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RESEARCH ARTICLE

THE NITROGEN IN GRAIN YIELD AND AT LODGING OAT CULTIVARS

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ABSTRACT

While promoting yield gains, nitrogen can bring huge losses by lodging. The work aimed to analyze the behavior of oat elite cultivars pattern of resistance and susceptibility to lodging the use nitrogen for grain yield and effects on lodging in favorable and unfavorable years of cultivation in Augusto Pestana and Capão do Leão on Rio Grande do Sul. Propose the recommendation of high grain yield cultivars with reduced lodging, independent of the agricultural year and indicate the breeding programs potential genotypes for advances in grain yield with resistance to lodging. The study was conducted in 2013 and 2014 in Capão do Leão and Augusto Pestana, RS, Brazil. The experimental design was a randomized block with four replications, following a factorial model in the use of three nitrogen doses (30; 90 and 150 kg ha-1) and eight elite cultivars with contrasting patterns of resistance and susceptibility to lodging.The grain yield and lodging were strongly influenced by year of cultivation. Brisasul showed high grain yield with greater resistance to lodging at the conditions of fertilization with nitrogen, independent of years and location of cultivation. The Brisasul cultivar, of reduced plant lodging and URS Corona of high grain yield, look promising in the development of segregating populations simultaneously adding favorable alleles for these traits.

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INTRODUCTION

The oats (*Avena sativa* L.) have been assuming a big highlight in the cold season of the year, mainly due to the great demand of its derivatives in the production of different food types (Crestani *et al.,* 2010; Silva *et al.,* 2012). As a winter crop, its cultivation is concentrated in the Rio Grande do Sul and Paraná states, responsible for more than 90% of national production (Conab, 2015). The grain yield is the end product of a interactions series that occurring in the oat agrosystem, because, the maximum productive potential of the crop involves the factors influence related to the management, climate and soil that can maximize the genetic potential of a cultivar (Boschini *et al.,* 2011; Simili *et al.,* 2008). Apart from this, climate changes on the planet has provided a new challenge in world agricultural production, needing of more productive cultivars and that are tolerant of environmental stresses (Araus *et al.,* 2008) and efficient in the light and nutrients use (Oliveira *et al.,* 2011). In this context, the inadequate nitrogen management contributes to the low productivity of oat grains, whose use efficiency is directly linked to the fertilizer quality, cultivation techniques and edaphoclimatic conditions (Costa *et al.,* 2013; Veloso *et al.,* 2009). It is noteworthy that high nitrogen doses, although they can increase grain yield, can favor the plant lodging, bringing losses in the production and quality grains (Silva *et al.,* 2012).

The grain yields responds significantly to the increase of the dose and the correct time of nitrogen application under favorable cultivation conditions (Denčić *et al.,* 2011;Flores *et al.,* 2012). However, in unfavorable years the use can be compromised, reducing productivity and increasing production costs, besides the losses by volatilization and leaching in the generation of environmental pollution (Ma *et al.,* 2010; Silva *et al.,* 2015; Viola *et al.,* 2013). Nitrogen dynamics studies on new genotypes available on the market are essential for updating the technical recommendations and provide more tailor-made management technologies to farmers, bringing economically satisfactory yields and with lower risk of soil and

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water pollution (Prando *et al.,* 2013; Teixeira Filho *et al.,* 2010). Thus, this study aimed to analyze the behavior of resistant and susceptible oat cultivars to lodging in the efficiency of nitrogen use in relation to grain yield in favorable and unfavorable cultivation years. To propose the recommendation of cultivars to high grain yield and low lodging with suggestion of promising combinations to the breeding programs for advances in grain yield with lodging resistance.

MATERIALS AND METHODS

In the 2013 and 2014 crop seasons were sown to field eight oat cultivars recommended for cultivation in southern Brazil. They were selected according to the high potential of grain yield and of the resistance and susceptibility to lodging from the results to joint analysis of the assays at Brazilian Oat Research Commission (CBPA), considering 18 evaluation locations between the years 2008 and 2012. Are they: Brisasul, URS FapaSlava, UPFA Ouro and URS Taura classified as lodging resistant; and the FAEM Carlasul, URS Corona, URS Guria and IAC 7 cultivars, lodging susceptible. The experiments were conducted in the municipalities of Augusto Pestana - RS, latitude 28°27' S, longitude 53°54' W, altitude of 280 m, soil classified asTypic Dystrophic Red Latosol and, Capão do Leão - RS, latitude 31°45' S, longitude 52°29' W, altitude of 13 m, soil classified as Dystrophic Yellow Red Argisol. Before sowing, was performed a soil analysis and the average of the two years, the following chemical characteristics were obtained to the location: i) Augusto Pestana (Clay = 42%; Organic matter = 3.4%; pH= 6.5; P= 20.8 mg dm^{-3}; K= 244.7 mg dm^{-3}; Al= 0.0 $cmol_c dm^{-3}$; Ca= 6.3 $cmol_c$ $dm^{-3}$and Mg= 2.5 $cmol_c$ dm^{-3}); ii) Capão do Leão (Clay= 21%; Organic matter = 2.1%; pH= 6.0; P= 22.1 mg dm^{-3}; K=120.0 mg dm^{-3}; Al= 0.2 $cmol_c$ dm^{-3}; Ca= 3.2 $cmol_c$ dm^{-3} and Mg= 2.1 $cmol_c$ dm^{-3}). The soil preparation followed the recommendations of the Brazilian Oat Research Commission with fertilization of macronutrients (NPK) in function of the levels verified in the chemical analysis of the soil of each location and yearin order to meet the demands of culture. According to the necessity, were applied fungicide of tebuconazole active ingredient (trade name FOLICUR 200 EC®) at a dose of 0.75 L ha^{-1}. Weed control was performed with herbicide of metsulfuron-methyl active ingredient (trade name ALLY®) at a dose of 4 g $ha^{-1}$and with manual weeding. All experiments were conducted following the randomized block design with four replications in a factorial arrangement 3x8, for three doses of nitrogen (30; 90 and 150 kg N ha^{-1}) and eight oat cultivars referenced previously.

The seeds of each genotype were evaluated in germination and vigor test to adjust the sowing in 350 viable seeds $m^{-2}$of area. The experimental unit (plot) was composed with five lines of 5.0 m length, spaced at 0.20 m, totaling 5.0 m^2. The harvest for the estimation of grain yield occurred manually by cutting the three central rows of each plot, and then threshing it with a stationary harvester. The grains were then directed to the laboratory for grain humidity correction to 13% and weighing, in order to estimate the yields, converted to the unit of one hectare. Plant height analysis was performed near physiological maturity, considering the average of three plants randomly evaluated in the plot. The lodging was obtained by the visual analysis of two duly trained raters and obtained an average for each experimental unit. After analyzing the assumptions of homogeneity and normality of the data via *Bartlett* and *Lilliefors* tests, analysis of variance was performed to detect the main effects and the interaction of dose, year and cultivar by cultivation location. Based on the average behavior of the cultivars in the set of environments was done the grouping of means by Scott & Knott test at 5% probability. It is noteworthy that in the ANOVA both the sources of variation cultivar as at nitrogen doses were defined as fixed effects. From this, regressions were performed to determine the behavior of each genotype under the conditions tested. All procedures and analysis were run on the GENES software (Cruz, 2013).

RESULTS AND DISCUSSION

Significant triple interaction between year, dose and cultivar were detected in the expression of grain yields and lodging, independently of location. In Capão do Leão the height of plants presented significant interaction between dose and cultivar and in Augusto Pestana between year and cultivar and significant main effect by nitrogen doses (Table1). The highest magnitude of mean square for plant height and grain yield in Capão do Leão were by cultivar source variation, except by lodging, where the nitrogen doses were most expressive (Table 1). In Augusto Pestana, the effects of cultivation year were more effective in altering grain yield and plant height. Therefore, despite the contribution of nitrogen doses and the genotypic effect, the cultivation year promoted greater effect on the expression of these variables. On the other hand, the nitrogen doses promoted greater contribution of alteration on the lodging. The differentiated performance of oat cultivars in response to changes in location and cultivation year has been observed in the conditions of southern Brazil in several traits of agronomic interest (Crestani *et al.,* 2010). The interactions between climatic conditions and the nitrogen use result in the year-to-year variations in grain yield, being the water availability is the most decisive factor (Benin *et al.,* 2012) on the efficiency of nitrogen use. Besides that, stresses caused by lack or excess water in the soil affect negatively the plant development (Guarienti *et al.,* 2005) and also causing strong volatilization and nitrogen leaching, with a direct effect on final yield. Therefore, soil and climate variability altered nitrogen availability and requirement by plant, consequently also restricting the vegetal productivity (Simili *et al.,* 2008). In Capão do Leão, the cultivation years evidenced certain stability to the productivity of grains because present very close averages in the two conditions. In Augusto Pestana, at the year of 2013 was obtained greater productivity of grains in relation to the year 2014 (Table 3).In this sense, the effective favoring of the year 2013 corroborates with the information in Figure 1, highlighting the adequate precipitation, be near of the days before fertilization with N-fertilizer as well as throughout the growing cycle. Furthermore, after fertilization, greater was the rainfall volume and distribution, condition favoring the climatic elements to elaborate grain yield. On the other hand, in 2014 there was a high rainfall precipitation, both at the beginning of the crop, harming the development of the seedling and at the end, interfering in the physiological maturation or the harvest point, compromising the filling and grains quality. Its noteworthy that in the years favoring the maximum grain yields, he cumulative total rainfall during the crop cycle was similar to the historical average of 30 years of precipitation (Table 2). However, reduced expression of grain yield in the municipality of Augusto Pestana in 2014 was conditioned by the high rainfall volume compared to the historical mean (30 years).

Table 1. Summary of variance analysis of nitrogen use in oat cultivars in the cultivation years in Capão do Leão and Augusto Pestana, RS. Pelotas, 2016

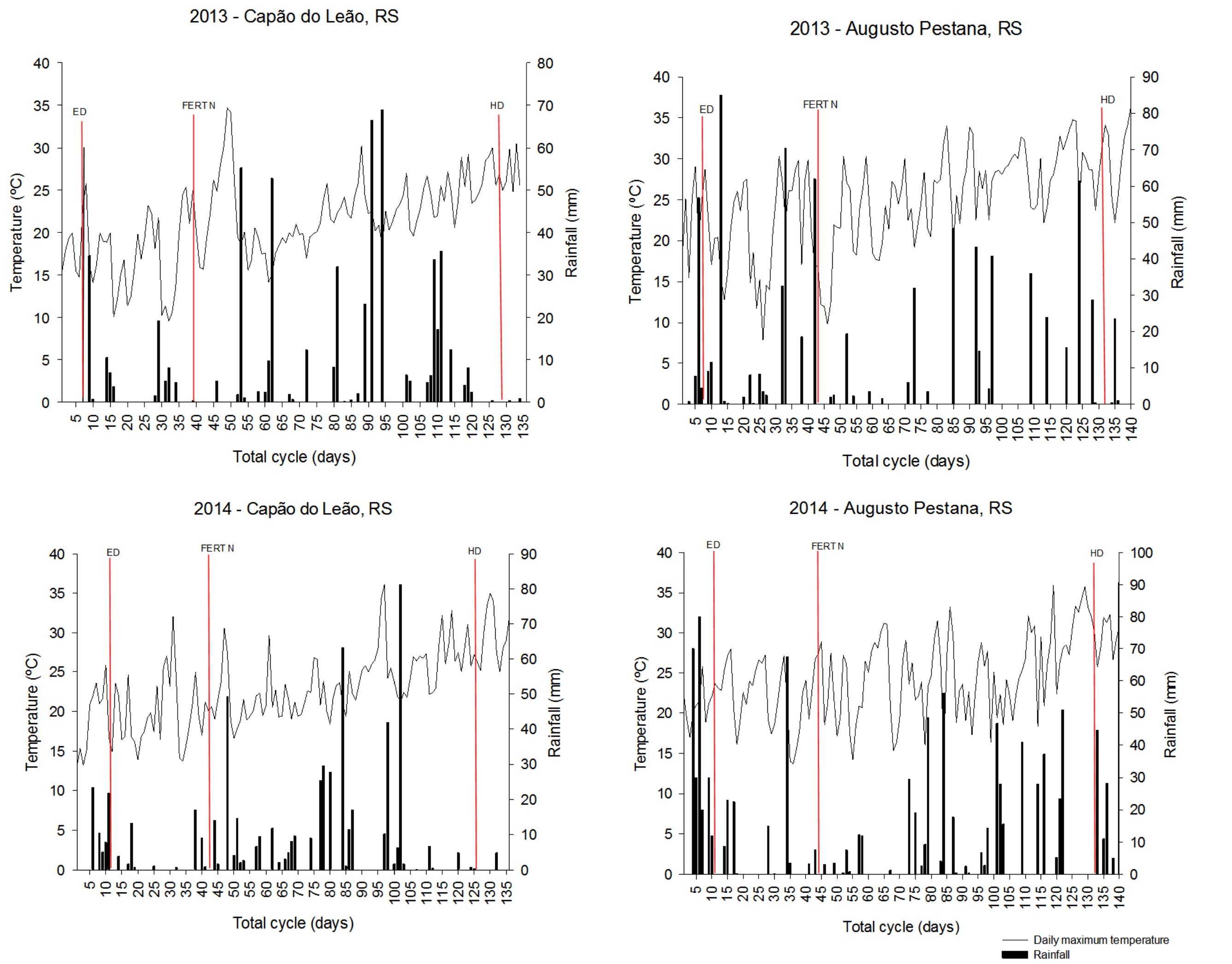
Source of variation	D.F.	Means Square		
		Lodging (%)	Height (cm)	Grain yield (kg ha^{-1})
			Capão do Leão, RS	
Block	3	164	25	210420
Year (Y)	1	7056*	111^{ns}	227631^{ns}
Dose (D)	2	35311*	123*	1320142*
Cultivar (C)	7	8811*	265*	3327182*
Y x D	2	1597*	32^{ns}	1283909*
Y x C	7	348*	27^{ns}	572926*
D x C	14	1001*	38*	180474*
Y x D x C	14	581*	19^{ns}	171966*
Error	141	49	20	80923
Total	191			
General means		40	99	2213
C.V. (%)		17.3	4.5	12.8
			Augusto Pestana, RS	
Block	3	49	117	150007
Year (Y)	1	11056*	6697*	134975022*
Dose (D)	2	46400*	1165*	1731742*
Cultivar (C)	7	10948*	626*	2285375*
Y x D	2	887*	33^{ns}	21346^{ns}
Y x C	7	1523*	89*	617764*
D x C	14	1736*	18^{ns}	99373*
Y x D x C	14	261*	30^{ns}	59018*
Error	141	39	31	47917
Total	191			
General means		39	106	1915
C.V. (%)		15.8	5.2	11.4

* Significant at 5% of error probability by test F; ^{ns}= Not significant at 5% of error probability by test F; D.F.= Degrees of Freedom; C.V.=Coefficient of variation.

Table 2. Temperature and precipitation data in the months and years of oat cultivation in Capão do Leão and Augusto Pestana, RS. Pelotas, 2016

Year	Month	Temperature (ºC)			Precipitation (mm)		Class
		Minimum	Maximum	Mean	Mean 25 years*	Occurred	
				Capão do Leão, RS			
2013	June	8.0	18.4	13.2	105.7	75.8	FY
	July	7.2	17.8	12.5	146.0	56.6	
	August	7.0	17.1	12.0	117.4	95.3	
	September	11.5	21.1	16.3	123.7	133.7	
	October	13.5	22.1	17.8	100.7	214.7	
	November	16.9	24.9	20.9	99.5	136.7	
	Total	-	-	-	693.0	712.8	
2014	June	9.6	18.2	13.9	105.7	144.7	IY
	July	10.5	18.9	14.7	146.0	207.2	
	August	9.5	20.0	14.7	117.4	82.9	
	September	12.9	21.1	17.0	123.7	143.7	
	October	15.8	23.9	19.8	100.7	254.3	
	November	16.8	26.4	21.6	99.5	104.0	
	Total	-	-	-	693.0	936.8	
				Augusto Pestana, RS			
2013	June	7.9	18.4	13.1	162.5	191.0	FY
	July	8.3	19.2	13.7	135.1	200.8	
	August	9.3	20.4	14.8	138.2	223.8	
	September	9.5	23.7	16.6	167.4	46.5	
	October	12.2	25.1	18.6	156.5	211.3	
	November	15.8	28.2	22.0	153.5	168.7	
	Total	-	-	-	913.2	1042.1	
2014	June	8.6	19.0	13.8	162.5	412.0	UY
	July	9.6	21.8	15.7	135.1	144.3	
	August	8.8	23.6	16.2	138.2	77.8	
	September	13.3	23.5	18.4	167.4	274.8	
	October	16.0	27.4	21.7	156.5	230.8	
	November	17.1	29.8	23.3	153.5	251.8	
	Total	-	-	-	913.2	1391.2	

*= Average rainfall obtained in the respective months between the years 1971 to 2001 (Capão do Leão) and 1982 to 2012 (Augusto Pestana); Class=classification suggested by the authors; FY= Favorable year; UY= Unfavorable year; IY= Intermediate Year. Source: Agroclimatological Station of Pelotas/Embrapa Temperate Agriculture (Capão do Leão); Regional Institute for Rural Development/IRDeR/UNIJUÍ (Augusto Pestana).



ED= Emergency day; FERT N= Nitrogen fertilization at 30 days after emergence; HD= Harvest day.
Source: Agroclimatological Station of Pelotas/Embrapa Temperate Agriculture (Capão do Leão); Regional Institute for Rural Development/IRDeR/UNIJUÍ (Augusto Pestana). Sowing date= Augusto Pestana: 10/07/2013 and 25/07/2014; Capão do Leão: 25/07/2013 and 29/07/2014.

Figure 1. Precipitation data and maximum temperature in the different years and cultivation locations

In this same year, in Capão do Leão, the rains remained close to the mean, but in the final phase of the cycle (Grain filling), occurred a precipitation of great proportion, followed by periods of water restriction and high temperatures. From the results of grain yield obtained, according to Table 3 and the climatic data presented in the Table 2 and Figure 1, the years were classified as being: 2013- Augusto Pestana (Favorable year=FY) and Capão do Leão (Favorable year= FY); 2014- Augusto Pestana (Unfavorable year=UY) and Capão do Leão (Intermediate year=IY). Battisti *et al*. (2013) argue that rainfall is the main meteorological variable affecting crop yields, though, the temperature, light and solar radiation are also important in the biological process to the elaboration of biomass and grains. The type of soil directly influences the amount of water available to meet the needs of agricultural crops, which in turn directly affects the development, growth and yield (Streck and Alberto, 2006). The soil water deficit hinders the processes involved in plant nutrition, showing that grain yield due to higher efficiency of nitrogen use can be considerably increased with moisture adequate (Cazetta *et al.,* 2008). Means with linear slope parameter observed (Table 3) indicate that Capão do Leão in 2013 showed low lodging values in the URS Taura, Brisasul and URS FapaSlava cultivars. Among these, highlight the URS Taura cultivar, which did not show increment of lodging in the increase of nitrogen doses.

Although the URS Taura cultivar showed lower performance in grain yield, was highlighted in the others by the significant linear tendency in the elevation of nutrient doses. Also noteworthy are the FAEM Carlasul, URS Corona and URS Guria cultivars, of the susceptible group, which evidenced a significant linear trend in the nitrogen use for grain yield. Among these, in the general means, the most expressive performance was obtained by the URS Corona cultivar. These results identify the presence of genes that allow greater of nitrogen uptake to the expression of grain yield in a favorable cultivation condition (favorable years), are being genotypes of the resistant or susceptible group to lodging. Generally, was visible the differentiation between the standard groups of lodging resistance analyzed, denoting that to every 1 kg of nitrogen applied, increases by 0.27% of lodging in the resistant group and 0.61% in the susceptible group. In the year 2014, classified as an intermediate to the oats cultivation, the differentiation between the groups was also evident. In this year, the lowest expression of the lodging was obtained in the Brisasul, URS Taura and URS FapaSlava genotypes. It is noteworthy that the elevation of the nitrogen doses did not promote an increase in the expression of the lodging in the Brisasul and URS Fapa Slava cultivars. Although grain yield has evidenced significant values in most cultivars, only the UPFA Ouro cultivar evidenced expression linearity of the grain yield with the increase of the nitrogen doses.

Table 3. Means of lodging and grain yields and linear slope parameter of nitrogen response in oat cultivars in different years and locations

Group	Cultivar	Lodging (%)				Grain yields (kg ha^{-1})			
		$\bar{X}$	$\pm b_{ix}$	P (b_{ix})	R^2	$\bar{X}$	$\pm b_{ix}$	P (b_{ix})	R^2
		Capão do Leão, RS							
		Year 2013							
Resistant	Brisasul	19.4 c	0.40x	*	83.0	2700 a	2.40x	ns	63.1
	URS Taura	5.9 c	0.07x	ns	97.2	1966 c	4.68x	*	99.7
	URS FapaSlava	12.4 c	0.21x	*	79.4	1476 d	-1.85x	ns	28.5
	UPFA Ouro	29.6 b	0.38x	*	72.9	2454 b	3.88x	ns	42.3
	Mean	16.8	0.27x	-	83.1	2149	2.28x	-	53.4
Susceptible	FAEM Carlasul	47.4 a	0.48x	*	78.2	2408 b	4.33x	*	87.2
	URS Corona	48.1 a	0.66x	*	99.7	2856 a	4.23x	*	72.5
	URS Guria	51.0 a	0.62x	*	99.8	2427 b	6.13x	*	70.6
	IAC 7	61.4 a	0.68x	*	93.8	1695 d	1.74x	ns	37.1
	Mean	52.0	0.61x	-	92.8	2346	4.11x	-	66.9
		Year 2014							
Resistant	Brisasul	24.4 b	0.19x	ns	79.0	2301 a	-0.78x	ns	44.7
	URS Taura	30.9 b	0.34x	*	96.4	2273 a	0.92x	ns	90.7
	URS FapaSlava	28.1 b	0.20x	ns	44.9	1913 b	0.70x	ns	99.4
	UPFA Ouro	42.5 a	0.21x	*	48.1	2354 a	5.18x	*	98.7
	Mean	31.5	0.24x	-	67.1	2210	1.51x	-	83.4
Susceptible	FAEM Carlasul	61.7 a	0.35x	*	77.2	2326 a	1.22x	ns	53.4
	URS Corona	50.9 a	0.53x	*	98.5	2368 a	-0.71x	ns	27.4
	URS Guria	67.8 a	0.47x	*	71.7	2390 a	2.28x	ns	13.7
	IAC 7	71.5 a	0.37x	*	90.1	1546 c	1.81x	ns	15.6
	Mean	63.0	0.43x	-	84.4	2157	1.15x	-	27.5
		Augusto Pestana, RS							
		Year 2013							
Resistant	Brisasul	6.7 c	0.13x	ns	81.2	2851 a	3.04x	ns	34.8
	URS Taura	7.3 c	0.11x	ns	92.0	2852 a	5.49x	*	78.9
	URS FapaSlava	17.6 c	0.34x	*	87.7	2491 b	0.49x	ns	23.8
	UPFA Ouro	45.3 b	0.73x	*	99.4	2849 a	1.94x	ns	77.8
	Mean	19.2	0.33x	-	90.1	2760	2.74x	-	48.8
Susceptible	FAEM Carlasul	60.4 a	0.76x	*	85.1	3112 a	3.83x	ns	80.3
	URS Corona	47.4 b	0.75x	*	99.1	2599 b	0.44x	ns	12.4
	URS Guria	35.8 b	0.60x	*	99.7	2894 a	2.21x	ns	22.7
	IAC 7	37.8 b	0.51x	*	98.5	2387 b	-0.54x	ns	72.7
	Mean	45.4	0.66x	-	95.6	2748	1.49x	-	47.0
		Year 2014							
Resistant	Brisasul	12.9 b	0.16x	*	80.0	1455 a	2.55x	ns	55.6
	URS Taura	25.6 b	0.35x	*	96.9	626 c	1.77x	ns	98.9
	URS FapaSlava	19.1 b	0.19x	*	91.2	602 c	2.27x	ns	80.8
	UPFA Ouro	47.1 a	0.52x	*	98.7	1463 a	2.30x	ns	79.7
	Mean	26.2	0.31x	-	91.7	1036	2.22x	-	78.8
Susceptible	FAEM Carlasul	65.4 a	0.56x	*	81.9	1483 a	2.68x	ns	36.6
	URS Corona	57.1 a	0.58x	*	95.1	1322 a	1.44x	ns	14.4
	URS Guria	76.5 a	0.41x	*	81.8	1169 b	-1.19x	ns	14.7
	IAC 7	62.6 a	0.44x	*	76.8	619 c	1.67x	ns	98.6
	Mean	65.4	0.50x	-	83.9	1148	1.15x	-	41.1

* and^{ns}= Significant and not significant at 5% oferror probability by test t, respectively; Averages followed by the same lowercase letter in column (In each year and place) not differ from each other at 5% significance;$\bar{X}$= General Mean; b_{ix}= Slope of the line; P(b_{ix})= Significant probability (*) or not significant (^{ns}); R^2 = Coefficient of determination, in percentage.

Therefore, identifying in this cultivar a greater ability to take nitrogen advantage under more restrictive conditions (Intermediate year). The N-fertilizer use has the great function of maximizing the productive potential in cereals, however, the nitrogen interactivity and meteorological conditions play a decisive role in plant lodging (Bredemeier *et al.,* 2013).The susceptibility to lodging may be related to excessive vegetative growth, caused by nutritional imbalance, reduced stem resistance, unfavorable climatic factors, among others (Espindula *et al.,* 2010). In studies carried out with wheat, the increase in the nitrogen doses in coverage significantly favored the plant lodging (Prando *et al.,* 2013). The authors also commented that the lodging levels suffered differences in the cultivation years, mainly due to excessive rainfall, causing more pronounced effects. The nitrogen promotes the highest plant growth and the increase of internodes length, promotes greater shading between plants, which, because they receive less radiation, modify the biophysical stem properties, leading to a lower resistance (Berry *et al.,* 2000).

In the year 2013 (Favorable year) in Augusto Pestana, similar behavior to what happened in Capão do Leão was detected, qualifying the Brisasul, URS Taura and URS FapaSlava cultivars with the lowest lodging values (Table 3). Of these cultivars, both Brisasul and URS Taura did not show significant linear growth in lodging expression in the elevation of nitrogen doses. Although the majority of the cultivars showed in general high means of grain yields, only the Taura URS cultivar indicated a positive linear trend, strengthening the hypothesis of the favorable genes presence in this cultivar the maximum efficiency of nitrogen utilization to grain yield under these conditions. In the more restrictive cultivation year (2014), reduced lodging was obtained in the Brisasul, URS Taura and URS FapaSlava cultivars.It is noteworthy that the nitrogen increment favored significantly the occurrence of plant lodging. Although the Brisasul and UPFA Ouro cultivars, from the resistant group, and FAEM Carlasul and URS Corona from the susceptible group, showed in general average, higher grain yield, there was no significant positive linearity in the

Table 4. Overall mean height and linear slope parameter of nitrogen response in oat cultivars in different years and locations. Pelotas, 2016

Group	Cultivar	Height (cm)			
		$\bar{X}$	b_{ix}	$P(b_{ix})$	R^2
		Capão do Leão, RS			
Resistant	Brisasul	102 b	0.07x	*	90.4
	URS Taura	100 b	0.05x	ns	58.1
	URS FapaSlava	100 b	0.08x	*	91.1
	UPFA Ouro	114 a	0.02x	ns	82.1
	Means	105	0.06x	-	80.4
Susceptible	FAEM Carlasul	111 a	0.05x	ns	61.1
	URS Corona	107 a	0.06x	ns	60.1
	URS Guria	108 a	0.08x	*	70.2
	IAC 7	108 a	0.08x	*	84.3
	Means	109	0.07x	-	68.8
		Augusto Pestana, RS			
General		107	0.07x	*	89.9
Group	Cultivar			Means/Years	
		2013		2014	
		Augusto Pestana, RS			
Resistant	Brisasul	A 105 b		B 98 b	
	URS Taura	A 105 b		B 95 b	
	URS FapaSlava	A 109 b		B 91 c	
	UPFA Ouro	A 120 a		B 103 a	
	Means	110		99	
Susceptible	FAEM Carlasul	A 115 a		B 107 a	
	URS Corona	A 112 a		B 102 b	
	URS Guria	A 115 a		B 102 b	
	IAC 7	A 116 a		B 100 b	
	Means	115		103	

* and ns= Significant and not significant at 5% of error probability by test t, respectively; Averages followed by the same lowercase letter in column not differ from each other at 5% significance; $\bar{X}$= General Mean; b_{ix}= Slope of the line; $P(b_{ix})$= Significant probability (*) or not significant (ns); R^2 = Coefficient of determination, in percentage.

use of higher nutrient doses. The interesting thing was that the groups of resistance and susceptibility to lodging had no relation with grain yield, for not always the genotypes with greater resistance to lodging were those that showed more expressive productivities. The results obtained in these genotypes of great acceptance of cultivation highlight the possibility of promising crosses that simultaneously add high grain yield with greater stem resistance to the lodging. The high nitrogen doses lead to a high vegetative growth in grasses causing lodging, consequently, reduces grain quality and yield (Barraclough *et al.,* 2010; Pagliosa *et al.,* 2013). In Capão do Leão, the values of plant height were not shown with a strong distinction in the average between the lodging resistance groups (Table 4). The variability among the genotypes indicated two phenotypic classes, qualifying the Brisasul, URS Taura and URS FapaSlava cultivars of shorter height. Among these, singular condition was observed in the URS Taura, the only one that did not show a significant linear tendency for increase of plant height in relation to the increment of the nitrogen dose. In Augusto Pestana, similar behavior was observed between oat cultivars, highlighting an increase of 0.07 cm per kilogram of nitrogen applied. On the other hand, differences in plant height expression were observed among genotypes in each crop year. Although the differences between years are visible, genotypes with higher resistance to lodging such as Brisasul, URS Taura and URS FapaSlava were also the ones that showed lower plant height. Thus, in these genotypes, there is a certain relationship between the lower plant height and lodging resistance. In the expression of grain yield, linear increases, quadratic behavior or absence of effects have been reported with the use of increasing nitrogen doses (Braz *et al.,* 2006). The use of high nitrogen doses may result in increased plant height, with consequent lodging, that when it occurs in the phase of grains filling, limits the translocation of carbohydrates in the plants, reducing the grains quality (Hawerroth *et al.,* 2015). However, the maximum exploitation of the cultivar genetic potential is related to the best use of environmental stimuli, suggesting that the adjustment of the nitrogen dose to the agricultural bio systems and the appropriate cultivar use can bring an efficient alternative to promote vegetal productivity (Krüger *et al.,* 2011). Including, Tavares *et al.* (2014) report that under favorable cultivation conditions, the use of high nitrogen levels are not always the most indicated, allowing with improvements in the system to maximize the use by the plant with lower fertilization.

Conclusion

The expression of grain yield and plant lodging in the biotypes resistant and susceptible to lodging went highly influenced by the crop year. Generally the Brisasul cultivar, showed high grain yield and higher resistance to lodging under low, medium and high fertilization with nitrogen, independent of years and location of cultivation. The Brisasul cultivar, of reduced plant lodging and URS Corona of high grain yield, look promising in the development of segregating populations simultaneously adding favorable alleles of these traits.

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