, which results in a lower risk of lodging in grain crops. In addition to the effect on this phenomenon, the use of growth reducers would be justified, more by the increase in productivity that they can cause, than by the control of lodging: the architectural changes that their use can cause in plants, due to the height reduction, can improve the capture of radiant energy, for example (Zagonel & Fernandes, 2007). Thus, the use of trinexapac-ethyl may include other benefits in addition to lodging control.

Trinexapac-ethyl is used in several species, such as sugarcane (*Saccharum officinarum* L.), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oats (*Aven*a spp.), triticale (x *Triticosecale* sp. Wittmack ex A. Camus 1927) and ryegrass (*Lolium multiflorum* Lam.). In sugar cane for seedling production, the product aims to accelerate the plant maturation process and the accumulation of sucrose in the stalk. However, in winter cereals, its application aims to reduce plant growth and strengthen internodes culm basalts to reduce the risk of tipping over (Zagonel et al., 2002).

It is known that the effect of trinexapac-ethyl varies according to environmental conditions (Matysiak, 2006; Bazzo et al., 2019), but there are still issues to be explored, such as the possible interaction of dose and cultivar. For example, the recommendation to use trinexapac-ethyl for wheat (100 to 125 g a.i ha^{-1}) does not take into account the height class of the cultivars, although there are reports that there is a differential response (Zagonel & Fernandes, 2007). Medium to small cultivars are less responsive to trinexapac-ethyl. However, they can maximise their grain yield by better leaf architecture and

radiation capture, by increasing the number of fertile tillers and by the most extensive direction of photoassimilates for production (Pagliosa et al., 2013). According to these questions, the aspects related to the effect of the product on the expression of descriptors used to protect cultivars have not been investigated yet, neither for white oat nor for other cultures.

In the case of white oat, to request the protection of cultivars, the breeder must inform the state expression of the descriptors of the material under analysis, according to the protocol of the Cultivar Protection Service (Brasil, 2002) for the tests of distinguishability, homogeneity and stability (DHS). In seed production fields, official inspections are carried out based on the species descriptors in order to verify the presence of atypical plants among plants of the same species, for example, plant length, cycle, type of panicle branching, pigmentation of the motto, leaf and stem hairiness (Brasil, 2011). In this context, if the use of a growth regulator compromises the identification of cultivars, production fields may be cancelled if the presence of atypical plants above the maximum number allowed is found.

Thus, this work aimed to evaluate whether the trinexapac-ethyl growth regulator alters the expression of descriptors of *Avena* spp., and explore its influence on characters measured linearly, considering cultivars of different height classes in years with different rainfall.

2. Methodology

Concerning the objective, this research is classified as descriptive-explanatory, since the effect of trinexapac-ethyl on white oats descriptors is characterized and compared through experimental procedures in the field. In terms of nature, it is classified as quantitative (Silveira & Córdova, 2009).

Six white oat cultivars were used in this study to contemplate different height classes: a) short: Brisasul and URS Taura; b) medium: cv. Artemis IPR; c) high: cvs. URS Altiva, URS Brava and URS 21 (Oliveira et al, 2011; Federizzi et al., 2015; Nava et al, 2016). Regarding the cycle, two are medium cycle (Artemis and Brisasul) and the others are precocious. The effect of trinexapac-ethyl was tested (a) with product applicationand (b) without product application (control). The experiment consisted of a 6 (cultivar) x 2 (trinexapac-ethyl, TE) bifactorial scheme, whose factors and levels were allocated in a split-plot (main plot: TE; subplot: cultivar); the main plot was distributed in a randomised block design, with three replications, and the subplot was completely randomised. The experimental units consisted of 5 m x 1 m plots containing five lines spaced 0.17 m apart.

The experiments were carried out over two agricultural years (June-November/2017; May-November/2018), in Passo Fundo (28° 15' south, and 52° 24' west, and altitude of ~700 m). The climate is subtropical Cfa, with an average annual temperature of 22 ℃ (Kuinchtner & Burial, 2001). For the 2017 experimental period, the average temperature was above normal, while rainfall was below regular; during the following year, the temperature was close to normal, but the total precipitation was above the historical series for May to November (Table 1).

Table 1 - Total rainfall and average monthly temperature of the experimental period in 2017 and 2018, compared to normal for Passo Fundo-RS

Month	Year 2017	Year 2018	Normal
		Precipitation (mm)	
May	-	88.6	114.3
June	214.0	200.5	133.6
July	21.3	107.5	161.8
August	166.7	120.8	184.8
September	85.5	305.5	197.7
October	276.2	319.5	152.9
November	182.0	211.6	131.7
Total	945.7	1354.0	1079.8
		Average temperature (ºC)	
May	-	15.5	15.2
June	13.4	11.7	12.9
July	13.6	13.5	13.3
August	15.0	11.9	13.9
September	19.4	16.5	15.7
October	17.8	17.8	17.6
November	19.2	20.9	19.6
Average	16.4	15.4	15.5

Source: Embrapa Trigo.

The soil in which the experiments were established is humic dystrophic Red Latosol type. In the samples collected in the 0 to 10 cm layer, it was found: clay = 39.5%; pH in H_2O = 5.0; SMP index = 5.5; P = 25.5 mg dm^{-3}; K = 286 mg dm^{-3}; organic matter = 3.3%; Ca = 4.6 cmol dm^{-3}; Mg = 1.4 cmol dm^{-3}; H + Al = 7.7 cmol dm^{-3}; CTC = 14.4 cmol dm^{-3}; base saturation = 46%; Al saturation = 9%; K saturation = 5.1%; b) 2018: clay = 40.7%; pH in H_2O = 5.0; SMP index = 5.6; P = 40.0 mg dm^{-3} K = 362 mg dm^{-3}; organic matter = 3.0%; Ca = 3.6 cmol dm^{-3}; Mg = 1.5 cmol dm^{-3}; H + Al = 6.9 cmol dm^{-3}; CTC = 12.9 cmol dm^{-3}; base saturation = 46%; Al saturation = 8%; K saturation = 7.2%. Over the two years of the experiment, 200 kg ha^{-1} of the 5-20-20 formulation of N-P_2O_5-K_2O was applied at sowing. Nitrogen was surface applied as urea (67 kg N ha^{-1}), half in tiller and half in stem elongation.

Sowing was mechanised with 300 suitable seeds m-2 in 6/21/2017 and 5/29/2018. During the crop cycle, chemical control of weeds, pests, and diseases was carried outfollowing crop recommendations. Trinexapac-ethyl was applied at a dose of 100 g a.i ha^{-1} (400 mL ha^{-1} Moddus 250 EC®) in the elongation stage of the culture, when the first node of the main stalk was visible and the second node was noticeable (Espindula et al., 2009; Espindula et al., 2010; Grijalva-Contreras et al., 2012). In 2017, this occurred in 8/23 (URS Altiva), 8/30 (Brisasul, URS Brava and URS Taura) and 4/9 (IPR Artemis and URS 21); during the following year, the applications were in 11/8 for cv. URS Altiva, and in 8/16 for the other cultivars. The application was carried out with a back spray, with a spray volume of 200 L ha^{-1}.

Phenotypic evaluations were performed following the protocol for DHS assays for *Avena* spp. (Brasil, 2002) and carried out in ten plants per plot so that each treatment was evaluated according to the phenotypic expression of thirty plants. Plants were randomly chosen and identified with coloured string from the beginning to the end of the crop cycle. Among the total descriptors for *Avena* spp., habit and hairiness of the lower leaf sheath were not examined as these characters must be evaluated in the tillering stage, which is before the beginning of elongation of the stalk when the growth regulator is applied. Thus, the expression of the state of the following descriptors was verified: hairiness of the edges of the blade immediately below the flag-leaf, frequency of plants with curved flag-leaf, position of the flag-leaf, cycle (first spikelet visible in 50% of the panicles), hairiness and hairiness intensity of the upper node, position and orientation of branches in the panicle, panicle density, spikelet position, glume length, lemma waxiness, plant and floral axis length, glume shape, hairiness of the glume,

presence/absence of bark, hairiness at the base of the grain, length of the grains' basal hairs, length of rachilla and lemma, motto colour, tendency to aerist and type of edge.

In the case of characters measured before classification into categories, the protocol (Brasil, 2002) establishes criteria for panicle density, floral axis length and plant length. Panicle density varies according to the internode length (IL) of the floral axis: low (IL>3.5 cm), medium (IL = 2.5-3.5 cm) or high (IL<2.5 cm cm); the plant length, according to the sum of stem and panicle, is classified as very short (<70 cm), short (70 to 90 cm), medium (90 to 110 cm), long (110 to 130 cm) or too long (>130 cm). For the floral axis, the protocol establishes: short (<10 cm), medium (15 cm) and long (>20 cm); therefore, in this work, in the "medium" category, the length of 10 to 20 cm was established. For cycle, glume and lemma length, due to the lack of scale of values in the official protocol, the following was adopted: a) cycle (days between emergence and emission of 50% of panicles): early (<80 d), medium (80 to 90 d) and late (>90 d); b) lemma: very short (<10 mm), short (10 to 13 mm), medium (>13 to 16 mm), long (>16 to 19 mm) and very long (>19 mm); c) glume: short (<20 mm), medium (20 to 22 mm) and long (>22 mm).

The multicategorical data related to the descriptors of *Avena* spp. were submitted to the determination of the mode. For the descriptors quantitatively evaluated before classification (plant length and floral axis, and panicle density), analysis of variance was performed, with the unfolding of the growth regulator interaction (RC)*cultivar (CUL). According to the recommendation of Perecin and Cargnelutti Filho (2008), a less rigorous significance level ($p = 0.25$) of the F test was used for the interpretation of the TE*CUL interaction "by experiment"; in this case, when a significant interaction was found ($p \leq 0.25$), the split was carried out, keeping the usual $p = 0.05$ for interpretation of the "by comparison" effect. Then, the means were compared by Tukey test ($p < 0.05$).

3. Results

State of expression of descriptors in response to trinexapac-ethyl

Cultivars were monomorphic for 12 descriptors, regardless of whether they were subjected to application of the trinexapac-ethyl (TE) or not, and presented, both in 2017 and 2018: 1) absence or very weak hairiness of the blade edges immediately below the flag leaf, 2) presence of hairiness in the upper node of the stalk, 3) decumbent spikelets, 4) absence of waxy in the lemma, 5) pointed glume, 6) absence of hairiness in the glume, 7) presence of husk in the grain, 8) grain with short basal hairs, 9) short rachilla, 10) yellow lemma, and 11) absence or very low tendency to enlistment; in 2017, the length of the floral axis was medium (between 10 and 20 cm), and in 2018, it became long (>20 cm) for all cultivars. The cultivars showed variability among themselves for 11 out of 23 descriptors. Among the 25 descriptors of *Avena* spp., two of them were not evaluated: intensity of waxiness of the lemma, due to the absence of waxiness, and type of edge, due to the tendency of the awning absence or very low.

For seven out of 23 descriptors, considering 2017 and 2018, there was a growth regulator effect: 1) cycle, 2) plant length, 3) floral axis length, 4) lemma length, 5) branch position in the panicle, 6) panicle density and 7) glume length. The first five showed some phenotypic modification to the application of TE in the two years, whereas panicle density was only changed in 2017 and the glume length in 2018 (Table 2). Thus, there was 74% stability of descriptors each year in response to the TE.

Table 2 - Expression status of white oat cultivars of different height classes and percentage change in relation to cycle, plant length, floral axis (FA), glume (GL) and lemma, panicle density (PD) and branching position in the panicle (PRP) according to the use (WGR) or not (0-GR) of the trinexapac-ethyl growth regulator (GR) in the years 2017 and 2018. Passo Fundo-RS, 2017/18

Cultivars[1]	GR	Cycle[2]	Plant[2]	FA[4]	GL[4]	Lemma[4]	PD[5]	BPP[6]	Change (%)
					Year 2017				
Brisasul	0-GR	M	S	M	S	L	H	SE	14.3
	WGR	M	VS	M	S	L	H	SE	
URS Taura	0-GR	M	VS	M	S	L	M	SD	28.6
	WGR	M	VS	M	S	L	H	SE	
IPR Artemis	0-GR	M	S	M	L	L	M	SE	42.9
	WGR	M	VS	M	L	VL	H	SE	
URS Altiva	0-GR	M	S	L	M	L	H	H	42.9
	WGR	M	VS	M	M	VL	H	SE	
URS Brava	0-GR	M	S	M	M	L	M	SD	57.2
	WGR	L	VS	M	M	L	H	SE	
URS 21	0-GR	M	S	M	M	L	H	H	28.6
	WGR	M	VS	M	M	L	H	SE	
Alteration (%)		16,6	83,3	16,6	0	33,3	50,0	66,6	
					Year 2018				
Brisasul	0-GR	L	M	L	M	S	M	SD	14.3
	WGR	L	M	L	S	S	M	SD	
URS Taura	0-GR	L	M	L	M	M	M	SD	28.6
	WGR	L	S	L	S	M	M	SD	
IPR Artemis	0-GR	L	M	M	L	L	M	SD	14.3
	WGR	L	M	M	L	L	M	H	
URS Altiva	0-GR	M	L	L	M	S	M	SD	57.2
	WGR	L	M	L	M	M	M	H	
URS Brava	0-GR	L	L	L	M	S	M	SD	42.9
	WGR	L	M	M	M	M	M	SD	
URS 21	0-GR	M	M	L	M	M	M	SD	14.3
	WGR	L	M	L	M	M	M	SD	
Alteration (%)		33.3	50.0	16.6	33.3	33.3	0	33.3	

[1]Low: Brisasul e URS Taura; Medium: IPR Artemis; High: URS Altiva, URS Brava e URS 21. [2]Cycle: medium (M); late (L); [3]Very Short (VS); Short (S); medium (M); long (L); [4]Short (S); medium (M); long (L); very long (VL); [5]High (H); medium (M); low (L); [6]Semi-erect (SE); semi-decumbent (SD); horizontal (H). Source: Authors.

From another perspective, the oat cultivars showed different levels of variability. The short stature class cultivars were the least unstable, especially cv. Brisasul, as both in 2017 and 2018, this cultivar showed changes in only one descriptor (Table 2); the cv. URS Taura changed two descriptors in both years. The opposite was found in two cultivars of the tall stature class (URS Altiva and URS Brava), which had changed in three or four out of seven descriptors, depending on the experimental year; on the other hand, cv. URS 21, which belongs to this class, stood out for its high phenotypic stability (Table 2, Figure 1). The cv. IPR Artemis (average height class) was at an intermediate level, compared to cv., but in the year with the lowest rainfall, was similar to cv. URS Altiva.

Figure 1 - Annual and average phenotypic stability of white oat (*A. sativa*) cultivars of different stature classes (Low: Brisasul and URS Taura; Medium: IPR Artemis; High: URS Altiva, URS Brava and URS 21) to the application of the trinexapac-ethyl growth regulator, according to the state of expression of 23 descriptors for *Avena* spp. Passo Fundo-RS, 2017/18.
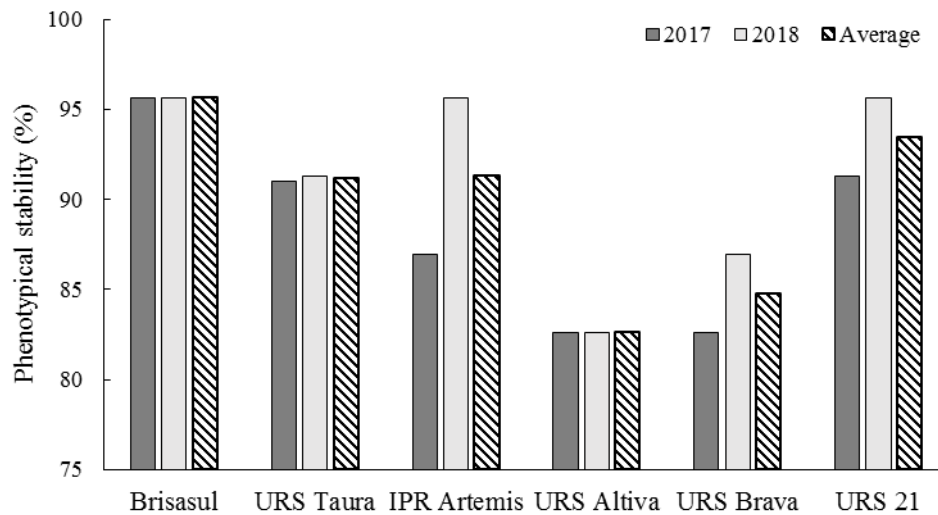
Source: Authors.

In 2017, TE did not affect the state of expression of glume length, opositelly to what occurred in the following year; the reverse was observed for panicle density. Also, comparing the two years, in 2017, there was the highest percentage of change in plant length, panicle density and position of branches in the panicle; in 2018, more changes were observed in cycle and glume length, in which there was a change in two cultivars for these characters (33.3%). For floral axis and lemma length, there was an equal percentage of change in the two years. In general, the descriptor that showed the highest percentage of change was plant length, reaching 83.3% of cultivars in 2017, and 50% in the following year.

The plant length was predominantly "short" in 2017 and "medium" in 2018; however, in both years, the use of TE reduced the longitudinal growth of plants. Thus, in 2017, five oat of six cultivars became "very short"; only the cv. URS Taura showed this state of expression, regardless the use or not of the growth regulator. In 2018, the plants showed greater length, and most cultivars were classified as "medium", with no evidence of "very short" status. With the use of TE, a shortening of the plant length was observed in 50% of the cultivars, which changed to the "short" category (URS Taura) or, from "long" to "medium" (URS Altiva and URS Brava). That year, three of them did not vary to the application of the growth regulator in this regard, remaining in the "medium" category (Brisasul, IPR Artemis and URS 21).

Analogous to plant length, the floral axis was mainly "medium" in 2017, and "long" in the following year. However, there was a change in only one cultivar each year in response to the TE: in 2017, cv. URS Altiva, and in 2018, cv. URS Brava, showed shortening of the floral axis. Panicle density was hegemonically "average" in 2018, unaffected by growth regulator treatment. However, 50% of the cultivars varied from "medium" to "high" in the previous year, as they shortened their internodes in response to trinexapac-ethyl: URS Taura, IPR Artemis and URS 21. The other cultivars remained in the "high" category, regardless of the product usage (Table 2). The branches position in the panicle was modified in (66.6%) cultivars in 2017 and in two cultivars (33.3%) in the following year (Table 2). In 2017, the use of the growth regulator changed the expression status of this character, from "semi-decumbent" (URS Taura and URS Brava) and "horizontal" (URS Altiva and URS 21) to "semi-upright". In the following year, two cultivars showed a response to the product, changing the position of the branches from "semi-decumbent" to "horizontal" (IPR Artemis and URS Altiva).

For the glume length, in 2017, it was invariant to the use of the TE, noting three types of expression (medium, short and long); however, in the following year, this descriptor varied according to the lodging management, as two cultivars showed shorter length (Brisasul and URS Taura) to the application of the growth regulator (Table 2). Differently from the previous year, there was a higher prevalence of the length "medium." The lemma length was mainly long in 2017 when two cultivars became "very long" in response to the growth regulator (IPR Artemis and URS Altiva). In the following year, most cultivars showed lemma short or medium; in this occasion, the two out of three cultivars with short lemma (URS Altiva and URS Brava) became "medium" due to the use of trinexapac-ethyl.

On the other hand, the percentage of cultivars that showed cycle change in response to TE ranged from 16.6 to 33.3%, also varying the category according to the year: in 2017, most cultivars had an average cycle, regardless of the application or not of the growth regulator, as only cv. URS Brava became "late" under the action of the product. Opositelly, in 2018 the cultivars' behavior was predominantly "late", except for URS Altiva and URS 21, which only under the effect of TE went from "medium" to "late" cycle (Table 2).

Considering the response of the cultivars to the growth regulator of the 23 descriptors of *Avena* spp., in the two years there was, on average, 89% of stability (Figure 1). The cultivar with the greatest phenotypic stability (96%) in relation to the growth regulator was Brisasul, as it had expression variation in only one descriptor in each year. On the contrary, cv. URS Altiva was the least stable (83%), as the expression status varied in four descriptors in the two years of the experiment. According to the year, the other cultivars oscillated in stability: instability. IPR Artemis was the most affected cultivar by the year, as it had less stability (87%) in 2017 compared to 2018 (96%).

Effect of trinexapac-ethyl on quantitative characters

The characters evaluated linearly by measuring the length of flowering structures, such as lemma, glume, floral axis and internode of the floral axis (panicle density) and plant, were submitted to ANOVA. The F test showed a significant effect ($p<0.05$) of the cultivar (CUL) for these five descriptors in the two years of study (Tables 3 and 5); for the data obtained in 2017, there was a significant effect ($p<0.05$) of RC for floral axis length, panicle density and plant length (Table 3). For these three characters (Table 3) and lemma length (Table 5), the TE*CUL interaction was also significant ($p \leq 0.25$). On the other hand, for the data obtained in 2018, there was a significant effect of this interaction only for glume and lemma length (Table 5).

Table 3 - Summary of analysis of variance (MS - Mean square) and unfolding of growth regulator interaction (GR)*Cultivars (CUL) for floral axis length (FAL), panicle density (PD) and plant length (PL) of white oat (*A. sativa*) cultivars in the 2017 and 2018 experiments. Passo Fundo-RS, 2017-2018.

SV[1]	DF[2]	FAL (cm)		PD (cm)		PL (cm)	
		MS	Pr>F	MS	Pr>F	MS	Pr>F
Year 2017							
Regulator (GR)[3]	1	59.06	0.0269*	0.78	0.0350*	7195.84	0.0022*
Cultivars (CUL)[4]	5	4.62	0.0054*	0.08	0.0100*	175.44	0.0000*
GR*CUL	5	3.27	0.0242*	0.03	0.2290*	61.43	0.0079*
GR/cv. URS Altiva	1	32.11	0.0000*	0.09	0.0402*	812.47	0.0000*
GR/cv. IPR Artemis	1	4.20	0.0522 ns	0.02	0.3121 ns	947.77	0.0000*
GR/cv. URS Brava	1	7.73	0.0110*	0.14	0.0154*	1750.35	0.0000*
GR/cv. Brisasul	1	1.98	0.1713 ns	0.06	0.1057 ns	1084.07	0.0000*
GR/cv. URS Taura	1	3.28	0.0828 ns	0.42	0.0002*	735.49	0.0000*
GR/cv. URS 21	1	26.08	0.0000*	0.19	0.0055*	2172.84	0.0000*
CUL/With GR	5	1.60	0.1970 ns	0.05	0.0611 ns	59.58	0.0090*
CUL/Without GR	5	6.27	0.0011*	0.06	0.0349*	177.30	0.0000*
Average		16.25		2.32		60.97	
CV$_1$%[5]		7.91		7.37		6.56	
CV$_2$%[6]		6.11		6.12		6.19	
Year 2018							
Regulator (GR)[3]	1	0.59	0.5093 ns	0.00	0.9199 ns	226.75	0.0846 ns
Cultivar (CUL)[4]	5	5.82	0.0072*	0.29	0.0100*	46.74	0.0014*
GR*CUL	5	1.75	0.2914 ns	0.05	0.6572 ns	20.83	0.7627 ns
Average		20.58		2.84		104.91	
CV$_1$%[5]		4.72		10.34		10.38	
CV$_2$%[6]		5.58		9.21		6.07	

[1]SV = sources of variation; [2]DF = degress of freedom; [3]Regulator = growth regulador trinexapac-ethyl (GR) [4]CUL = oat cultivars; [5]CV$_1$ = coefficient of variation for installment; [6]CV$_2$ = coefficient of variation for subplot. *Significant at 25% for average interacton GR*CUL and at 5% for de effect of GR and CUL and interaction unfolding RG*CUL. Source: Authors.

In 2017, the cultivars showed similarity (p>0.05) regarding the length of the floral axis (rachis) to the application of trinexapac-ethyl, contrary to what was observed in the absence of the product (Table 4). On average, the floral axis was 14.3% smaller in the treatment with TE compared to that obtained without the product. Thus, in the absence of the growth regulator, the tall stature class cultivars (URS Altiva, URS Brava and URS 21) showed similarity; the cv. URS Altiva was the only one to distinguish itself from short and medium height cultivars, exhibiting a longer floral axis, between 16 and 19.5%. In another measure, there was a significant difference between the TE treatments only for the tall cultivars; in the other cultivars, the floral axis length did not change (p>0.05) with the application of the growth regulator. In this sense, the reduction of panicle rachis ranged from 6.5 to 23.3%, in which the tall stature class cultivars presented a reduction between 12.8 (URS Brava) and 23.3% (URS 21).

Table 4 - Response of white oat (*A. sativa*) cultivars of different height classes to the application of trinexapac-ethyl (WGR) growth regulator and absence of this practice (0-RG) in relation to floral axis length, density panicle and plant length, with respective reduction. Passo Fundo-RS, 2017/18.

Cultivars[1]	FA (cm)			Density panicle (cm internode $^{-1}$)			Plant (cm)		
	0-GR	WGR	Red (%)	0-GR	WGR	Red (%)	0-GR	WGR	Red (%)
				Ano 2017					
Brisasul	16.8 Ab	15.7 Aa	6.5	2.3 Aa	2.1 Bab	8.7	73.2 Ab	46.3 Bab	36.7
URS Taura	16.4 Ab	15.0 Aa	8.5	2.7 Aa	2.2 Bab	18.5	62.9 Ac	40.8 Bb	35.1
IPR Artemis	16.1 Ab	14.4 Aa	10.6	2.5 Aab	2.4 Aa	4.0	72.6 Abc	47.5 Bab	34.6
URS Altiva	20.0 Aa	15.4 Ba	23.0	2.4 Aab	2.1 Bab	12.5	75.5 Ab	52.3 Ba	30.7
URS Brava	17.9 Aab	15.6 Ba	12.8	2.5 Aab	2.2 Bab	12.0	85.3 Aa	51.1 Ba	40.1
URS 21	18.0 Aab	13.8 Ba	23.3	2.4 Aab	2.0 Bb	16.7	81.0 Aab	42.3 Bab	47.8

[1]Low: Brisasul e URS Taura; Medium: IPR Artmemis; High: URS Altiva, URS Brava and URS 21. Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ by Tukey's test ($p<0.05$). Source: Authors.

Table 5 - Summary of analysis of variance (MS - Mean square) and unfolding of growth regulator interaction (GR)*Cultivar (CUL) for glume length and lemma of white oat (*A. sativa*) cultivars in 2017 and 2018. Passo Fundo-RS, 2017-2018.

SV[1]	DF[2]	Glume (mm)		Lemma (mm)	
		MS	Pr>F	MS	Pr>F
Year 2017					
Regulator (GR)[3]	1	0.95	0.3941 ns	7.12	0.1110 ns
Cultivars (CUL)[4]	5	21.52	0.0000*	3.71	0.0003*
GR*CUL	5	0.29	0.6960 ns	1.21	0.0612*
GR/cv. URS Altiva	1	4.13	0.0081	4.13	0.0081*
GR/cv. IPR Artemis	1	3.11	0.0191	3.11	0.0191*
GR/cv. URS Brava	1	1.72	0.0719	1.72	0.0719 ns
GR/cv. URS Brisasul	1	1.72	0.0727	1.72	0.0727 ns
GR/cv. URS Taura	1	1.39	0.1036	1.39	0.1036 ns
GR/cv. URS 21	1	1.14	0.1392	1.14	0.1392 ns
CUL/With GR	5	8.76	0.0000	3.54	0.0004*
CUL/Without GR	5	13.05	0.0000	1.39	0.0394*
Average		20.97		18.20	
CV$_1$%[5]		4.32		5.34	
CV$_2$%[6]		3.33		3.80	
Year 2018					
Regulator (GR)[3]	1	0.64	0.6749	2.65	0.1619 ns
Cultivars (CUL)[4]	5	9.82	0.0000*	11.73	0.0000*
GR*CUL	5	0.45	0.2132*	0.86	0.1367*
GR/cv. URS Altiva	1	0.00	0.9280 ns	0.81	0.1936 ns
GR/cv. IPR Artemis	1	0.13	0.4956 ns	0.28	0.4380 ns
GR/cv. URS Brava	1	0.10	0.5586 ns	1.65	0.0695 ns
GR/cv. Brisasul	1	1.36	0.0413*	0.05	0.7277 ns
GR/cv. URS Taura	1	1.00	0.0753 ns	0.00	0.9425 ns
GR/cv. URS 21	1	0.28	0.3333 ns	4.13	0.0066*
CUL/ With GR	5	6.66	0.0000*	5.20	0.0000*
CUL/ Without GR	5	3.07	0.0000*	7.38	0.0000*
Average		21.16		13.86	
CV$_1$%[5]		7.79		5.39	
CV$_2$%[6]		2.53		4.84	

[1] SV = sources of variation; [2]DF = degrees of freedom; [3]Regulator = trinexapac-ethyl (GR) growth regulator; [4]CUL = oat cultivars; [5]CV$_1$ = coefficient of variation for the plot; [6]CV$_2$ = coefficient of variation for subplot. *Significant at 25% for average GR*CULT interaction and 5% for GR and CULT effects and for GR*CUL interaction unfolding. Source: Authors.

Conversely to the floral axis length, the cultivars varied among themselves in panicle density only under TE application (Table 4). On average, the shortening of the spinal internodes, which determines greater or lesser panicle density, was 12% with the application of the growth regulator. However, only two cultivars showed a difference (p<0.05) between this character using TE: panicle density of cv. URS 21 (2.0 cm) was about 17% higher than cv. Artemis IPR (2.4 cm). The other cultivars were similar among themselves and in relation to these two cultivars. In all cultivars, except for cv. IPR Artemis, trinexapac-ethyl significantly increased (p<0.05) panicle density, reaching a maximum of 18.5% increase in cv. URS Taura.

The most significant impact of the growth regulator wason plant length, which showed an average reduction of 38% in relation to the situation in which the product was not applied (Table 4). For this aspect, the cultivars showed variation among themselves according to the use or not of the TE: without the application of the TE, the cultivars of the tall stature class exhibited longer plants, particularly cv. URS Brava which differed (p<0.05) from four cultivars, showing similarity only to cv. URS 21. With the use of the growth regulator, five cultivars were similar, including cv. URS Brava; in this case, this cultivar only differed from the cultivar that showed the smallest plant length (URS Taura). The greatest reduction in plant length in response to TE occurred in cv. URS 21, with 48% (Table 4); otherwise, the smallest impact of the product was on cv. URS Altiva (30.7%).

In terms of effect on spikelet structures, in 2018, there was an effect of lodging management on glume length, whereas in the two years, this occurred for the lemma (Table 6). As opposed to what was observed for plant and panicle (axis and density), the growth regulator increased or reduced the length of the lemma and glume, depending on the cultivar. In the case of the lemma, the cultivars showed variation among themselves only under the use of TE, without difference in the absence of the product, with emphasis on the cultivars with greater (IPR Artemis) and smaller (URS 21) length, as they differed ($p<0.05$) from three other cultivars. In another aspect, only IPR Artemis and URS Altiva expressed significant variation in the lemma, with elongation between 7.4 and 9.5%, respectively, compared to the values presented without the TE. Only cv. URS 21 showed an abbreviation in the lemma (-4.4%) when using the product, which did not differ from the control.

Table 6 - Response of white oat (*A. sativa*) cultivars of different height classes to the application of trinexapac-ethyl (WGR) growth regulator and absence of this practice (0-GR) in relation to lemma and glume length, with respective change, in the years 2017 and 2018. Passo Fundo-RS, 2017/18.

Cultivars[1]	Glume (mm)			Lemma (mm)		
	0-GR	WGR	Change (%)	0-GR	WGR	Change (%)
Year 2017						
Brisasul	19.5 Ac	19.5 Abc	0.0	17.1 A	18.1 Abc	+5.8
URS Taura	19.4 Ac	19.2 Ac	-1.0	17.0 A	17.9 Abc	+5.3
IPR Artemis	25.0 Aa	24.0 Aa	-4.0	18.8 B	20.2 Aa	+7.4
URS Altiva	21.5 Ab	21.0 Ab	-2.3	17.8 B	19.5 Aab	+9.5
URS Brava	20.9 Abc	20.8 Abc	-0.5	17.8 A	18.8 Aabc	+5.6
URS 21	20.5 Abc	20.2 Abc	-1.5	18.1 A	17.3 Ac	-4.4
Year 2018						
Brisasul	20.4 Ab	19.5 Bd	-4.4	12.5 Ab	12.2 Ac	-2.4
URS Taura	20.6 Ab	19.8 Acd	-3.9	13.6 Ab	13.6 Abc	0.0
IPR Artemis	23.2 Aa	23.5 Aa	+1.3	16.6 Aa	16.2 Aa	-2.4
URS Altiva	21.0 Ab	21.1 Abc	+0.5	12.7 Ab	13.4 Ac	+5.5
URS Brava	21.7 Ab	22.0 Ab	+1.4	12.6 Ab	13.6 Abc	+7.9
URS 21	20.8 Ab	20.4 Acd	-1.9	13.6 Bb	15.3 Aab	+12.5

[1]Low: Brisasul e URS Taura; Medium: IPR Artemis; High: URS Altiva, URS Brava and URS 21. Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ by Tukey's test ($p<0.05$). Source: Authors.

In 2018, the impact of TE was especially evident on this cultivar, which showed 12.5% of elongation in the lemma in relation to the treatment without application of the product; that year, cv. URS 21 was the only one that showed a significant response to the growth regulator for this attribute ($p>0.05$) (Table 6). Trinexapac-ethyl had little effect on glume length, demonstrated only in 2018 when cv. Brisasul expressed a 4.4% reduction compared to the absence of the product (Table 6). In both years and treatments with TE, cv. IPR Artemis exhibited the most extended glume length, as the two short stature class cultivars had the smallest values.

4. Discussion

In this study, the hypothesis that the expression of descriptors for application for the protection of white oat cultivars (Brazil, 2002) can be modified with trinexapac-ethyl (TE) to a greater or lesser degree, depending on the cultivar, was confirmed. This interaction can also be affected by the environment, more specifically, by the rainfall regime. In fact, following the cultivar evaluation protocol adopted in Brazil (2002), the results showed different levels of (in)stability between cultivars under the effect of the growth regulator in question. This information was unknown in the literature, including for other crops, since the works carried out with TE, mainly in cereals, has been prioritised aspects related to lodging, yield and

grain quality (Kaspary et al, 2015; Bazzo et al, 2019), without identifying possible changes in species descriptors.

Trinexapac-ethyl is primarily concerned the plant height reduction. According to studies carried out in wheat, medium and small cultivars are less responsive to the product, requiring a reduction in the product dose (Zagonel & Fernandes, 2007; Pagliosa et al, 2013). For this reason, in this study, cultivars belonging to different height classes were tested, and to obtain greater reliability of results, the tests were carried out in two consecutive years, 2017 and 2018, as the action of the TE can be modified by environmental factors (Matysiak, 2006; Bazzo et al, 2019).

However, the same cultural management was maintained, and sowing took place in the same soil type and relief, in accordance with the standardisation of procedures for collecting, measuring and analysing data. Fortunately, the rainfall regime differed in the two years of experiments, which provides greater scope to the study's conclusions. Rainfalls were below average in 2017, but in 2018 they exceeded the historical series (30 years) in 25% average (Table 1).

When genotype x environment interaction results from unpredictable variations in environmental factors, such as year-to-year variation in rainfall distribution, breeders need to develop stable cultivars that can perform reasonably well under a range of environmental conditions (Singh et al., 2019). Although this desired stability is relative to productivity, it is equally important that this extends to morphoagronomic descriptors.

In genetic resources, descriptors are measurable attributes, characteristics or peculiarities observed in accession of a genetic bank, which do not need to be highly heritable. The descriptors are part of a process regulated by national and international bodies, following the International Union's recommendations for the Protection of New Varieties of Plants (UPOV). It is a phenotyping process, which includes qualitative and quantitative assessments.

Most characters of *Avena* spp. (Brasil, 2002) are evaluated by observation, based on the evaluator's judgment, but other characters are measured by linear scale measure other characters. However, all descriptors are expressed by codes, in nominal and ordinal scale, configuring multi categorical variables, including binary (presence/absence). Each descriptor has an expression state, which represents the variation in the observations or measurements performed, to which a corresponding numeric code is allocated. To obtain more information about the influence of trinexapac-ethyl in oats, it was decided to carry out the analysis of variance, followed by a comparison of means, in addition to descriptive approach (Brasil, 2002).

In this study, in only seven out of 23 (30%) multi categorical characters used to describe *Avena* spp. (Brasil, 2002; UPOV, 1994) there was an alteration in the state of expression using the growth regulator (Table 2). The results are especially consistent for five of them: cycle, plant length, floral axis, lemma, and position of branches in the panicle, since the expression state changes occurred in the two years of the experiment. The other descriptors (glume length and panicle density) showed variation to the application of trinexapac-ethyl only in one of the years: panicle density in 2017 and glume length in 2018. Thus, the descriptors reflect not just the cultivar genetic constitution but also the interaction of the genotypes with the environment in which it is expressed (Lin & Bins, 1984). Therefore, identifying stable genotypes under a wide range of agroclimatic conditions is of special significance for genetic improvement (Singh et al, 2019).

In this study, most descriptors did not vary with the factors tested, which is highly positive, mainly because they were obtained under different rainfall conditions. On the other hand, the characters that showed some variation in the state of expression are related to the regulation of processes mediated by gibberellins, such as flowering, internode elongation, leaf growth and apical dominance.

Trinexapax-ethyl is a plant growth retardant that acts on the synthesis of gibberellic acid, which reduces the elongation of the internodes and, thus, the longitudinal growth of the plant (Rademacher, 2000; Espindula et al., 2010). This was proven in this study, both by the qualitative perspective (Table 2) and by the quantitative approach (Tables 4 and 5): through the method adopted by MAPA (Brazil, 2002), according to UPOV guidelines (1994), the plant length was the character with the highest frequency of alteration in the state of expression (Table 2), even more in the year with water

restriction (2017), when five out of six cultivars changed category due to the shorter length of stem+panicle under the action of TE. Such impact was especially detected when verifying the high mean square of the TE*CUL interaction (Table 3) and the magnitude of plant length reduction in all cultivars (30 to 48%) (Table 4).

Thus, the adoption of analysis of variance and means comparison by Tukey test reinforce the impact of this growth regulator in modifying this important descriptor of oat cultivars. The data corroborate the results of other studies, in which the reduction in oat height reached levels above 50%, but with r doses higher (150 to 175 g a.i ha^{-1}) than the used here (100 g a.i ha^{-1}) (Guerreiro & Oliveira, 2012; Kaspary et al., 2015).

Even in the year in which there was water surplus (2018), half of the cultivars showed variation in the category of plant length when applying the product (Table 2), but without significance ($p > 0.05$). Furthermore, the action of TE is admittedly dependent on environmental conditions: in wheat, Matysiak (2006) found greater shortening of plants with the application of TE in the year in which there was water restriction. The intensity of the reduction in lodging in response to the product can be exacerbated under water deficit, as both conditions reduce plant growth. In fact, unless the decrease in water availability does not occur in the days following the product application, which would make its absorption difficult, droughts limit plant growth, exacerbating the effect of the product as a reduction in canopy height.

In this sense, it was found that, in the average of cultivar and management, plants with smaller height were obtained in 2017, as well as with smaller length of floral axis and gluma. In other crops, such as wheat and corn, there are reports of a distinct response to trinexapac-ethyl depending on cultivar, management and environmental factors (Penckowski et al., 2009; Mendes et al., 2018).

In addition to the effect most commonly reported as a response to the product, which is plant shortening, trinexapac-ethyl was shown to be a potential reductor in the elongation of other structures, such as glume, floral axis and floral axis internodes (Tables 2, 4 and 6), but in lower frequency and magnitude among cultivars. In the case of internodes of the floral axis (rachis), their shortening reflects an increase in panicle density (cm internode^{-1}), resulting in more or less dense panicles (Table 2). In this study, data were used in the nominal form (Table 2) and also quantitative in order to explore the effect of TE on this attribute. Thus, it can be seen that the change in panicle density class under the effect of the product from "medium" to "high", occurred in three cultivars (URS Taura, URS Altiva and URS 21), can be detected in another measure when examined by ANOVA (Table 3) and means comparison (Table 4).

According to Perecin and Cargnelutti Filho (2008), when performing routine analysis of variance, the F statistic tests the mean interaction or pooled; it can be said that it is a test of experiment interaction of. Therefore, the authors suggest the use of a less rigorous significance level ($p = 0.25$), keeping the usual $p = 0.05$ for effects comparison, in order to explore interactions between factors. From this perspective, it was found that trinexapac-ethyl significantly affected ($p < 0.05$) panicle density in five cultivars (Table 4). There was no nominal change of expression state (Table 2) coinciding with this result because except for cv. URS Taura, all other cultivars exhibited a floral axis internode length of less than 2.5 cm, which is already indicative of high panicle density (Brasil, 2002).

The reduction in panicle internodes may be due to increased meristematic activity: in rice (*Oryza sativa* L.) varieties carrying the "erect panicle" (Ep) gene, it was found that this determines the reduction of inflorescence internodes, increasing the number of grains and, consequently, the yield (Huang et al., 2009). It is possible that this occurs even in the length of the panicle ramifications, but studies are unknown in this regard: here it was observed that trinexapac-ethyl changed the state of expression of these structures, whose "position" changed from semi-decumbent or horizontal to semi-upright (Table 2). Perhaps, these modifications resulted from the shortening of the branches, whose measurement is not adopted in DHS assays but which deserves attention in future studies. In oats, compact panicles, usually found in short stature genotypes, can determine higher grain yield (Bertagnolli & Federerizzi, 1994), while more erect branches can result in greater effectiveness in

using solar energy, as attested in rice (Hirooka et al., 2018).

In opposition to what was verified for the plant, floral axis and glume, the increase in lemma length of two cultivars, there is no reference about the influence of trinexapac-ethyl on this structure. In *Festuca arundinacea* Schreb. and *Lolium perenne* L., the product promoted greater carbon allocation to inflorescences at the expense of vegetative tillers (Rolston et al., 2004) and increased the number of seeds per spikelet (Chastain et al., 2014). Therefore, it can be speculated that the inhibition of the hormone by trinexapac-ethyl interferes, also in the development of floral structures, such as lemma and palea. Among the hypotheses for increasing the lemma length under the action of this product is a possible association with grain size and stem diameter.

The descriptors "cycle" and "plant length" are considered minimum requirements of the International Union for the Protection of New Varieties of Plants (UPOV, 1994; Brasil, 2002). Thus, they can be the descriptors with the greatest impact on the recognition of cultivars in seed production fields. in addition to the effects on plant length, trinexapac-ethyl delayed flowering of the three cultivars of the tall stature class. In the year with less rainfall, cultivars manifested as a medium cycle and only cv. URS Brava became "late" under the effect of the growth regulator. However, there was a preponderant late behavior in cultivars in the year of water surplus, except in cvs. URS Altiva and URS 21, which only moved to this phenological category under the effect of TE. Thus, the rainfall regime is a variable that interferes in the response of plants to TE, and also in the phenological and morphological issues. In other crops, such as wheat (Grijalva-Contreras et al., 2012), rice (Nascimento et al., 2009) and corn (*Zea mays*) (Mendes et al., 2018), the effect of TE in prolonging the vegetative stage is already determined.

The different behaviorof the cultivars against the product suggests an association with the height class, as the most stable cultivars, in general, were those from the short class, as opposed to the cultivars from the tall height class. Almost total stability (96%) of the cv. Brisasul (short stature class) when comparing its behavior in the set of 23 descriptors (Figure 1) as well showing changes in only one of the seven descriptors that were responsive to trinexapac-ethyl, computing 86% stability in this case. On the other hand, two cultivars of tall stature class, URS Altiva and URS Brava, showed the lowest percentage of stability (≤85%) in relation to the total of descriptors evaluated and, especially, among the seven variant descriptors to the TE, in which the stability ranged from 43 to 57% (Table 2).

The similarity of these two cultivars is supported by their genealogy, as both have cv. URS 21 (Federizzi et al., 2015; Nava et al., 2016). The cv. URS 21, also from the tall stature class, showed stability similar to those of short stature (Table 2) when dealing with the descriptors evaluated by the qualitative approach, showed the highest percentage of reduction in plant length and floral axis (Table 4). The result in oat, found here, is supported by data obtained in other studies with wheat, in which the smaller effect of trinexapac-ethyl on small to medium-sized cultivars is stand out, with the possibility of dose adjustment (Zagonel & Fernandes, 2007; Pagliosa et al., 2013).

5. Conclusion

In conclusion, the effect of trinexapac-ethyl to control lodging in white oat depends on the genotype and on the water regime. In case the product is applied in seed production fields, this may result in the modification of the expression status of descriptors for *Avena* spp. (UPOV, 1994; Brasil, 2002), such as cycle and plant length, which may affect the identification of cultivars. Therefore, it is recommended that seeds producers inform the inspection body when using the product in order to avoid problems of this nature.

More studies are needed to verify the effect of this product on the quality and nutrient content of white oat grains and test the effect of the product at different concentrations together with different nitrogen doses under white oat descriptors.

Acknowledgments

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