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Growth retardant and nitrogen levels in wheat agronomic characteristics

Redutor de crescimento e doses de nitrogênio em características agrônômicas do trigo

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Abstract

Facing the use of high rates of nitrogen (N) fertilizer in wheat crop, the importance of the use of plant growth regulators is observed, and it has become important technology to improve the production efficiency of various species of plants. Thus, we aimed at evaluating the effect of N fertilization, with Sulfammo[®], and the use of growth reducer on the agronomic traits of wheat cultivars. The work was conducted in the experimental area of the Federal University of Santa Maria, Frederico Westphalen campus, in the period from 06 June to 20 October 2012. The soil in the area is classified as dystrophic Red Latosol and the experimental design was a randomized complete block in a 3x5x2 factorial, with three cultivars (TBIO Mestre, TBIO Iguaçú e TBIO Itaipú), five rates of N (0, 40, 80, 120 and 160 kg ha⁻¹) and application or not of growth reducer (trinexapac-ethyl) at a dose of 100 g ha⁻¹, with three replications. The growth reducer reduces the length of the second and third internode to the TBIO Itaipú and TBIO Iguaçú, the total biomass of the plant, increases thousand grain weight and increases the number of spikelets per spike in TBIO Itaipú. Increasing the rates of N as Sulfammo[®] allows increasing the length of the first, second and third internodes, culm length, ear length and mass of the spike.

Additional keywords: nitrogen fertilization; *Triticum aestivum* L.; yield components.

Resumo

Frente à utilização de elevadas doses de adubação nitrogenada na cultura do trigo, observa-se a importância do uso de reguladores de crescimento vegetal, sendo que o mesmo tem se tornado tecnologia importante para melhorar a eficiência produtiva de várias espécies de plantas. Assim, objetivou-se avaliar o efeito de doses de adubação nitrogenada, na forma de Sulfammo[®], e a utilização de redutor de crescimento nos caracteres agrônômicos de cultivares de trigo. O trabalho foi realizado na área experimental da Universidade Federal de Santa Maria, campus de Frederico Westphalen, no período de 6 de junho a 20 de outubro de 2012. O solo da área é classificado como Latossolo Vermelho distrófico típico e o delineamento experimental utilizado foi o de blocos casualizados, em esquema fatorial, sendo três cultivares (TBIO Mestre, TBIO Iguaçú e TBIO Itaipú), cinco doses de nitrogênio (0, 40, 80, 120 e 160 kg ha⁻¹) e aplicação ou não do redutor de crescimento (trinexapac-ethyl), na dose de 100 g ha⁻¹, com três repetições. O redutor de crescimento reduz o comprimento do segundo e terceiro entrenó nas cultivares TBIO Itaipú e TBIO Iguaçú, a fitomassa total da planta, aumenta a massa de mil grãos e incrementa o número de espiguetas por espiga na cultivar TBIO Itaipú. O aumento da dose de N na forma de Sulfammo[®] possibilita o aumento do comprimento do primeiro, segundo e terceiro entrenós, comprimento de colmo, comprimento da espiga e massa da espiga.

Palavras-chave adicionais: adubação nitrogenada; componentes da produção; *Triticum aestivum* L.

Introduction

Wheat (*Triticum aestivum* L.) is the largest source of calories and protein to the world population, being a culture of a great importance for Brazil, with a growing demand for its oil. The Brazilian production of wheat is around 5 million tons per year, well below the annual wheat demand, which is 10 million tons. The technologies currently employed enabled an average productivity of 700 kg ha⁻¹, in the 1940, to reach 2,140 kg ha⁻¹ (CONAB, 2013).

There are several features that can be manipulated in wheat crop that result in grain yield increase. For example, the increase in the number of grains per area, in the harvest index, an increased optimization of the ear and a maximized capacity and photosynthetic efficiency (Foulkes et al., 2011; Parry et al., 2011).

The interest in maximizing wheat yield has encouraged the adoption of intensive crop management practices, in which the use of high doses of nitrogen fertilization and the use of plant growth regulators are highlighted. This has become an important technology to improve production efficiency of various plant species, among which wheat (Vieira et al., 1995).

Among management practices, the fertilization with nitrogen (N) is underlined because it is the most required element by the culture, knowing that the soil does not normally provide sufficient quantities of it for cultivation and present positive responses in grain productivity. If the deficiency of this element is observed, the culture will tend to reduce its biomass production and its solar radiation use efficiency, with a great effect on grain yield and its components (Heinemann et al., 2006; Kutman et al., 2011).

The use of slow-release fertilizers, among them Sulfammo®, in which N protection is performed through a nitrification inhibitor such as, for example, 3,4-dimethylpirazolfosfate (DMPP). It prolongs the N-time in a non-leachable form (NH₄⁺), allowing an adequate supply of N throughout the crop cycle and the reduction of leaching losses (Zerulla et al., 2001). In this context, the use of Sulfammo® becomes an interesting alternative to supply an N deficiency, and this fertilizer allows nutrients to be available continuously to plants, minimizing the risk of nutritional deficiencies throughout the crop cycle.

Among the strategies associated with the use of high doses of N in wheat are the use of short cultivars or the application of growth retardants, among which trinexapac-ethyl, an growth retardant that interferes at the end of the metabolic pathway of the biosynthesis of gibberellic acid (Heckman et al., 2002) by inhibiting the enzyme 3 beta-hydroxylase, drastically reducing the level of active gibberellic acid (GA₁) and thus markedly increasing its biosynthetic immediate precursor GA₂₀ (Davies, 1987).

Thus, the use of trinexapac-ethyl has been

emphasized due to its ability to reduce plant height, improve leaf architecture of wheat and increase culm diameter, reducing the lodging and optimizing the use of solar radiation. Consequently, it increases productivity (Zagonel & Fernandes, 2007). Even in cultivars that have a reduced size, the application of growth retardants enabled positive results. With it, the plant shows a better leaf architecture and consequently a higher uptake of radiation due to the increase in the number of fertile tillers and a higher redirection of photoassimilates toward grain production, to the detriment of the development of the culm (Matysiak, 2006; Zagonel & Fernandes, 2007).

Assuming that the factors mentioned above are able to modify morphological and productive characteristics of the wheat crop and that their effects are influenced by the characteristics of the growing area, as well as by the cultivars used, it is necessary to quantify and characterize these effects in order to obtain satisfactory results related to the agronomic characteristics of this culture. Thus, the objective was to evaluate the effect of nitrogen fertilization doses using Sulfammo® and the use of a growth retardant on agronomic traits of wheat cultivars.

Material and methods

The study was conducted in the experimental area belonging to the Agroclimatology Laboratory of the Federal University of Santa Maria (UFSM), Frederico Westphalen campus, located in northern Rio Grande do Sul, Brazil, with geographic coordinates 27°23'48" S, 53°25'45" W and altitude of 490 m. According to the Köppen climate classification, the area's climate is Cfa. Frederico Westphalen is about 30 km far from Iraí, and the city was taken as a reference to the climatic classification data. As proposed by Maluf (2000), Iraí presents a subtemperate sub-humid climate, with an average annual temperature of 18.8 °C and the average temperature of the coldest month 13.3 °C.

The study was conducted in the period from June 6 to October 20, 2012. The soil of the area is classified as typical dystrophic Red Latosol, clayey, deep and well drained (Embrapa, 2006). It presented the following chemical characteristics: pH in water: 6.0; P (Mehlich): 3.0 mg dm⁻³; K: 160 mg dm⁻³; Ca: 6.2 cmol_c dm⁻³; Mg: 3.3 cmol_c dm⁻³; Al: 0.0 cmol_c dm⁻³; CTC: 9.9 cmol_c dm⁻³; base saturation: 76%; and organic matter: 3.1%. The experimental design was made with randomized blocks, in a 3x5x2 factorial design, with three cultivars (TBIO Mestre, TBIO Iguaçú and TBIO Itaipú), five N doses (0, 40, 80, 120 and 160 kg ha⁻¹) as Sulfammo®, and the application or not of the growth retardant (trinexapac-ethyl), with three replications. The size of each plot was six rows of three meters long, each spaced 17 cm.

The sowing was manually held on June 6,

2012 three centimeters deep and with a density of 350 seeds m^{-2} . The fertilization was made with potassium (K_2O) at the sowing, in the amount of 30 $kg\ ha^{-1}$, and phosphorus (P_2O_5) at a dosage of 65 $kg\ ha^{-1}$, according to the results of soil analysis and following technical indications of the Comissão de química e fertilidade do solo (2004). At the time of seeding, a nitrogen fertilizer at a dose of 20 $kg\ ha^{-1}$ was also used and the remaining was used as coverage in the early tillering stage. The weed control was performed through a manual weeding at 20 days after emergence (DAE).

The gradual release of commercial Sulfammo® was used as a source of N (26% N + 5% Ca; 9% S, 2% Mg and 0.3% B). The growth regulator used was trinexapac-ethyl, applied at a dose of 100 $g\ ha^{-1}$ through a backpack sprayer with an average application speed of 5.5 $km\ h^{-1}$, with a proportion spray volume of 130 $L\ ha^{-1}$. The application of the growth regulator was made when plants were in the flower differentiation period, when the first visible node appeared (stage 6.0). The cultivars show an average cycle and a maturation of around 145 days. They are moderately resistant to lodging, and TBIO Itaipú and TBIO Iguaçú cultivars have a medium/high stature. On the other hand, TBIO Master cultivar has a short stature.

Stem diameter (SD), length of the first internode (L1I), length of the second internode (L2I), length of the third internode (L3I), culm length (CL), ear length (EL), number of earlets per ear (EE), mass ear (EM), thousand grain mass (TGM), plant's biomass (PB) and apparent harvest index (AI) were evaluated. The SD was evaluated using a digital caliper, with which two measurements in the middle of the first internode were made. The results were expressed in mm seedling⁻¹. For the evaluation of L1I, L2I and L3I, a ruler graduated in centimeters was used. It measured from the middle of the first node to the middle of the second node, from the middle of the second node to the middle of the third node, from the middle of the third node to the middle of the fourth node, and so on.

To evaluate CL, the distance from the plant neck to the base of the ear was measured with the aid of a ruler graduated in centimeters, and the results were expressed in cm seedling⁻¹. To evaluate EL, a ruler graduated in centimeters, measuring from the base of the ear of the main culm to the tip of the ear, excluding the awns was used.

EE was determined by counting the number of earlets from the ear of the main culm. To determine EM, the ears were detached from the samples and the mass was measured with an analytical balance. The results were expressed in g ear⁻¹. The TGM was determined by counting a thousand grains collected at random from the total production of the plant. To evaluate PB, the shoot of wheat plants was removed by cutting it close to the ground and placing it in an

oven at 65 °C until it reached a constant weight (48 hours). AI, expressed in %, was calculated by the ratio between the total biomass of the plant and the seed yield.

The grain yield was determined to allow the calculation of the AI. It was conducted by collecting the plants contained in the four central rows of each plot. After the manual sorting, the mass of grains was measured and the data transformed into $kg\ ha^{-1}$ with 13% moisture.

All variables mentioned above were determined at harvest. The harvest was held on October 20, 2012, at the time the grains have reached maturity (stage 11.4).

The data were submitted to statistical analysis through the software *Statistical Analysis System Learning Edition 8.0* (SAS, 2003). Those variables, in which the hypothesis of equality was rejected at a 5% level of error probability, were compared by a Tukey test for the factors cultivar and growth retardant and regression for N dose.

Results and discussions

Figure 1 describes the precipitation values and the average daily temperature that occurred during the growing cycle of the wheat. For precipitation, it can be seen that, throughout the cycle, 605 mm of rain were recorded. Thus, the culture's water needs were met, not interfering with its development (Libardi & Costa, 1997). On June 6, 7 and 8, 2012, there were frosts, and they did not influence the development of culture, since it had not yet emerged.

The interactions cultivar-N level (CxN), N dose and growth retardant (DxR) were not significant for any of the analyzed variables, since the interaction between cultivar and growth retardant (CxR) presented a significance for SD, L1I, L2I, L3I, TGM, PB and EE variables (Table 1).

The application of the growth retardant was responsible for the reduction of 12.8% of the CL (Table 2). Regarding cultivars, the highest values of this variable were found for TBIO Iguaçú, followed by TBIO Mestre and TBIO Itaipú, and this same order was observed for the EM variable.

The use of a growth retardant increased SD only for TBIO Itaipú cultivar (Table 3). These results corroborate those by Zagonel et al. (2002a), who found a higher SD in wheat culture when subjected to the application of trinexapac-ethyl retardant at different doses of N. Similarly, Lozano & Leaden (2001) found an increased thickening of the sclerenchyma, which resulted in an increased culm diameter after the application of the same growth retardant in two wheat cultivars.

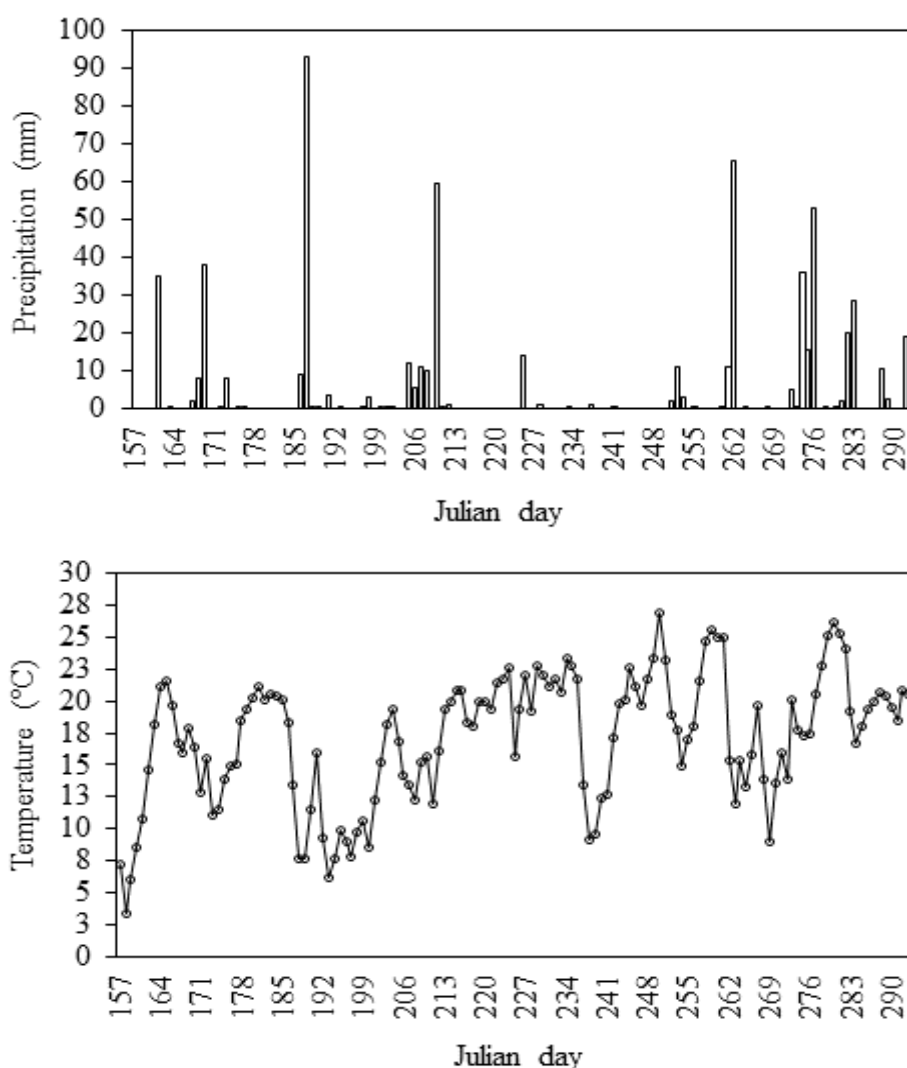


Figure 1 - Precipitation and average daily temperature during the experiment period (06/06/2012 to 10/20/2012), in the city of Frederico Westphalen - RS. UFSM/CESNORS *campus* Frederico Westphalen – RS, 2012

Table 1 - Analysis of variance for the variables stem diameter (SD; mm), length of the first internode (L1I; cm), length of the second internode (L2I; cm), length of the third internode (L3I; cm), culm length (CL; cm), ear length (EL; cm), earlets per ear (EE), ear mass (EM; g), thousand grains mass (TGM; g), plant's biomass (PB; g) and apparent harvest index (AI; %) of wheat cultivars in response to N doses and the use or not of a growth retardant, UFSM/CESNORS, Frederico Westphalen Campus - RS, 2012.

Factor	Medium square							r ²	CV
	Cultivar (C)	N Dose (D)	Retardant (R)	C x D	C x R	D x R	C x D x R		
SD	0.01*	0.05 ^{ns}	0.02*	0.08 ^{ns}	0.02*	0.01 ^{ns}	0.07 ^{ns}	0.73	0.96
L1I	32.86*	1.02*	0.05 ^{ns}	0.98 ^{ns}	2.42*	0.33 ^{ns}	0.27 ^{ns}	0.76	9.69
L2I	23.84*	2.06*	16.79*	0.45 ^{ns}	2.72*	0.41 ^{ns}	0.93 ^{ns}	0.67	8.48
L3I	8.33*	5.28*	66.07*	0.82 ^{ns}	29.36*	1.49 ^{ns}	0.44 ^{ns}	0.66	8.66
CL	193.40*	137.16*	1503.11*	7.64 ^{ns}	24.78 ^{ns}	22.15 ^{ns}	4.40 ^{ns}	0.64	8.55
EL	63.53 ^{ns}	261.68*	5.09 ^{ns}	41.67 ^{ns}	83.31 ^{ns}	77.19 ^{ns}	25.35 ^{ns}	0.53	9.02
EE	21.92*	12.31 ^{ns}	43.59*	5.97 ^{ns}	4.94*	13.97 ^{ns}	17.77*	0.55	20.49
EM	0.09*	0.27*	0.02 ^{ns}	0.02 ^{ns}	0.01 ^{ns}	0.01 ^{ns}	0.05 ^{ns}	0.51	12.42
TGM	1.81 ^{ns}	0.83 ^{ns}	12.42*	1.12 ^{ns}	3.75*	1.48 ^{ns}	1.26 ^{ns}	0.49	6.04
PB	1.80 ^{ns}	0.83 ^{ns}	12.42*	1.12 ^{ns}	3.75*	1.48 ^{ns}	1.26 ^{ns}	0.48	6.04
AI	6772.93 ^{ns}	100664.75 ^{ns}	23817.06*	4452.42 ^{ns}	1221.02 ^{ns}	6212.34 ^{ns}	4069.41 ^{ns}	0.66	14.02

* Significant at a 5% level of error probability; ^{ns}: not significant at a 5% level of error probability; r²: coefficient of determination; CV: coefficient of variation (%).

Table 2 - Culm length (CL) and ear mass (EM) in wheat cultivars, and in response to the use or not of a growth retardant, UFSM/CESNORS, Frederico Westphalen Campus - RS, 2013.

Variables		CL	EM
Retardant	With	55.6 b	-
	Without	63.7 a	-
Cultivar	TBIO Mestre	59.8 ab	1.33 ab
	TBIO Itaipú	57.0 b	1.28 b
	TBIO Iguaçu	62.1 a	1.39 a

Means followed by the same letter in the column do not differ by Tukey test at 5% error probability.

Table 3 - Culm diameter (CD; cm), length of the first internode (L1I; cm), length of the second internode (L2I; cm), length of the third internode (L3I; cm), thousand grains mass (TGM; g), plant's biomass (PB; g) and earlets per ear (EE) of wheat cultivars (TBIO Mestre, TBIO Itaipú and TBIO Iguaçu) in response to the use or not of the growth retardant, UFSM/CESNORS, Frederico Westphalen Campus - RS, 2013.

Variables	Retardant	Cultivar		
		TBIO Mestre	TBIO Itaipú	TBIO Iguaçu
CL	With	2.55 a B	2.60 a A	2.53 a C
	Without	2.54 a A	2.52 b B	2.52 a B
L1I	With	8.16 a A	5.97 a C	7.52 a B
	Without	7.51 a B	6.01 a C	8.01 a A
L2I	With	10.77 a A	8.74 b B	10.18 b A
	Without	10.94 a B	9.86 a B	11.47 a A
L3I	With	14.59 a A	12.47 b B	13.88 b A
	Without	14.06 a B	15.71 a A	16.32 a A
TGM	With	252.89 a B	257.7 a B	293.24 a A
	Without	245.95 a A	247.68 a A	264.95 b A
PB	With	17.05 a A	15.92 b B	16.6 a AB
	Without	17.31 a A	17.49 a A	17.05 a A
EE	With	12.63 a C	12.91 a B	15.63 a A
	Without	11.64 a A	11.94 a A	12.74 b A

Means followed by the same letter, capital in the column small in the line, do not differ by Tukey test at 5% error probability.

The application of the retardant did not influence L1I, with a difference only between cultivars (Table 3). In contrast, L2I and L3I variables were influenced by the application of the growth retardant, showing a reduction in cultivars TBIO Itaipú and TBIO Iguaçu values. Similar results were found by other authors, who evaluated the effect of trinexapac-ethyl in wheat and barley cultivars in different locations. They concluded that this retardant reduces significantly the length of internodes (Lozano & Leaden, 2001; Matysiak, 2006; Zagonel & Fernandes, 2007), and, in soybean, it reduces the plant's height (Linzmeier Júnior et al., 2008).

In addition, it is noteworthy that the right moment of application of the retardant is of fundamental importance for the occurrence of the expected effect. Thus, it should be noted that, in later applications, after the third node, a marked shortening of the culm may

happen, causing the ear to be retained in the leaf of the sheath-flag, which results in problems in blooming and, consequently, in wheat yield (Penckowski et al., 2009).

TBIO Iguaçu cultivar presented higher values of TGM with the use of the growth retardant (Table 3). However, in general, a numerically higher TGM was observed in all varieties when this product was used. According to Zagonel et al. (2002b), TGM is a very important variable, because it is correlated with the productivity of wheat.

TBIO Itaipú cultivar showed a decrease of 1.57 g in the PB with the application of the growth retardant (Table 3). These results may be explained due to the effect that the retardant provokes in the plant. Usually, the retardants bind themselves to receptors in the plant and trigger a series of cellular changes, which may affect the initiation or the modification of organs and tissues' development, such

as the stimulation of tillering, the redistribution of biomass with increased roots growth, and the inhibition of elongation of internodes, which may entail a reduction of the plant height (Lozano & Leaden, 2001; Matysiak, 2006; Berti et al., 2007; Zagonel & Fernandes, 2007).

Calderini et al. (1997) observed that the increase in grain yield, as well as the production of PB in wheat cultivars, is related to the application or not of the retardant. For, in their absence, higher PB values are obtained. However, the leaf is arranged in the prostrate form, making interception and absorption of photosynthetically active radiation difficult, and consequently the efficiency with which they convert radiant energy into chemical energy.

Likewise, Heinemann et al. (2006) point out that, in the presence of the retardant, lower PB values are found. However, the leaf stays in the upright position, absorbing more light, which causes it to produce more tillers and decrease the bedding, as well as obtaining a higher productivity. Therefore, any factor that alters the solar radiation use efficiency may influence the yield of wheat.

TBIO Iguaçú cultivar presented the highest EE value with the use of the growth retardant (Table 3). However, this difference was not observed in the absence of the retardant application among cultivars. Yet, it appears that the addition of N doses led to an increase in the number of EE in the three cultivars (Figure 2).

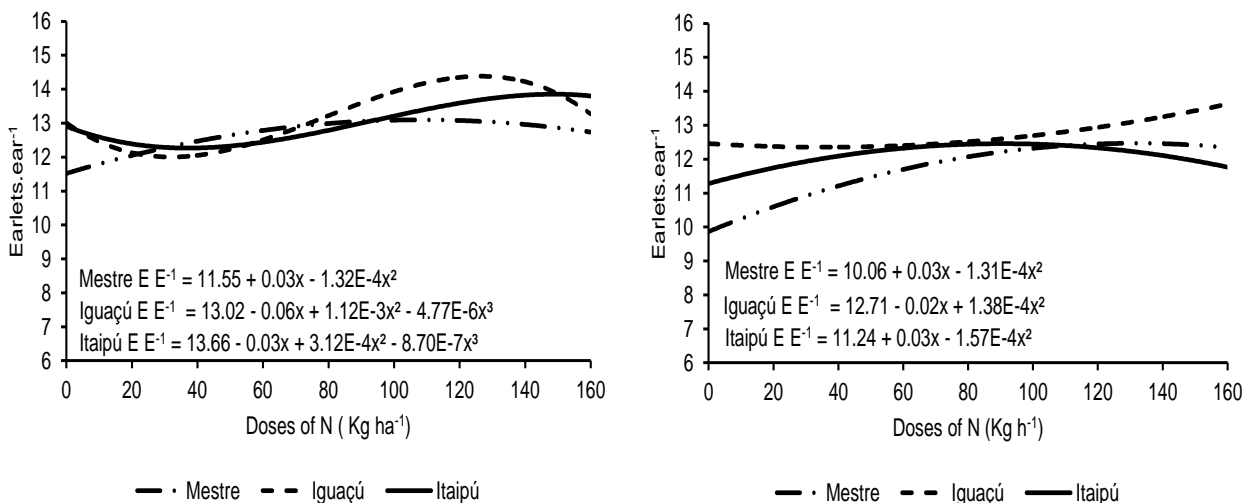


Figure 2 - Regression equations for the number of earlets.ear⁻¹ (EE; mm) of wheat cultivars under different doses of N and the use or not of the growth retardant, where A = with the use of retardant and B = without the use of retardant. UFSM/CESNORS, Frederico Westphalen campus – RS, 2012.

These results corroborate those reported by Zagonel et al. (2002a), who found that the application of trinexapac-ethyl caused a positive effect on the number of ears per meter, EE and TGM. Likewise, Teixeira Filho et al. (2007), studying the response of four irrigated wheat cultivars in the Cerrado region under different doses of N (0, 30, 60, 90 and 120 kg ha⁻¹), applied in coverage at 40 days after the emergence of plants, found that N doses had a significant influence by increasing EE.

The increase of the N doses increased L1I and L3I (Figure 3). These results corroborate those found by Zagonel et al. (2002b), who found that the application of N enhanced the length of internodes of wheat plants.

The N doses positively influenced EL, CL and EM (Figure 3). There was an adjust to quadratic functions, with the maximum point being achieved with the estimated doses of 140, 105 and 108 kg ha⁻¹ of N, respectively, for EL, CL and EM. Likewise, Freitas et al. (1994), studying the responses of grain yield and other agronomic characteristics of different

wheat cultivars submitted to nitrogen fertilization, observed an increase in EL related to used N doses. According to Silva (2010), EL has been considered as an important agronomic trait, because, when associated with other production components (EE, TGM, EM), it is of fundamental importance in order to obtain high culture yields.

Conclusions

The use of a growth retardant and of increasing doses of N significantly influences the agronomic characteristics of studied wheat cultivars.

The growth retardant reduces the length of the second and third internodes in TBIO Itaipú and TBIO Iguaçú cultivars and the total biomass of the plant, increases the thousand grains mass and increases the number of earlets per ear in TBIO Itaipú cultivar.

The increase of the dose of N as Sulfammo® enables the increase of the length of the first and third internodes, culm length, ear length and ear mass.

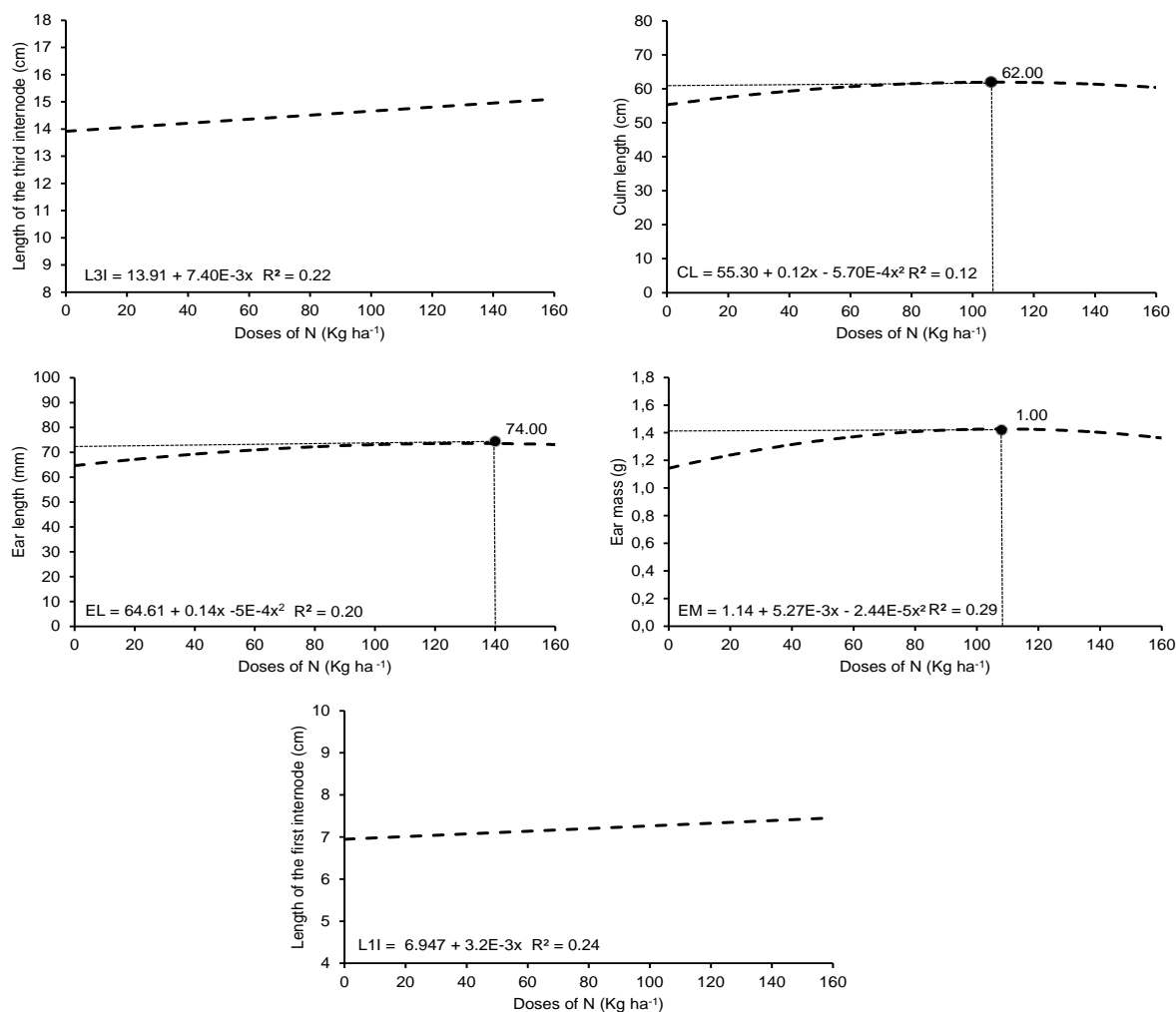


Figure 3 - Regression equations for the variables length of the first internode (L1I; cm), length of the third internode (L3I; cm), culm length (CL; cm), ear length (EL; mm) and ear mass (EM; g) of wheat cultivars submitted to different doses of N. UFSM/CESNORS, Frederico Westphalen campus - RS 2012.

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