Revista Thema
v.22 | n.3 | 2023
p.676-691

DOI: http://dx.doi.org/10.15536/thema.V22.2023.676-691.3241
ISSN: 2177-2894 (online)

CIÊNCIAS AGRÁRIAS

Agronomic characteristics of barley cultivars in response to nitrogen fertilization

Características agronômicas de cultivares de cevada em resposta à fertilização nitrogenada

Lanes Beatriz Acosta Jaques[1]
https://orcid.org/0000-0002-1597-1235 http://lattes.cnpq.br/3456075507202154
Ivan Ricardo Carvalho[2]
https://orcid.org/0000-0001-7947-4900 http://lattes.cnpq.br/7945266734797620
Henrique Eguilhor Rodrigues[3]
https://orcid.org/0000-0002-2164-4118 http://lattes.cnpq.br/8587378030849099
Ítala Thaisa Padilha Dubal[4]
https://orcid.org/0000-0002-6223-7834 http://lattes.cnpq.br/8298005370645812
Ruddy Alvaro Veliz Escalera[5]
https://orcid.org/0000-0002-9066-5780 http://lattes.cnpq.br/5917481242067215
João Roberto Pimentel[6]
https://orcid.org/0000-0002-6197-7224 http://lattes.cnpq.br/0037141585819893
Cristian Troyjack[7]
https://orcid.org/0000-0002-4748-7608 http://lattes.cnpq.br/3182228165141077
Vinícius Jardel Szareski[8]
https://orcid.org/0000-0002-8906-6510 http://lattes.cnpq.br/1069795934274923
Francine Lautenchleger[9]
https://orcid.org/0000-0003-0219-6062 http://lattes.cnpq.br/6498231937716051
André Luiz Radünz[10]
https://orcid.org/0000-0002-2397-011X http://lattes.cnpq.br/3349665124114025
Ana Carolina Sampaio Silva[11]
https://orcid.org/0000-0002-3753-8571 http://lattes.cnpq.br/6662648795241718
Rafael Dal Bosco Ducatti[12]
https://orcid.org/0000-0001-8916-6557 http://lattes.cnpq.br/7191703160610163
Tiago Aumonde Zanatta[13]
https://orcid.org/0000-0003-4790-8270 http://lattes.cnpq.br/3499020467982627
Tiago Pedó[14]
https://orcid.org/0000-0003-4327-8021 http://lattes.cnpq.br/0799661863186569

[1] E-mail: lanis.acosta@hotmail.com
[2] E-mail: carvalho.ircii@gmail.com
[3] E-mail: henrique_eguilhor@hotmail.com
[4] E-mail: italadubal@unipampa.edu.br

ABSTRACT

The aim of this study was to assess the impact of nitrogen doses on the yield of two barley cultivars, namely BRS Brau and BRS Cauê, cultivated in various growing environments in Southern Brazil. The research was conducted during the 2017 harvest season in Alegrete and Pelotas, RS, Brazil. A randomized block design with a factorial scheme of 2 x 2 x 4 (growing environments x barley cultivars x nitrogen doses) was employed, with four replications. Various parameters were evaluated, including plant height, number of tillers per plant, number of ears per square meter, number of seeds per plant, thousand seeds weight (TSW), and yield. The results indicated that the two barley cultivars responded differently to the growing environments and nitrogen doses. In Pelotas, BRS Brau exhibited superior performance in terms of plant height and TSW, while BRS Cauê showed a higher number of seeds per plant and seed yield. Furthermore, the combination of the Pelotas growing environment and a nitrogen dose of 200 kg ha-1 resulted in optimized growth and yield of barley seeds.

Keywords: cereal; genotype x environment interaction; Hordeum vulgare; seed production.

RESUMO

Objetivou-se avaliar a influência de doses de nitrogênio na produtividade de sementes em duas cultivares de cevada BRS Brau e BRS Cauê - produzidas em diferentes ambientes de cultivo. Este trabalho foi realizado na safra agrícola de 2017 em Alegrete-RS e Pelotas-RS, Brasil. O delineamento experimental foi em blocos casualizados em esquema fatorial, com 2 x 2 x 4 (ambientes de cultivo x cultivares de cevada x doses de nitrogênio), arranjados em quatro repetições. As variáveis avaliadas a estatura da planta, número de perfilhos por planta e número de espigas por metro quadrado, número de sementes por planta, massa de mil sementes e rendimento de sementes. As cultivares de cevada testadas responderam diferentemente aos ambientes de cultivo de Pelotas de Bagé e às doses de nitrogênio. Em Pelotas-RS, a cultivar BRS Brau foi superior para estatura de planta e massa de mil sementes. Já a cultivar BRS Cauê apresentou maior número de sementes por planta e produtividade de sementes. O ambiente de Pelotas-RS, aliado à dose de 200 kg ha-1 de nitrogênio, maximiza o crescimento e a produtividade das sementes de cevada.

Palavras-chave: *produção de semente; cereal; interação genótipo x ambiente.*

1. INTRODUCTION

Barley holds significant socioeconomic importance worldwide as a winter cereal. It is utilized for animal feed, forage, and human nutrition in various forms such as flour, flakes, or malt. (KAUR *et al.*, 2016). In Brazil, barley primarily serves the beverage and malting industries, with a production of 429 thousand tons in the 2022 harvest season. (CONAB, 2022). However, this production often falls short of meeting the demands of Brazilian industries.

To reduce the need for barley imports, maximize production, and fulfill market requirements, different management practices have been sought, including nitrogen fertilization. Nitrogen supply has been found to increase grain and seed yield while enhancing their quality. (CAIRES; MILLA, 2016).

[5] E-mail: ruddyescaleraveliz@gmail.com
[6] E-mail: jrobertopimentel@hotmail.com
[7] E-mail: cristiantroyjack@hotmail.com
[8] E-mail: viniciusszareski@gmail.com

As a primary macronutrient, nitrogen deficiency limits agricultural productivity (GIRRACA; NUNES, 2016) and leads to reduced tiller emission, stalk and ear count, as well as decreased seed yield per hectare. (SANGOI *et al.*, 2007; JAQUES *et al.*, 2019). Although some nitrogen required by crops is supplied by soil organic matter (SOM), additional nitrogen inputs are necessary to achieve higher crop yields. (SCHEFER *et al.*, 2016).

In southern Brazil, nitrogen fertilization practices are based on SOM content, previous crop history, and yield expectations. However, the applied nitrogen quantity may not adequately meet the crop's actual needs due to factors affecting SOM decomposition and nitrogen release. (ACOSTA *et al.*, 2014). Nitrogen can also be lost through volatilization (ammonia), leaching, and denitrification (nitrate). Consequently, increasing nitrogen fertilizers beyond recommended levels may prove beneficial for both plants and farmers. (BREDEMEIR *et al.*, 2013; FERRARI *et al.*, 2016a).

Elevating nitrogen doses in winter cereals has been shown to increase yield and improve seed/grain quality. (SHI *et al.*, 2010). Nitrogen is an essential and indispensable element for plants, as it constitutes vital biomolecules such as amino acids, nucleic acids, proteins, and enzymes. (FERRARI *et al.*, 2016b).

However, poorly managed nitrogen application can have adverse effects on yield and seed quality, as nitrogen's influence is linked with genetic, physiological, nutritional, and environmental factors. (PENCKOWSKI *et al.*, 2010; PIMENTEL *et al.*, 2019). Therefore, nitrogen supplementation should not be considered in isolation, as it directly impacts the number of tillers, ears per plant, thousand seed weight (TSW), number of seeds per square meter, and yield. The objective of this study was to assess the impact of nitrogen doses on the yield of different barley cultivars cultivated in different growing environments.

2. MATERIAL AND METHODS

The research was conducted during the 2017 harvest season in two regions of Rio Grande do Sul, Brazil. Alegrete (29°47'01.63’’S, 55°47'27.54’’W, and altitude of 102 meters) and Pelotas (52°21'24''W and 31°52'00''S, and altitude of 13.4 meters) are situated in a Subtropical Humid hot Cfa climate region according to the Köppen-Geiger classification. The soil in Alegrete is classified as a Sandy Dystrophic Red Argisol (EMBRAPA, 2005), while Pelotas has a Solodic Eutrophic Haplic Planosol (EMBRAPA, 2013).

Before the experiment was initiated, soil samples were collected from Alegrete and Pelotas at a depth of 0-20 cm for characterization (RAIJ; QUAGGIO, 1983). The soil analysis results for Alegrete indicated the following characteristics: clay content: 48%; pH in water: 5.5; Phosphorus (P): 48 mg dm^{-3}; Potassium (K): 200 mg dm^{-3}; Sulfur (S): 10.4 mg dm^{-3}; Organic matter (OM): 1.60%; Toxic aluminum (Al): 0.0 $cmol_c$ dm^{-3}; Calcium (Ca): 7.1 $cmol_c$ dm^{-3}; Magnesium (Mg): 2.9 $cmol_c$ dm^{-3}; Boron (B): 0.0 mg dm^{-3};

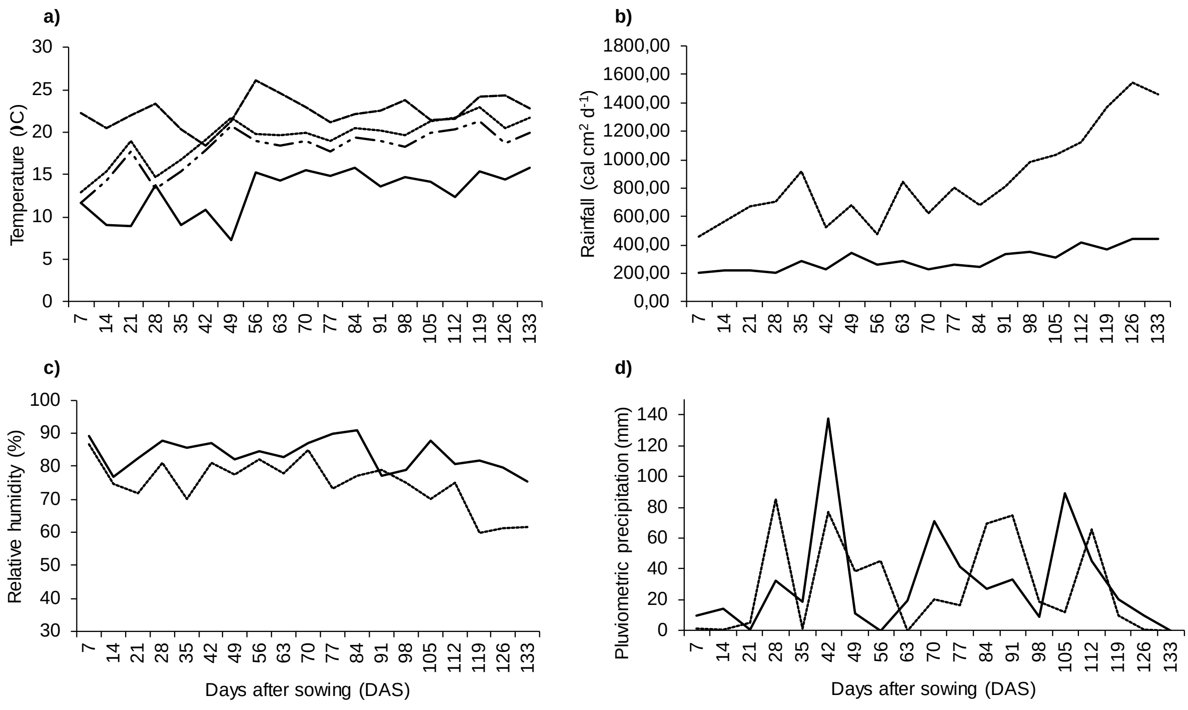
[9] E-mail: francinelautenchleger@hotmail.com
[10] Universidade Federal da Fronteira Sul – UFFS, Chapecó/SC – Brasil. E-mail: andre.radunz@uffs.edu.br
[11] E-mail: anacarolina.sampaiosilva@gmail.com
[12] E-mail: rafaelducatti1007@gmail.com

Copper (Cu): 3.0 mg dm^{-3}; Zinc (Zn): 1.3 mg dm^{-3}; Manganese (Mn): 26 mg dm^{-3}; Sodium (Na): 4 mg dm^{-3}; Cation exchange capacity (CEC): 11.2 cmol$_c$ dm^{-3}; base saturation: 54.8%.

The soil characteristics for Pelotas were as follows: clay content: 19%; pH in water: 5.0; Phosphorus (P): 46.0 mg dm^{-3}; Potassium (K): 53.0 mg dm^{-3}; Sulfur (S): 19.8 mg dm^{-3}; Organic matter (OM): 2.07%; Toxic aluminum (Al): 0.8 cmol$_c$ dm^{-3}; Calcium (Ca): 3.2 cmol$_c$ dm^{-3}; Magnesium (Mg): 0.9 cmol$_c$ dm^{-3}; Boron (B): 0.0 mg dm^{-3}; Copper (Cu): 1.4 mg dm^{-3}; Zinc (Zn): 1.8 mg dm^{-3}; Manganese (Mn): 14.2 mg dm^{-3}; Sodium (Na): 50 mg dm^{-3}; Cation exchange capacity (CEC): 5.3 cmol$_c$ dm^{-3}; base saturation: 45.0%.

Climatic data including temperature, solar radiation, relative humidity, and precipitation were obtained from meteorological stations. The meteorological station in Alegrete is situated within the Campus of the Farroupilha Federal Institute, while in Pelotas, the station is located at Embrapa Clima Temperado, in the municipality of Capão do Leão-RS. Figure 1 likely displays the specific climatic data recorded during the study.

Figure 1 – a) Minimum air temperature in Alegrete (−•••−), Maximum air temperature in Alegrete (••••), Minimum air temperature in Pelotas (−), Maximum air temperature in Pelotas (---); b) Solar radiation in Pelotas (−), Solar radiation in Alegrete (••••); c) Relative humidity in Pelotas (−), Relative humidity in Alegrete (••••); e d) Precipitation in Pelotas (−), Precipitation in Alegrete (••••).



Font: authors.

The sowing of the BRS Brau and BRS Cauê cultivars, which were the most important at that time, took place in the first two weeks of July. The experimental areas were

[13] E-mail: tiago.aumonde@gmail.com
[14] E-mail: tiago.pedo@gmail.com

cultivated under a no-tillage system. Before sowing, the areas received N-P-K fertilization based on soil analyses and crop recommendations for the state of Rio Grande do Sul. The population density for both cultivars was set at 2.5 million plants per hectare, with rows spaced at 17 cm. Each experimental unit consisted of eight rows, each measuring 2.5 meters in length. Nitrogen fertilization was applied at the tillering stage, using four different doses: 80, 120, 160, and 200 kg ha^{-1} of urea.

The study was conducted as a randomized block design arranged in a factorial scheme of 2 x 2 x 4 (growing environments x barley cultivars x nitrogen doses) with four replications. The two cultivars used were BRS Brau and BRS Cauê. Insect pests and diseases were controlled preventively. For harvesting, only the six central lines (excluding the ends) were considered to minimize the border effects. Seeds from the experimental units were harvested when they reached 18% humidity.

Subsequently, the seeds were dried in a stationary dryer at 35°C until they reached the desired humidity level of 13%. Manual cleaning of the seeds was performed for the determination of agronomic variables of interest. At the physiological maturity stage, ten randomly selected plants per plot were used to measure the following variables:

Plant height (PH): Measured using a graduated ruler, from the base of the plant to the tip of the last distended leaf (cm). Number of tillers per plant (NTP): Counted and expressed as units. Number of ears per square meter (NESM): Counted and expressed as units.

Number of seeds per plant (NSP): Counted by examining the seeds in each ear of the plant, expressed as units. Thousand seed weight (TSW): Determined according to the "Regras para Análise de Sementes". (BRASIL, 2009). Eight replicates of 100 seeds each were used, and the results were extrapolated to the weight of one thousand seeds (grams).

Seed yield (SY): After drying the seeds to a constant moisture level of 13%, they were manually cleaned and weighed using a precision scale. The results were extrapolated to one hectare and expressed as kg ha^{-1}.

The data were examined for outliers, and the assumptions of the analysis of variance (ANOVA) were checked, including normality and homogeneity of variances. The data were subjected to ANOVA to determine if there were significant differences between the means of the different factors in the experiment (growing environments x barley cultivars x nitrogen doses) at a significance level of 5% using the F test. When significant differences were observed, a Tukey test at a 5% probability was used for mean comparison. The factors "growing environments" and "barley cultivars" were considered qualitative variables, while "nitrogen doses" were analyzed as quantitative variables using linear regressions.

3. RESULTS AND DISCUSSION

The results of the analysis of variance revealed significant interactions between "growing environments," "barley cultivars," and "nitrogen doses" for various variables including plant height (PH), number of seeds per plant (NSP), thousand seed weight (TSW), and seed yield (SY). Additionally, the interaction between "growing environment" and "nitrogen doses" was significant for the variables number of tillers per plant (NTP) and number of ears per square meter (NESM). Furthermore, the interaction between "growing environment" and "barley cultivar" was significant for the variables NTP and NESM (Table 1).

Table 1 – Mean squares from the analysis of variance for the yield and growth parameters, and the interactions between the growing environments, cultivars, and nitrogen doses, for the harvest season of 2017.

	MEAN SQUARES						
VF	**DF**	**PH**	**NTP**	**NESM**	**NSP**	**TSW**	**SY**
Growing environments (A)	1	11431.14*	173.55*	3374208.31*	608202.38*	1926.90*	2930769148*
Barley cultivars (C)	1	46.03ns	0.017ns	537933.42ns	981.71ns	143.78*	21.00ns
A x C	1	1558.51*	171.45*	5303957.77*	1939.31ns	2.35ns	3335135ns
Nitrogen doses (D)	3	118.13*	45.5*	926430.71*	9045.76*	12.62ns	39227613*
A x D	3	49.34ns	46.35*	1171834.85*	3815*	24.62*	17259621*
C x D	3	17.99*	13.36ns	332688.10ns	8454.32*	39.38*	24273678*
A x C x D	3	190.09*	6.14ns	193183.76ns	6081.96*	22.44*	15768884*
Block	3	642.01*	230.95*	1230992.40*	8288.66*	70.75*	58351089*
CV (%)	-	8.21	34.00	39.10	28.40	6.92	31.10

*significant at a 5% probability according to the F-test. ns: not significant.

VF - variation factor;
PH - plant height;
NTP - number of tillers per plant;
NESM - number of ears per square meter;
NSP - number of seeds per plant;
TWS - thousand seed weight; e
SY - seed yield.

Font: authors.

The manipulation of nitrogen management during top dressing, the selection of specific cultivars, and variations in the growing environment had a notable impact on the responses of the variables under investigation. Increasing nitrogen doses proved to be beneficial for plant growth and yield, particularly in environments like Pelotas, where the organic matter content is low due to the predominance of soils with a low clay content. Consequently, in order to gain more precise insights into these behaviors, the significant interactions were further analyzed to obtain detailed information. These responses were examined individually using crop yield components, which facilitate a better understanding of seed growth, development, and overall yield. (ESPINDULA *et al.*, 2014).

In Alegrete, the analysis of plant height (PH) indicated that both barley cultivars exhibited a quadratic polynomial trend in response to nitrogen doses (Table 2). The cultivar BRS Brau demonstrated maximum efficiency at a nitrogen dose of 122 kg ha^{-1}, resulting in a height of 63 cm. On the other hand, the cultivar BRS Cauê achieved maximum efficiency with a nitrogen dose of 154 kg ha^{-1}, resulting in a height of 66 cm. In Pelotas, both cultivars, BRS Brau and BRS Cauê, exhibited a linear trend in height increase with higher nitrogen doses, reaching heights of 76.3 cm and 72.7 cm, respectively (Figure 2a).

Analyzing the interaction between "growing environments," "barley cultivars," and "nitrogen doses" with respect to plant height, it can be observed that the cultivars BRS Brau and BRS Cauê attained greater heights in Pelotas compared to Alegrete. The increase in barley plant height in Alegrete, as a result of nitrogen doses, may be attributed to the soil type, where a more pronounced response is observed compared to Pelotas. Similar findings were reported by Espindula *et al.* (2010) and Souza *et al.* (2013), who found an increase in wheat plant height with the application of nitrogen doses of 150 kg ha^{-1} and 320 kg ha^{-1}, respectively.

Table 2 – Interaction between the “growing environment” x “barley cultivars” x “nitrogen doses” for plant height (PH).

Nitrogen doses *(kg ha⁻¹)*	Growing environments			
	Alegrete – RS		Pelotas – RS	
	Barley cultivars			
	BRS Brau	BRS Cauê	BRS Brau	BRS Cauê
80	62.07 Aβ	61.99 Aβ	72.02 Aα	71.71 Aα
120	63.81 Aβ	65.12 Aβ	76.22 Aα	68.01 Bα
160	62.39 Bβ	67.49 Aβ	74.03 Aα	72.71 Aα
200	61.07 Bβ	65.75 Aβ	76.37 Aα	70.64 Bα
CV(%)	8.20			

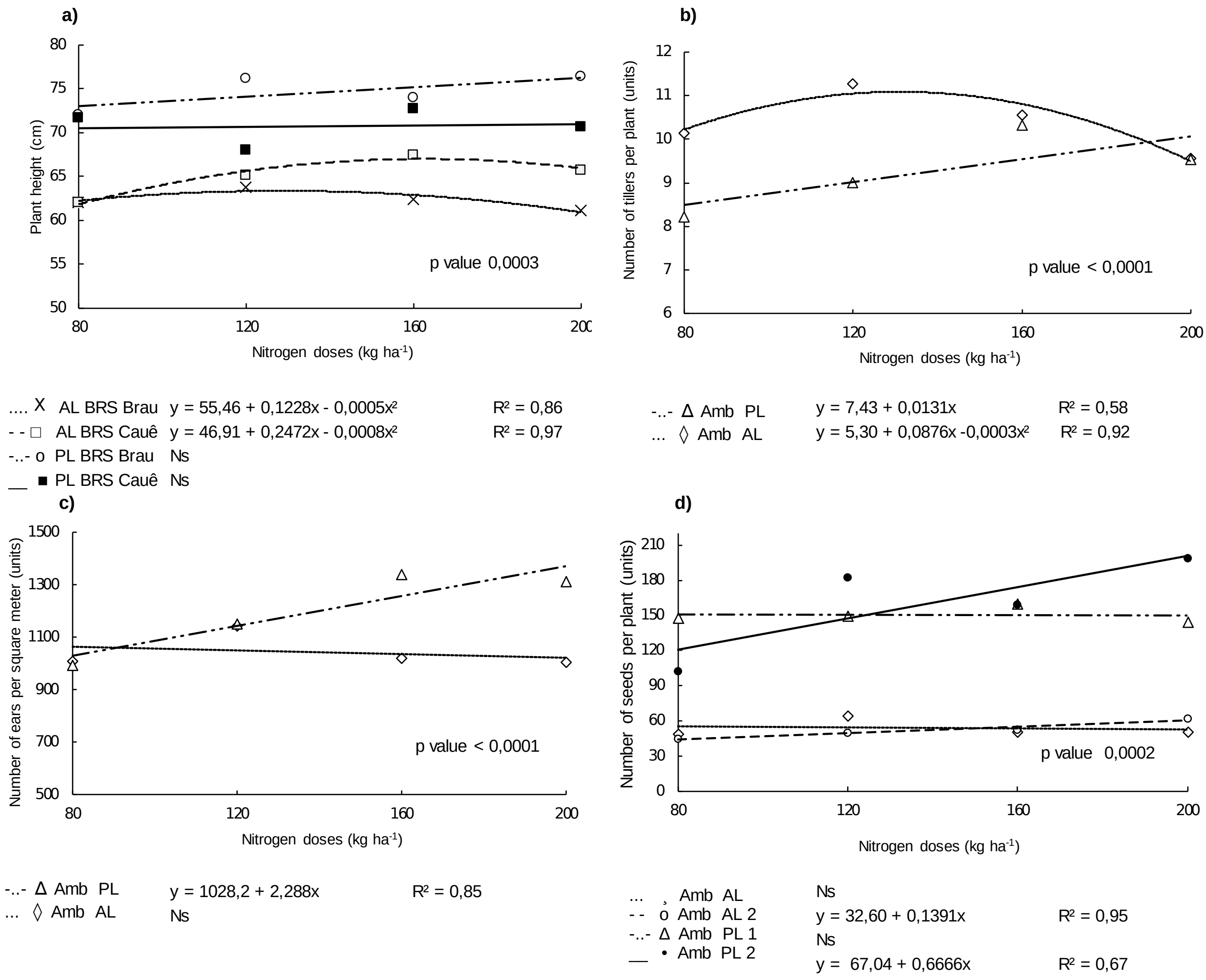
* Means followed by the same capital letter in the row (barley cultivars), and the same Greek letter in the line (growing environments) do not differ from each other according to the Tukey test at a 5% probability level.

Font: authors.

Plant height is influenced by the growing environment, plant population, and nitrogen availability. (PESKE *et al*., 2012). An increase in nitrogen availability can lead to stem elongation, which may result in higher lodging. However, taller plants are generally preferred for mechanized harvesting as they tend to have lower losses. (SCHWERZ *et al*., 2015).

Regarding the number of tillers per plant (NTP), there was a significant interaction between "growing environments," "barley cultivars," and "nitrogen doses." The highest number of tillers was observed in Alegrete with the cultivar BRS Brau (Table 3). In Alegrete, the interaction between "growing environment" and "nitrogen doses" for NTP followed a quadratic curve (Figure 2b). The maximum efficiency was achieved with a nitrogen dose of 146 kg ha^{-1}, resulting in approximately eleven tillers per plant. In Pelotas, an increase in the nitrogen dose led to an increase in NTP, reaching nine tillers per plant.

Figure 2 – Regressions for the interactions between the “growing environment” x “barley cultivars” x “nitrogen doses”. a) Plant height (PH); b) Number of tillers per plant (NTP); c) Number of ears per square meter (NESM); e d) Number of seeds per plant (NSP).
Being: (___) PL BRS Cauê, (-..-) PL BRS Brau, (- - -) AL BRS Cauê and (....) AL BRS Brau.



Font: authors.

Table 3 – Interaction between the “growing environments” x “barley cultivars” for the number of tillers per plant (NTP).

Number of tillers per plant		
Barley cultivars	**Alegrete-RS**	**Pelotas- RS**
BRS BRAU	10.90 aA	8.72 bB
BRS CAUE	9.84 bA	9.84 aA
CV (%)	34.00	

* Means followed by the same lowercase letter in the column (barley cultivars) and the same capital letter in the line (growing environments), do not differ from each other according to the Tukey test at a 5% probability level.

Font: authors.

The increase in nitrogen doses increased the number of tillers, highlighting the dose of 120 kg ha^{-1} for Alegrete. In Pelotas, the best outcome was observed with a nitrogen dose of 160 kg ha^{-1} per hectare (Table 4). According to Santos *et al.* (2017), nitrogen promotes the growth rate of new leaves in grasses, thereby increasing the emergence of new phytomers, which include various organs and an axillary bud. With higher nitrogen doses, there is an increased rate of auxiliary bud emergence, resulting in the development of new tillers.

Table 4 – Interaction between the “growing environments” x “nitrogen dose” for the number of tillers per plant (NTP).

Nitrogen doses (kg ha-1)	**Number of tillers per plant**	
	Alegrete – RS	**Pelotas – RS**
80	10.1 A	8.23 B
120	11.2 A	9.01 B
160	10.5 A	10.3 A
200	9.57 A	9.54 A
CV(%)	34.00	

* Means followed by the same capital letter in the line, do not differ from each other according to the Tukey test at a 5% probability level.

Font: authors.

Similar findings were reported by Martuscello *et al.* (2015), who observed a linear and positive influence of nitrogen fertilization on tillering, with nitrogen acting as a stimulator. A higher number of tillers is considered an important and desirable trait for winter cereals. It is influenced by environmental variations that have a positive impact on the crop, reflecting the greater phenotypic plasticity of the plants. (SANGOI *et al*., 2012).

The results indicate that the environment of Alegrete exhibited a higher number of tillers per plant at nitrogen doses of 80 and 120 kg ha^{-1} (Table 4). This could be attributed to the increased incidence of sunlight on barley plants during their growth cycle (Figure 1b), which may have induced tillering. Peri *et al.* (2007) suggested that a reduction in light intensity and prolonged periods of shading can inhibit tillering in plants. The amount of photosynthetically active radiation reaching the crop canopy is closely related to biomass production, as it influences light interception, absorption, and reflectance. (HEINEMANN *et al*., 2006).

Regarding the number of ears per square meter (NESM), there were significant interactions between "growing environment" and "barley cultivars," as well as between "growing environment" and "nitrogen doses." In Alegrete, the cultivar BRS Brau exhibited a higher number of ears per unit area. In Pelotas, the cultivar BRS Cauê followed the same trend, which differed from its performance in Alegrete (Table 5).

Table 5 – Interaction between the “growing environments” x “barley cultivars” for the number of ears per square meter (NESM).

Number of ears per square meter		
Cultivar	**Alegrete-RS**	**Pelotas- RS**
BRS Brau	1172.69 aA	1133.24 bA
BRS Cauê	915.40 bB	1266.33 aA
CV (%)	28.40	

* Means followed by the same lowercase letter in the column (barley cultivars) and the same capital letter in the line (growing environments), do not differ from each other according to the Tukey test at a 5% probability level.

Font: authors.

Based on the interaction between "growing environments" and "nitrogen doses," both Alegrete and Pelotas exhibited linear trends for the number of ears per square meter (NESM). In Alegrete, no significant differences were observed for the model. However, in Pelotas, there was a positive linear trend, where increasing nitrogen doses resulted in an increase in the number of ears per square meter, reaching 1312.56 ears (Figure 2c).

In Pelotas, the highest number of ears per unit area was achieved with nitrogen doses of 160 and 200 kg ha^{-1}, resulting in 1340.74 and 1312.56 ears per square meter, respectively (Table 6). In this particular location, nitrogen doses had a positive influence on the seed yield attribute of the number of ears, which is consistent with observations in wheat plants that respond positively to increased nitrogen levels in agricultural practices. (TEIXEIRA FILHO *et al.*, 2010).

Table 6 – Interaction between the “growing environments” x “nitrogen dose” for the number of ears per square meter (NESM).

Nitrogen doses *(kg ha^{-1})*	**Number of ears per square meter**	
	Alegrete – RS	**Pelotas – RS**
80	1008.26 A	994.30 A
120	1143.23 A	1151.53 A
160	1020.38 B	1340.74 A
200	1004.29 B	1312.56 A
CV(%)	39.10	

* Means followed by the same uppercase letter in the line, do not differ from each other according to the Tukey test at a 5% probability level.

Font: authors.

The number of seeds per plant (NSP) exhibited a significant interaction between "growing environments," "barley cultivars," and "nitrogen doses" (Table 7). In Alegrete, both cultivars demonstrated a positive linear trend in response to increasing nitrogen doses. The cultivar BRS Brau produced 51 seeds per plant at the highest nitrogen dose used, while the cultivar BRS Cauê produced 61 seeds per plant for the same dose.

In Pelotas, the cultivar BRS Brau displayed a negative linear trend with increasing nitrogen doses, resulting in 144 seeds per plant at a dose of 200 kg ha^{-1}. Conversely, the cultivar BRS Cauê exhibited a positive linear trend, reaching 198 seeds per plant for the same dose (Figure 2d). Regarding the interactions in NSP, it was observed that in Alegrete, there was no significant difference between the cultivars BRS Brau and BRS Cauê, as both exhibited an increase in the number of seeds per plant with increasing nitrogen doses. However, this increase was lower compared to that observed in Pelotas.

Table 7 – Interaction between the “growing environments” x “barley cultivars” x “nitrogen doses” for the number of seeds per plant (NSP).

Nitrogen doses *(kg ha⁻¹)*	**Number of seeds per plant**			
	Alegrete – RS		**Pelotas – RS**	
	Barley cultivars			
	BRS Brau	**BRS Cauê**	**BRS Brau**	**BRS Cauê**
80	49.03 Aβ	44.31 Aβ	148.00 Aα	101.80 Bα
120	64.65 Aβ	49.67 Aβ	149.57 Bα	182.07 Aα
160	50.65 Aβ	52.37 Aβ	160.25 Aα	159.35 Aα
200	50.65 Aβ	61.95 Aβ	144.02 Bα	198.25 Aα
CV(%)	28.40			

* Means followed by the same capital letter in the column (barley cultivars), and the same Greek letter in the line (growing environments) do not differ from each other according to the Tukey test at a 5% probability level.

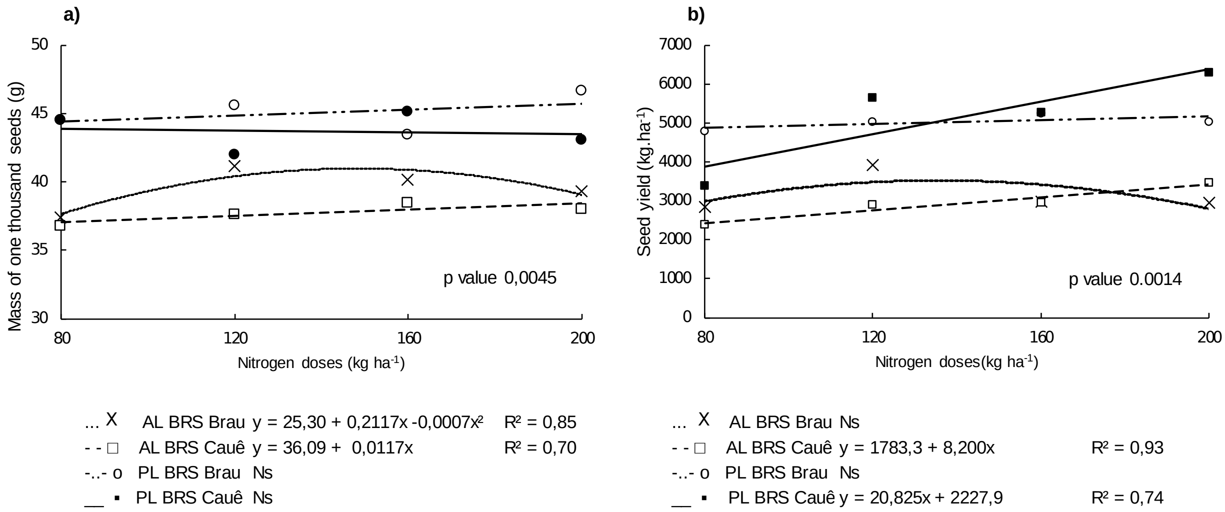
Font: authors.

The number of seeds per plant decreases depending on the incidence of diseases like head blight, insect pests, and abiotic factors inherent to the environment. Head blight, in particular, is a challenging disease to control, and there are currently no cultivars with a genetic tolerance level to this disease. Minimizing its impact can be achieved through practices such as crop rotation or the use of fungicides, as suggested by Lima (2016).

In Pelotas, the cultivars BRS Brau and BRS Cauê benefited from a higher number of seeds per plant. The increase in nitrogen dose during top dressing contributed to this increase in NSP. Cazetta *et al.* (2007) also observed similar results, obtaining higher seed yields through increased nitrogen fertilization. Espindula *et al*. (2010) explained that higher nitrogen fertilization provides greater nitrogen availability, which is important during the transition from vegetative to reproductive stages in plants.

Regarding the thousand seed weight (TSW), a positive interaction was observed between "growing environments," "barley cultivars," and "nitrogen doses." In Alegrete, the cultivar BRS Brau demonstrated a quadratic trend, with a maximum efficiency point at a nitrogen dose of 151 kg ha^{-1}, resulting in a weight of 41 grams. This represented a 9.5% increase compared to the recommended dose of 80 kg ha^{-1}. On the other hand, the cultivar BRS Cauê exhibited a linear increasing trend with higher nitrogen doses. The dose of 200 kg ha^{-1} enabled a weight of 38.0 grams, which was 5.0% higher than the recommended dose of 80 kg ha^{-1} (Figure 3a).

Figure 3 – Regression for the interaction between the "growing environment" x "barley cultivars" x "nitrogen doses". a) Thousand seed weight (TSW); e b) Seed yield (SY).



Font: authors.

In Pelotas, no significant differences were observed among nitrogen doses for the thousand seed weight (TSW). At a dose of 200 kg ha^{-1}, a weight of 46.7 grams was obtained, representing a 5% increment compared to the lowest recommended dose. Conversely, for the cultivar BRS Cauê, there was a 3.2% reduction in TSW at the highest nitrogen dose compared to the lowest recommended dose for the crop.

Barley cultivated in Pelotas exhibited a higher thousand seed weight (TSW) for both cultivars, and this difference was statistically significant compared to Alegrete (Table 8). According to Freitas *et al.* (2007), these variations in TSW can be attributed to genetic characteristics and their responses to the specific growing environment. The increase in TSW is influenced by nitrogen doses, which are associated with greater seed mass accumulation and the synthesis of reserve compounds. This, in turn, results in higher nutrient contents in the seed tissues, as noted by Rezende *et al.* (2015).

It is worth noting that there are contradictory findings in the literature regarding the effects of nitrogen use on TSW. While some authors report a positive effect, others suggest no significant difference between treatments with additional nitrogen doses. However, similar results to those presented in this work were obtained by Nunes *et al.* (2010), who observed an increase in TSW with nitrogen fertilization in wheat. Rezende *et al.* (2015) also reported a 7.69% increase in seed weight with higher nitrogen doses.

The seed yield (SY) exhibited a positive interaction between the "growing environments" x "barley cultivars" x "nitrogen doses". In Alegrete, no significant differences were observed for the cultivar BRS Brau, while the highest nitrogen dose resulted in a 12% increase in yield compared to the minimum recommended dose of 80 kg ha^{-1}. The cultivar BRS Cauê demonstrated a positive linear trend, with the dose of 200 kg ha^{-1} resulting in a seed yield of 3466 kg ha^{-1}. In Pelotas, no significant differences were found among nitrogen doses for both cultivars. The cultivar BRS Brau achieved a yield of 5028 kg ha^{-1}, while the cultivar BRS Cauê yielded 6281.25 kg ha^{-1} with the highest dose used (Figure 3b).

Table 8 – Interaction between the "growing environments" x "barley cultivars" x "nitrogen doses", for the One thousand seed weight (TSW).

Nitrogen doses *(kg ha^{-1})*	One thousand seed weight			
	Alegrete – RS		**Pelotas – RS**	
	Barley cultivars			
	BRS Brau	**BRS Cauê**	**BRS Brau**	**BRS Cauê**
80	37.43 Aβ	36.76 Aβ	44.53 Aα	44.54 Aα
120	41.13 Aβ	37.66 Aβ	45.60 Aα	42.03 Bα
160	40.18 Aβ	38.45 Aβ	43.47 Aα	45.14 Aα
200	39.31 Aβ	38.06 Aβ	46.72 Aα	43.11 Bα
CV(%)	6.90			

* Means followed by the same capital letter in the column (barley cultivars), and the same Greek letter in the line (growing environments) do not differ from each other according to the Tukey test at a 5% probability level.

Font: authors.

It was observed that Pelotas exhibited a higher seed yield compared to Alegrete (Table 9). In Pelotas, the cultivars showed statistically significant differences at doses of 80 and 200 kg ha^{-1} of nitrogen. In absolute values, the dose of 120 kg ha^{-1} of nitrogen maximized productivity for the cultivar BRS Brau, whereas for the cultivar BRS Cauê, the dose of 200 kg ha^{-1} was the most effective. These results indicate the superior efficiency of each cultivar in a specific environment, leading to improvements in production systems.

Table 9 – Interaction between the "growing environments" x "barley cultivars" x "nitrogen doses", for the seed yield (SY).

Nitrogen doses *(kg ha^{-1})*	**Seed yield**			
	Alegrete – RS		**Pelotas – RS**	
	Barley cultivars			
	BRS Brau	**BRS Cauê**	**BRS Brau**	**BRS Cauê**
80	2841.18 Aβ	2392.73 Aβ	4794.15 Aα	3380.90 Bα
120	3924.37 Aβ	2903.93 Aβ	5017.18 Aα	5641.24 Aα
160	2977.68 Aβ	2962.02 Aβ	5255.43 Aα	5270.18 Aα
200	2944.71 Aβ	3466.73 Aβ	5028.06 Bα	6281.25 Aα
CV(%)	31.16			

* Means followed by the same capital letter in the column (barley cultivars), and the same Greek letter in the line (growing environments) do not differ from each other according to the Tukey test at a 5% probability level.

Font: authors.

The growing environment and the increment of nitrogen doses had a direct influence on the yield of barley seeds. In the case of Pelotas, the effects of nitrogen fertilization on seed yield were evident. Lower yields were observed when nitrogen was applied at a dose of 80 kg ha^{-1}, while higher doses resulted in increased seed yield. This is consistent with findings by Teixeira Filho (2010) who observed that increasing nitrogen doses lead to higher grain productivity, regardless of the application timing.

The satisfactory response of barley to nitrogen fertilization can be attributed to the importance of nitrogen as a crucial nutrient for plant growth and development. Nitrogen plays essential roles in plant metabolism and physiology. Its deficiency can cause nutritional disorders, leading to reduced seed yield, shorter plant height, slower development, and a lower number of tillers. (CAMPONOGARA *et al*., 2016).

4. FINAL CONSIDERATIONS

The findings of this study highlight the significance of nitrogen supplementation in achieving higher seed yields for barley cultivated in specific regions of southern Brazil. It is clear that environmental conditions have a significant impact on barley performance, and in some instances, increasing the nitrogen dose may not lead to significant benefits in terms of seed yield.

This research has contributed to determining the appropriate nitrogen doses required to enhance seed quality, promote crop development, and achieve positive outcomes in seed yield.

By evaluating various nitrogen doses in different environments, it becomes possible to optimize production processes and make more assertive decisions regarding the most productive dose for a given environment and cultivar. The recommended nitrogen doses range from 120 to 160 kg ha-1 for both studied cultivars in these specific environments.

5. REFERENCES

ACOSTA, J. A. A. *et al*. Decomposição da fitomassa de plantas de cobertura e liberação de nitrogênio em função da quantidade de resíduos aportada ao solo sob sistema de plantio direto. **Ciência Rural**, v.44, n.5, p.801-809, 2014.

CAIRES, E. F.; MILLA, R. Adubação nitrogenada em cobertura para o cultivo de milho com alto potencial produtivo em sistema de plantio direto de longa duração. **Revista Bragantia**, v.75, n.1, p.87-95, 2016.

CAMPONOGARA, A. S. *et al.* Avaliação dos componentes de rendimento do trigo quando submetido a diferentes fontes de nitrogênio. **Revista eletrônica em Gestão**, **Educação e Tecnologia Ambiental**, v.20, n.1, p.524-532, 2016.

CAZETTA, D. A.; FORNASIEI FILHO D.; ARF, O. Resposta de cultivares de trigo e triticale ao nitrogênio no Sistema de plantio direto. **Científica**, Dracena, v.35, n.2, p.155-165, 2007.

CONAB. **Acompanhamento da safra brasileira de grãos**. Brasília: Companhia Nacional de Abastecimento, mai. 2022. v.9 – Safra 2021/22 / n.8 – Oitavo levantamento. p.1-100.

DE MORI, C.; MINELLA, E. **Aspectos econômicos e conjunturais da cultura da cevada**. Passo Fundo: Embrapa Trigo, 2012. p.28.

EMBRAPA. **Sistema Brasileiro de análise do solo**. Brasília: Empresa Brasileira de Pesquisa Agropecuária, 2005. p.374.

EMBRAPA. **Sistema Brasileiro de Classificação de Solos**. 3. ed. Rio de Janeiro: Empresa Brasileira de Pesquisa Agropecuária / Embrapa Solos, 2013. p.353.

ESPINDULA, N. C. *et al.* Doses e formas de aplicação de nitrogênio no e produção da cultura do trigo. **Ciência e Agrotecnologia**, v.34, n.6, p.1404-1411, 2010.

FERRARI, M. *et al.* Manejos e fontes de nitrogênio nos componentes de afilhamento de trigo. **Agrária (Recife. Online)**, v.11, p.178-185, 2016a.

FERRARI, M. *et al.* Morphological and yield components of wheat due to the splitting and sources nitrogen. **Australian Journal of Basic and Applied Sciences**, v.10, p.242-249, 2016b.

FREITAS, J. G. *et al.* Produtividade de cultivares de arroz irrigado resultante da aplicação de doses de nitrogênio. **Bragantia**, v.66, n.2, p.317-325, 2007.

GONDIM, T. C. O. *et al.* Análise de trilha para componentes do rendimento e caracteres agronômicos de trigo sob desfolha. **Pesquisa Agropecuária Brasileira**, v.43, n.4, p.487-493, 2008.

JAQUES, L. A. *et al*. Physiologic quality and biochemical characters of barley seeds produced under nitrogen doses and growing environments. **Journal of Agricultural Science**, v.11, n.12, p.65-78, 2019.

LIMA, M. I. **Reduzindo perdas por giberela**. Passo Fundo: Embrapa trigo, 2018. Informativo Embrapa. Available at: https://www.embrapa.br/busca-de-noticias/-/noticia/13347958/artigo---reduzindo-perdas-por-giberela. Access in: 01 apr. 2023.

NUNES, A. S.; SOUZA, L. C. F.; MERCANTE, F. M. Adubos verdes e adubação mineral nitrogenada em cobertura na cultura do trigo em plantio direto. **Bragantia**, v.70, n.2, p.432-438, 2011.

PENCKOWSKI, L. H.; ZAGONEL, J.; FERNANDES, E. C. Qualidade industrial do trigo em função do trinexapac-ethyl e doses de nitrogênio. **Ciência e Agrotecnologia**, Lavras, v.34, n.6, p.1492-1499, 2010.

PERI, P. L.; LUCAS, R. J.; MOOT, D. J. Dry matter production, morphology and nutritive value of Dactylis glomerata growing under different light regimes. **Agroforestry Systems**, v.70, n.1, p.63-79, 2007.

PESKE, S. T.; VILLELA, F. A.; MENEGUELLO, G. E. **Sementes**: fundamentos científicos e tecnológicos. 3. ed. Pelotas: Editora e Gráfica da UFPel, 2012. p.573.

PIMENTEL, J. R. *et al.* Nitrogen and sulfur association: effects on yield components and physical attributes of wheat seeds. **Journal of Agricultural Science**, v.11, n.12, p.50-64, 2019.

REZENDE, R. K. S.; MARQUES, R. F.; MASETTO, T. E. Características morfológicas e produtivas do crambe em função da adubação nitrogenada. **Revista Agrarian**, v.8, n.29, p.279-286, 2015.

SANGOI, L. *et al.* Características agronômicas de cultivares de trigo em resposta à época da adubação nitrogenada de cobertura. **Ciência Rural**, v.37, n.6, p.1564-1570, 2007.

SANGOI, L. *et al.* A remoção dos perfilhos não aumenta o rendimento de grãos de milho, independente da época de semeadura. **Ciência Rural**, v.42, n.8, p.1354-1359, 2012.

SANTOS, M. E. R. *et al.* Estrutura do dossel e característica de perfilhos em pastos de capim-piatã manejados com doses de nitrogênio e períodos de diferimento variáveis. **Revista Ciência Animal Brasileira**, v.18, n.1, p1-13, 2017.

SCHEFER, A. *et al.* Eficiência técnica e econômica da cultura da soja submetida à aplicação de fertilizantes nitrogenados em semeadura e cobertura. **Revista Scientia Agraria**, v.17, n.2, p.14-20, 2016.

SCHWERZ, F. *et al.* Growth retardant and nitrogen levels in wheat agronomic characteristics. **Científica**, Dracena, v.43, n.2, p.93-100, 2015.

SHI, R. *et al.* Influence of long-term nitrogen fertilization on micronutrient density in grain of winter wheat (Triticum aestivum L). **Journal of Cereal Science**, v.51, n.1, p.165-170, 2010.

SOUZA, W. P. *et al.* Desenvolvimento inicial de trigo sob doses de nitrogênio em Latossolo Vermelho de Cerrado. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.17, n.6, p.575-580, 2013.

TEIXEIRA FILHO, M. C. *et al.* Doses, fontes e épocas de aplicação de nitrogênio em trigo irrigado em plantio direto. **Pesquisa Agropecuária Brasileira**, v.45, n.8, p.797-804, 2010.

* Revisão de Língua Inglesa: Rafael Dal Bosco Ducatti[15]
https://orcid.org/0000-0003-2015-3103 ttp://lattes.cnpq.br/8586226056974886

Submetido em: **01/04/2023**

Aceito em: **07/07/2023**

[15] E-mail: rafaelducatti1007@gmail.com