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Efficiency of nitrogen use by wheat depending on genotype and previous crop¹

Eficiência do uso de nitrogênio pelo trigo em função do genótipo e da safra anterior

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HIGHLIGHTS:

The selection of more efficient genotypes is related to increased productivity and food quality.

Nitrogen exerts high interference in the composition of the plant.

Productivity is higher in the high carbon: nitrogen system at the dose with expected yield of 3 t ha⁻¹.

ABSTRACT: The efficiency of nitrogen use by wheat crop depends on genetic and environmental stimuli. The aim of this study was to evaluate the efficiency of nitrogen use by wheat crop, through biomass, productivity and grain quality indicators, as a function of the genotype and previous harvest, in Southern Brazil cereal cultivation systems. The experiments were conducted in soybean/wheat and maize/wheat systems during 2015, 2016, and 2017 in Augusto Pestana, RS, Brazil. The experimental design was a randomized block with four repetitions, following a 5 × 4 factorial scheme, referring to five wheat cultivars (Quartzo, TBIO Sinuelo, TBIO Sintonia, TEC 10 and TEC Vigore) and four nitrogen doses (0, 60, 120 and 180 kg ha⁻¹) applied as a topdressing during the phenological stage of the expanded third leaf, stage 13. There were genetic differences in nitrogen use efficiency, for the productivity (yield and biomass) and quality of wheat. However, these genetic differences were influenced by the carbon:nitrogen ratios of the previous crop. Quartzo and TBIO Sinuelo had the greatest nitrogen use efficiency for grain yield, TBIO Sinuelo had the greatest nitrogen use efficiency for biomass production and Quartzo had the greatest nitrogen use efficiency for grain quality with expectation of 3 Mg ha⁻¹, regardless of the succession system, in the joint analysis of agricultural years.

Key words: *Triticum aestivum*, C:N ratio, sustainability

RESUMO: A eficiência de uso do nitrogênio pela cultura do trigo depende de estímulos genéticos e ambientais. Este estudo teve como objetivo avaliar a eficiência do uso do nitrogênio pela cultura do trigo, através dos indicadores de biomassa, produtividade e qualidade dos grãos, em função do genótipo e da safra anterior, em sistemas de cultivo do cereal no sul do Brasil. Os experimentos foram conduzidos nos sistemas soja/trigo e milho/trigo nos anos de 2015, 2016 e 2017, em Augusto Pestana, RS, Brasil. O delineamento experimental foi o de blocos casualizados com quatro repetições, seguindo o esquema fatorial 5 × 4, referente a cinco cultivares de trigo (Quartzo, TBIO Sinuelo, TBIO Sintonia, TEC 10 e TEC Vigore) e quatro doses de nitrogênio (0, 60, 120 e 180 kg ha⁻¹) aplicadas em cobertura em estágio fenológico de terceira folha expandida, estágio 13. Existem diferenças genéticas de uso do nitrogênio sobre a elaboração da produtividade e qualidade química de grãos de trigo, com influência dos sistemas de cultivo de alta e reduzida relação carbono/nitrogênio, comumente empregado no sul do Brasil. A maior eficiência de uso do nitrogênio na expressão da produtividade de grãos de trigo é obtida com as cultivares Quartzo e TBIO Sinuelo. Além disso, com a TBIO Sinuelo de maior contribuição na expressão de palha e a Quartzo na concentração de proteína dos grãos, na dose de nitrogênio para expectativa de 3 Mg ha⁻¹, independente do sistema de sucessão, na análise conjunta dos anos agrícolas.

Palavras-chave: *Triticum aestivum*, relação C:N, sustentabilidade

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INTRODUCTION

Wheat (*Triticum aestivum*) is a globally cultivated cereal, mainly for human consumption (Goergen et al., 2017; Mamann et al., 2019). In Brazil, winter wheat is economically important because of the large imports required to supply domestic demand (Arenhardt et al., 2015; Trautmann et al., 2020). Thus, there is need for scientific advancement in the genetics and management of winter wheat to promote self-sufficiency (Luche et al., 2017; Costa et al., 2018).

Nitrogen is the most required nutrient during wheat development, and can change yield and grain quality (Wrobel et al., 2016; Costa et al., 2017). The nitrogen dose required by cereals depends on the soil moisture, vegetation cover, and yield expectation (Ma et al., 2010; Mantai et al., 2015; Siqueira Neto et al., 2010; Silva et al., 2016). Genetic differences have been observed between cultivars for nitrogen absorption efficiency, assimilation and changeover, yield and grain quality (Siqueira Neto et al., 2010; Silva et al., 2015). The selection of genotypes with high nitrogen use efficiency could help in meeting the yield and grain quality demands of the domestic market and increase sustainability by reducing nutrient losses.

This study aimed to evaluate the efficiency of nitrogen use by wheat crop, through biomass, productivity and grain quality indicators, as a function of the genotype and previous harvest, in Southern Brazil cereal cultivation systems.

MATERIAL AND METHODS

This study was conducted in the agricultural years 2015, 2016 and 2017 in the municipality of Augusto Pestana, RS, Brazil (28° 26' 30" S latitude and 54° 00' 58" W longitude, and altitude of 400 m). The soil of the experimental area is classified as Oxisol and the climate of the region as Cfa type, by the Köppen classification, with hot summer without dry season. In the succession system, there is high (soy/wheat) and low (corn/wheat) release of N-residual. In the three years of study, soil analysis was performed ten days before sowing and the following chemical characteristics of the site were determined: i) maize/wheat system: (pH = 6.5, P = 34.4 mg dm⁻³, K = 262 mg dm⁻³, MO = 3.5%, Al = 0.0 cmol_c dm⁻³, Ca = 6.6 cmol_c dm⁻³ and Mg = 3.4 cmol_c dm⁻³) and; ii) soybean/wheat system: (pH = 6.2, P = 33.9 mg dm⁻³, K = 200 mg dm⁻³, MO = 3.4%, Al = 0.0 cmol_c dm⁻³, Ca = 6.5 cmol_c dm⁻³ and Mg = 2.5 cmol_c dm⁻³). The seeds were sown at 400 viable seeds m⁻² (based on germination and vigor tests) with a seeder-fertilizer (brand Máquinas SB, model Semina 1400) in five 5 m length lines spaced by 0.20 m, forming a 5 m² experimental unit. At sowing, 30 and 20 kg ha⁻¹ of P₂O₅ and K₂O, respectively, were

applied based on soil P and K concentrations to meet the grain yield expectation of 3 Mg ha⁻¹, for soil with high concentrations of these elements. During the study, tebuconazole fungicide (0.75 L ha⁻¹) and metsulfuron-methyl herbicide (4 g ha⁻¹) were applied to control pests.

In each cropping system (soybean/wheat and maize/wheat systems) two experimental studies were conducted. One to quantify biomass yield (BY, kg ha⁻¹) and another to estimate grain yield (GY, kg ha⁻¹). Therefore, the four experiments were conducted in a randomized block design with four repetitions in a factorial scheme of 5 x 4 for the five wheat cultivars (Quartzo, TBIO Sinuelo, TBIO Sintonia, TEC 10 and TEC Vigore) and four nitrogen doses (0, 60, 120, and 180 kg ha⁻¹). The main characteristics of the wheat cultivars used in this study are presented in Table 1.

The harvest to estimate grain yield and biomass was obtained by cutting the three central lines of each plot, close to maturity (125 days) with grain moisture at 15%. The plots were threshed with a stationary threshing machine (brand Maquinas SB, model Semina 1400), weighed and corrected to 13% grain moisture to estimate grain yield. The plots for estimating biomass yield were dried in a forced-air oven at 65 °C until constant weight was obtained. The values from biomass and grain yield were used to predict straw yield (SY, kg ha⁻¹ = BY-GY) and harvest index (HI, kg kg⁻¹ = GY/BY). The determination of crude protein (CP%), crude fiber (CF%) and starch (ST%), was done by sampling the unhulled grains using near infrared spectrophotometry (NIRS) Perten, model Diode Array DA7200. The meteorological data of air temperature and rainfall were obtained from a Total Automatic Station installed (brand Davis), electronically operated, located 500 m from the experimental area.

By following the assumptions of homogeneity and normality via Bartlett tests, variance analysis was performed to detect the significance of the main effects and the interaction between the cultivars and N doses by joint analysis of agricultural years. The varieties were compared by the Scott-Knott test, whereas nitrogen doses were compared with regression equation adjustment (linear or quadratic).

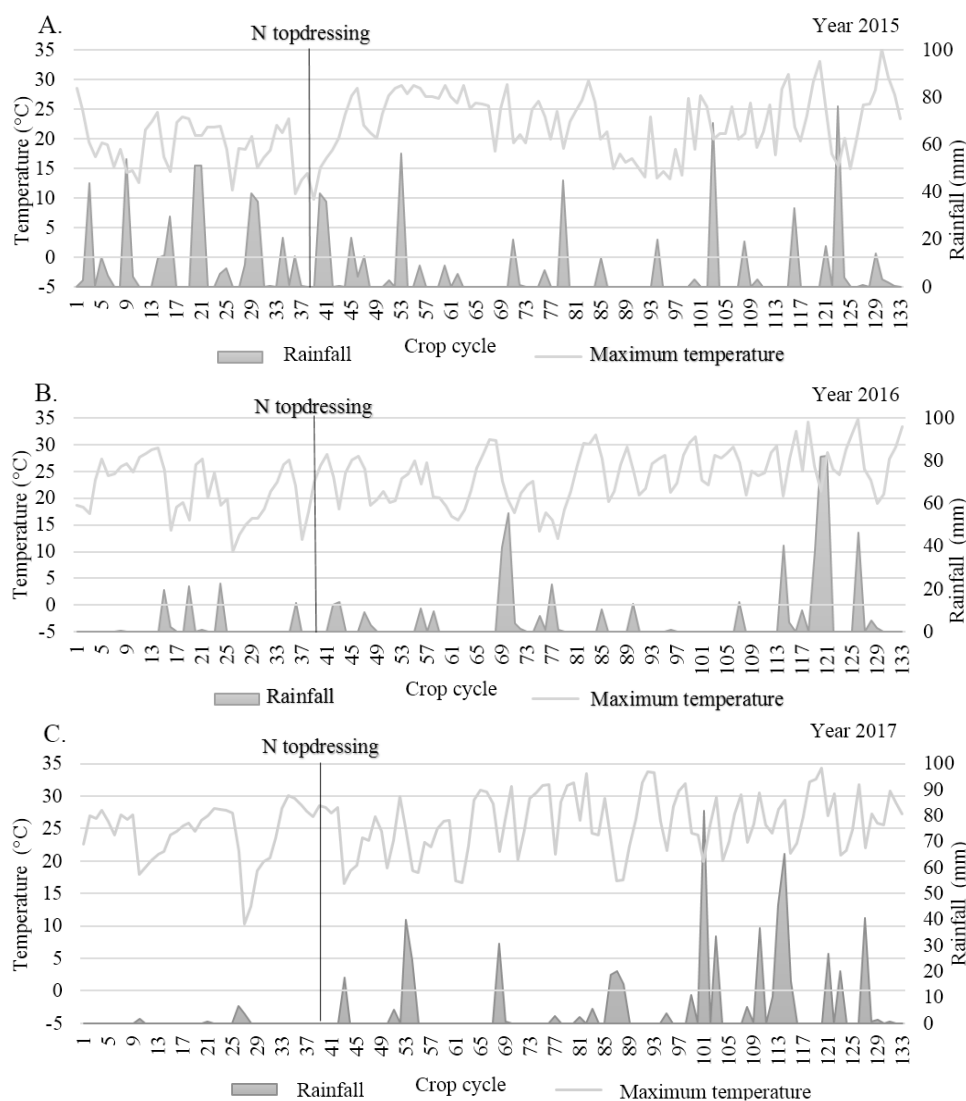
RESULTS AND DISCUSSION

In 2015 (Figure 1A), the maximum temperature remained higher at the beginning of the wheat development cycle, which may have quickly favored elongation with reduced production of new tillers, a component directly linked to grain yield. The amount of rainfall was significant during the entire growing cycle, mainly after nitrogen application, this promoted greater nitrogen losses by lixiviation. In 2016 (Figure 1B),

Table 1. Main characteristics of the five wheat cultivars evaluated for nitrogen use efficiency

Characteristic	Cultivars				
	TBIO Sintonia	TBIO Sinuelo	Quartzo	TEC Vigore	TEC 10
Cycle	Early	Medium-late	Medium	Early	Medium
Height	Medium	Medium-short	Medium	Medium	Medium
Logding	MR	R/MR	MR	MR	MR
Leaf rust	MS	MR	MR/MS	R	MR
Leaf spots	MR/MS	R/MR	MR	MR/MS	MR
Technological class	Bread	Bread	Bread	Bread	Bread

* MR - Moderately resistant; MS - Moderately susceptible; R - Resistant



Data was obtained from the automatic station located 500 m from the experimental area of the Regional Institute of Rural Development/IRDeR

Figure 1. Rainfall and maximum air temperature at the wheat cycle and the time of nitrogen supply

the maximum temperature remained mild before and after N-fertilizer usage with favorable condition of soil moisture. The amount of rainfall was higher at the end of the growing cycle and could lead to damage of the product during harvest. In 2017 (Figure 1C), the maximum temperature was higher and with reduced rainfall all over the crop cycle, which favored greater nitrogen losses by volatilization.

The information provided in Figure 1 shows different environmental conditions, promoting the potentialization of results presented in the general context, providing an agronomic response more independent of the year condition, for analysis of the genetic efficiency of nitrogen use on grain yield and quality.

Rainfall is highlighted as one of the main factors responsible for agricultural yield variation. Prior knowledge of rainfall condition may indicate management ways that ensure crop success (Arenhardt et al., 2015; Scremin et al., 2017). In winter cereals, there is less rainfall but it sustains suitable soil moisture and is well distributed over the cycle, this characterizes a favorable environment to nitrogen management and higher productivity (Marolli et al., 2018; Silva et al., 2020). Besides rainfall, air temperature seriously affects nitrogen use and

yield expression. Temperature acts as a biological process catalyzer, whereby plants need a minimum and maximum temperature for normal physiological activities (Tonin et al., 2014; Marolli et al., 2017). In cereals such as oat and wheat, milder temperature and radiation quality favor new tillers and grains grow impacting productivity (Arenhardt et al., 2015; Trautmann et al., 2020). In nitrogen management, the occurrence of intense rainfall right after fertilization, reduces the plant's efficiency due to lack of oxygenation and generates nutrient loss by leaching. Also, higher temperatures reduce fertilizer efficiency due to losses by volatilization (Ercoli et al., 2013; Scremin et al., 2017).

Analysis of variance detected significance between the main effects and the interaction between cultivars and N doses in the combined analysis of agricultural years (table not shown).

In the soybean/wheat system, TBIO Sinuelo had the highest grain yield, regardless of the N-fertilizer dose (Table 2).

For straw yield, TBIO Sintonia and Sinuelo recorded the highest values for the higher (120 and 180 kg ha⁻¹) and lower nitrogen doses (0 and 60 kg ha⁻¹), respectively. Consequently, these two cultivars had lower harvest indices at these rates. In the soybean/wheat system, there were no differences between

Table 2. Mean yield and quality of five wheat grain genotypes at each nitrogen dose in a soybean/wheat system

Cultivars	N doses (kg ha ⁻¹)				N doses (kg ha ⁻¹)			
	0	60	120	180	0	60	120	180
	(2015 + 2016 + 2017)							
	Grain yield (kg ha ⁻¹)				Starch (%)			
Quartzo	1306b	2548a	2933a	3592a	70.02a	70.00a	69.70a	69.52a
TBIO Sintonia	1529a	2410b	2695b	3618a	69.06a	68.92a	68.17a	67.50a
TBIO Sinuelo	1410a	2637a	3076a	3708a	69.37a	70.30a	70.27a	70.20a
TEC 10	1107c	2032c	2417c	3105b	69.32a	69.42a	68.67a	69.67a
TEC Vigore	1304b	1838d	2565b	2250c	68.67a	68.27a	68.12a	66.60a
	Straw yield (kg ha ⁻¹)				Crude protein (%)			
Quartzo	3647b	6644b	9410b	8997a	12.5b	12.6c	13.1c	13.7c
TBIO Sintonia	2916c	4067d	10647a	8489a	13.5a	14.0a	14.7a	15.4a
TBIO Sinuelo	4912a	7652a	8558c	7741b	12.2b	12.2c	12.5d	12.8d
TEC 10	4482a	5590c	9810b	6837c	13.1a	13.4b	13.9b	14.5b
TEC Vigore	4766a	5256c	6862d	6951c	13.7a	14.1a	14.4a	15.9a
	Harvest index (kg kg ⁻¹)				Crude fiber (%)			
Quartzo	0.26b	0.27b	0.24b	0.28c	3.22a	3.22a	3.17a	3.27a
TBIO Sintonia	0.34a	0.37a	0.20c	0.30b	3.17a	3.17a	3.20a	3.27a
TBIO Sinuelo	0.22c	0.25b	0.26a	0.32a	3.22a	3.22a	3.27a	3.27a
TEC 10	0.20c	0.27b	0.20c	0.31a	3.27a	3.17a	3.22a	3.20a
TEC Vigore	0.21c	0.26b	0.27a	0.24d	3.30a	3.27a	3.27a	3.27a

* Means followed by the same letters in columns do not differ statistically from each other at $p \leq 0.05$ by the Scott-Knott test

cultivars for the starch content and crude fiber in all nitrogen doses.

In all N doses, TBIO Sintonia and TEC Vigore were always the best cultivars. In the maize/wheat system, the cultivar Quartzo had the highest grain yield in all nitrogen doses (Table 3).

For straw yield, TBIO Sinuelo presented the greatest values for all nitrogen doses, except 0 kg ha⁻¹. The harvest index varied between cultivars at different nitrogen doses. In the maize/wheat system, the starch and crude fiber results were also similar to the results obtained in the soybean/wheat system, supporting the absence of linear relation on these variables, with nitrogen Quartzo having the highest grain protein concentration for all nitrogen doses.

In Table 4, regression analysis in the soybean/wheat system, the increase in nitrogen doses promoted linear increases with significant angular coefficient on grain yield in the Quartzo,

TBIO Sintonia and TBIO Sinuelo cultivars. TEC Vigore was the only cultivar that had reached maximum yield before the highest nitrogen dose, possibly indicating less nitrogen use efficiency.

For straw yield, all cultivars showed quadratic behavior, which indicates that the variable reached stability at a relatively low nitrogen dose. The harvest index for the cultivars Quartzo and TBIO Sintonia, was not significant. However, TBIO Sinuelo showed a linear response and TEC 10 and TEC Vigore both had quadratic responses to increases in nitrogen dose. Only grain protein had a significant positive linear response to nitrogen dose.

The inclusion of 60 kg ha⁻¹ nitrogen dose in the soybean/wheat system in the significant regression model for each variable, indicated greater grain yield in the combined analysis of the crop year for the cultivars Quartzo, TBIO Sintonia and TBIO Sinuelo. At this dose, TBIO Sinuelo

Table 3. Average yield and quality of five wheat grain genotypes at each nitrogen dose in a maize/wheat system

Cultivars	N doses (kg ha ⁻¹)				N doses (kg ha ⁻¹)			
	0	60	120	180	0	60	120	180
	(2015 + 2016 + 2017)							
	Grain yield (kg ha ⁻¹)				Starch (%)			
Quartzo	1133a	2507a	3119a	2631a	67.80a	69.40a	69.72a	70.00a
TBIO Sintonia	942b	2520a	2725b	2633a	68.77a	69.87a	69.17a	69.10a
TBIO Sinuelo	1166a	2612a	2846b	2277c	69.30a	70.07a	69.07a	69.30a
TEC 10	1055a	2167c	2651c	2437b	68.77a	68.77a	69.62a	68.80a
TEC Vigore	1016a	2304c	2470d	2254c	68.70a	68.77a	69.32a	68.97a
	Straw yield (kg ha ⁻¹)				Crude protein (%)			
Quartzo	4638a	6502a	8729b	7693b	12.5a	13.0a	13.5a	14.9a
TBIO Sintonia	4289b	5690b	8842b	6653c	12.5a	12.7b	12.9b	13.1b
TBIO Sinuelo	4254b	6302a	9994a	8217a	12.3a	12.5b	12.7b	13.4b
TEC 10	4806a	5313b	5853c	5206d	12.2a	12.9a	13.3a	13.7b
TEC Vigore	5113a	5286b	6327c	7316b	12.9a	12.9a	13.1a	13.6b
	Harvest index (kg kg ⁻¹)				Crude fiber (%)			
Quartzo	0.20a	0.28b	0.26b	0.25c	3.37a	3.27a	3.32a	3.22a
TBIO Sintonia	0.18b	0.31a	0.24c	0.28b	3.27a	3.17a	3.37a	3.30a
TBIO Sinuelo	0.21a	0.29b	0.22c	0.22d	3.22a	3.22a	3.27a	3.27a
TEC 10	0.18b	0.29b	0.31a	0.32a	3.27a	3.27a	3.27a	3.37a
TEC Vigore	0.17b	0.30a	0.28b	0.24c	3.27a	3.32a	3.30a	3.27a

* Means followed by the same letters in columns do not differ statistically from each other at $p \leq 0.05$ by the Scott-Knott test

Table 4. Mean yield estimate and quality of wheat in the soybean/wheat system

Cultivars	Y	MS _Y	Equation Y = a ± bx ± cx ² (2015 + 2016 + 2017)	CV	R ²	N _{3t ha⁻¹} (kg ha ⁻¹)	Y _{ET}
				(%)	(%)		
Quartzo (Bread)	GY (kg ha ⁻¹)	104980*	1508+12.07*x	12.8	94	60	2232 A
	SY (kg ha ⁻¹)	116315*	3499+73.99*x-0.23*x ²	10.1	97		7110 B
	HI (kg kg ⁻¹)	0.0012*	0.27-0.00038x+0.0000024x ²	8.7	-		-
	ST (%)	0.6480*	70.08-0.0030x	5.1	-		-
	CP (%)	3.2401*	12.39+0.0067*x	4.3	92		12.7 C
	CF (%)	0.0100 ^{ns}	-	-	-		-
TBIO Sintonia (Breeder)	GY (kg ha ⁻¹)	8590980*	1580+10.92*x	14.3	96	60	2235 A
	SY (kg ha ⁻¹)	1095270*	2208+80.19*x-0.22*x ²	9.4	74		6227 C
	HI (kg kg ⁻¹)	0.00490*	0.36-0.0014x+0.0000048x ²	9.6	-		-
	ST (%)	9.94050*	69.60-0.01x	7.2	-		-
	CP (%)	8.51512*	13.45+0.01*x	6.6	99		14.0 A
	CF (%)	0.02112*	3.15+0.00060x	7.1	-		-
TBIO Sinuelo (Bread)	GY (kg ha ⁻¹)	107619*	1607+12.22*x	10.5	95	60	2340 A
	SY (kg ha ⁻¹)	126558*	4917+60.12*x-0.24*x ²	10.1	99		7660 A
	HI (kg kg ⁻¹)	0.01922*	0.22+0.00051*x	9.8	91		0.25 A
	ST (%)	1.2005 ^{ns}	-	-	-		-
	CP (%)	1.08112*	12.13+0.0038*x	6.9	94		12.3 C
	CF (%)	0.0080 ^{ns}	-	-	-		-
TEC 10 (Bread)	GY (kg ha ⁻¹)	813513*	1208+10.62*x	13.6	97	60	1845 B
	SY (kg ha ⁻¹)	169924*	3966+69.82*x-0.28*x ²	12.8	66		7147 B
	HI (kg kg ⁻¹)	0.02048*	0.21-0.00000050x+0.00060x ²	9.9	-		-
	ST (%)	1.4580 ^{ns}	-	-	-		-
	CP (%)	4.46512*	13.03+0.0078*x	7.4	97		13.4 B
	CF (%)	0.00612 ^{ns}	-	-	-		-
TEC vigore (Bread)	GY (kg ha ⁻¹)	2546124*	1242+16.55*x-0.060*x ²	15.4	91	60	2019 B
	SY (kg ha ⁻¹)	421867*	4634+18.61*x-0.027*x ²	12.1	90		5653 D
	HI (kg kg ⁻¹)	0.00525*	0.20+0.0012x-0.0000050x ²	10.6	92		0.25 A
	ST (%)	8.12812*	68.87-0.010x	6.1	-		-
	CP (%)	9.31612*	13.50+0.011*x	4.5	85		14.1 A
	CF (%)	0.00062 ^{ns}	-	-	-		-

Y - Variable; MS_Y - Mean square of the variables Y; P(b_{ix}) - Parameters of the equation; R² - Coefficient of determination; N_{3t ha⁻¹} - Nitrogen dose to 3 Mg ha⁻¹ expectation; Y_{ET} - Estimated values by nitrogen dose to expectation of 3 Mg ha⁻¹; ns, * - Not significant, significant at p ≤ 0.05 by the F test, respectively; GY - Grain yield; SY - Straw yield; HI - Harvest index; ST - Starch; CP - Crude protein; CF - Crude fiber

showed the highest straw yield expression, TBIO Sinuelo and TEC Vigore the highest harvest index and TBIO Sintonia and TEC Vigore, the highest crude protein concentration in the grain.

In Table 5, regression analysis in the maize/wheat system showed significant quadratic behavior for the grain yield of all cultivars, unlike what occurred in the soybean/wheat system. This may be due to differences in the carbon:nitrogen ratio of the previous crop. The straw yield also showed significant quadratic behavior for all the cultivars, except TEC Vigore with significant linearity due to nutrient usage. The harvest index analysis showed significant quadratic behavior for all cultivars. Grain crude protein was the only chemical variable that showed linear behavior for all cultivars, except TBIO Sintonia. In the maize/wheat system at the 90 kg ha⁻¹ nitrogen dose, the significant regression model for each variable indicated greater grain yield for Quartzo and TBIO Sinuelo, which did not differ. For this nitrogen dose, TBIO Sinuelo showed the highest straw yield expression, TEC Vigore the highest harvest index and the cultivars Quartzo, TEC 10 and TEC Vigore the highest grain crude protein content.

Benin et al. (2012) observed variability in wheat cultivars in response to nitrogen usage and a positive effect of fertilizer level on grain yield components. They also noted that the cultivars' genetic variability in nitrogen use evinces a greater contribution than the fertilization levels. Sangoi et al. (2007) reported that the cultivars' technological classes

can interfere with the absorption capacity, assimilation, nitrogen exchange and yield. This is because cultivars differ substantially in their ability to emit tillers, in their cycle, in plant architecture and in production potential. In addition, each year new genotypes are launched, and because they have a different genetic basis, may present a different response to the dose and timing of nitrogen application. Silva et al. (2015) observed that wheat cultivars of high technological quality can express average values in production components higher than those of lower quality. These authors observed efficiency alteration on nitrogen use through the type of residual cover of high and low Carbon:Nitrogen ratios, with 78 and 114 kg ha⁻¹ of N-fertilizer in soybean/wheat and maize/wheat, respectively.

In oats, Mantai et al. (2015) found a growth trend in the biomass rate with the increase in nitrogen doses, a condition not always accompanied by higher grain yield. Todeschini et al. (2016) found that nitrogen use efficiency is defined by the genetic capacity of the cultivar to absorb and transform nutrients in the biomass and grains. Schmidt et al. (2009) realized greater efficiency of wheat cultivars in absorbing nitrogen and converting it into crude protein. This linear increase promotes higher consumption of carbohydrates through protein synthesis, which can reduce starch accumulation and compromise grain yield expression. This condition was also observed by Ferrari et al. (2016), who found that nitrogen use increases grain protein content

Table 5. Regression of yield estimate and quality of wheat in a maize/wheat system

Cultivars	Y	MS _Y	Equation Y = a ± bx ± cx ² (2015 + 2016 + 2017)	CV	R ²	N _{3t ha⁻¹} (kg ha ⁻¹)	Y _{ET}
				(%)	(%)		
Quartzo (Bread)	GY (kg ha ⁻¹)	346704*	1116+31.78*x-0.12*x ²	14.4	99	90	3004A
	SY (kg ha ⁻¹)	840420*	4457+55.22*x-0.20*x ²	13.7	92		7806B
	HI (kg kg ⁻¹)	0.0085*	0.20+0.0013*x-0.0000064*x ²	9.2	82		0.26B
	ST (%)	1.7556 ^{ns}	-	-	-		-
	CP (%)	5.8806*	12.32+0.012*x	6.8	92		13.4A
	CF (%)	0.0320*	3.36-0.00066x	5.5	-		-
TBIO Sintonia (Breeder)	GY (kg ha ⁻¹)	278723*	996+29.66*x-0.11*x ²	12.7	97	90	2774B
	SY (kg ha ⁻¹)	128916*	3934+61.95*x-0.24*x ²	12.2	77		7565B
	HI (kg kg ⁻¹)	0.0060*	0.19+0.0013*x-0.0000053*x ²	10.6	76		0.26B
	ST (%)	1.3806 ^{ns}	-	-	-		-
	CP (%)	0.2025 ^{ns}	-	-	-		-
	CF (%)	0.0006*	3.24+0.00045x	6.8	-		-
TBIO Sinuelo (Bread)	GY (kg ha ⁻¹)	446793*	1186+31.13*x-0.14*x ²	14.3	99	90	2854A
	SY (kg ha ⁻¹)	146306*	3898+73.78*x-0.26*x ²	13.3	86		8432A
	HI (kg kg ⁻¹)	0.0076*	0.22+0.0009*x-0.000006*x ²	8.8	-		0.25B
	ST (%)	0.3025 ^{ns}	-	-	-		-
	CP (%)	1.8225*	12.20+0.0058*x	5.9	90		12.7B
	CF (%)	0.0080 ^{ns}	-	-	-		-
TEC 10 (Bread)	GY (kg ha ⁻¹)	176026*	1051+24.29*x-0.092*x ²	10.6	99	90	2491C
	SY (kg ha ⁻¹)	132940*	4745+17.31*x-0.080*x ²	11.1	-		5655D
	HI (kg kg ⁻¹)	0.0105*	0.18+0.0020*x-0.0000071*x ²	8.1	97		0.30A
	ST (%)	0.6806 ^{ns}	-	-	-		-
	CP (%)	1.2656*	12.29+0.0082*x	6.9	97		13.0A
	CF (%)	0.0180*	3.25+0.00050x	7.1	-		-
TEC vigore (Bread)	GY (kg ha ⁻¹)	114811*	1053+25.26*x-0.10*x ²	15.6	97	90	2516C
	SY (kg ha ⁻¹)	117106*	4862+12.75*x	13.8	93		6009C
	HI (kg kg ⁻¹)	0.0210*	0.17+0.0024*x-0.000010*x ²	9.4	79		0.30A
	ST (%)	0.1806 ^{ns}	-	-	-		-
	CP (%)	0.1806*	12.78+0.0038*x	5.2	80		13.1A
	CF (%)	0.0056 ^{ns}	-	-	-		-

Y - Variable; MS_Y - Mean square of the variables Y; P(b_{ix}²) - Parameter that measures the slope significance of the line; R² - Coefficient of determination; N_{3t ha⁻¹} - Nitrogen dose to 3 Mg ha⁻¹ expectation; Y_{ET} - Estimated values by nitrogen dose to expectation of 3 Mg ha⁻¹; ns, * - Not significant, significant at p ≤ 0.05 by the F test, respectively; GY - Grain yield; SY - Straw yield; HI - Harvest index; ST - Starch; CP - Crude protein; CF - Crude fiber

and reduces grain yield. Pinnow et al. (2013) showed that the wheat grain protein concentration increases as a function of the N-fertilizer dose and the reminiscent lower carbon:nitrogen ratio contributes to grain protein increase. Henz et al. (2016) asserted that N-fertilizer linearly and positively changes forage production and wheat grain, with emphasis on chemical composition by mineral matter, crude protein, non-fibrous carbohydrates and fibers.

The results presented in this study indicate that the genetic variability between cultivars, in response to N-fertilizer and type of residual cover, is an important strategy to maximize productivity and wheat grain quality.

CONCLUSIONS

1. There are genetic differences in nitrogen use productivity and wheat grain quality, influenced by the higher and lower carbon:nitrogen ratios of the main crop systems, commonly used in Southern Brazil.

2. The greatest effect of nitrogen use efficiency on the expression of wheat grain yield was obtained with the cultivars Quartzo and TBIO Sinuelo. In addition, TBIO Sinuelo had the greatest straw yield, and Quartzo the greatest protein concentration, in the nitrogen dose expected for 3 Mg ha⁻¹, regardless of the succession system, in the joint analysis of agricultural years.

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