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Agronomic performance of wheat BRS Tarumã under different sowing densities, nitrogen fertilization and cutting managements

Desempenho agronômico de trigo BRS Tarumã em resposta a diferentes densidades de semeadura, adubação nitrogenada e manejos de corte

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Abstract

The use of dual-purpose wheat can be an important tool for the diversification of activities and farm profitability. The objective of this study was to evaluate forage production and grain yield in dual-purpose wheat cultivar BRS Tarumã under different nitrogen doses, sowing densities and cutting managements. The experimental design was completely randomized, with four replications, in a factorial arrangement (sowing density x nitrogen doses), in the main plots, with subdivided plots (cutting managements). The sowing densities used were 400 and 500 suitable seeds m^{-2}. Nitrogen rates were 100, 150, 200, 250 and 300% of the recommended dose, applied at the base, at tillering and after each cut. The subplots were divided according to the cutting management (no cut, a single cut and two cuts). There was no significant interaction between nitrogen doses, sowing density and cutting management for the evaluated characteristics. Nitrogen doses and sowing density did not affect grain and forage yield, therefore the dose of 80 kg ha^{-1} and 400 suitable seeds m^{-2} allowed maximum grain yield. The cutting management did not change grain size or yield. However, the second cut promoted greater forage accumulation and did not reduce grain yield, therefore, it is feasible to use it for dual-purpose production. The forage crude protein content decreased in the second cut, but was higher than 22%.

Additional keywords: crop-livestock integration; forage production; grain yield; *Triticum aestivum*.

Resumo

A utilização de trigo de duplo propósito pode constituir-se em importante ferramenta de diversificação de atividades e da composição de renda da propriedade. O objetivo do trabalho foi avaliar a produção de forragem e a produtividade de grãos, em cultivar de trigo de duplo propósito BRS Tarumã, submetidos a diferentes doses de nitrogênio, densidades de semeadura e regimes de corte. Utilizou-se o delineamento experimental inteiramente casualizado, com quatro repetições, em um arranjo fatorial (densidade de semeadura x doses de nitrogênio), nas parcelas principais, com parcelas subdivididas (manejos de corte). As densidades de semeadura utilizadas foram de 400 e 500 sementes aptas m^{-2}. As doses de nitrogênio foram de 100; 150; 200; 250 e 300% da dose recomendada, aplicadas na base, no perfilhamento e após cada corte. As subparcelas foram divididas conforme o manejo de corte (sem corte, um corte e dois cortes). Não houve interação significativa entre as doses de nitrogênio, a densidade de semeadura e o manejo dos cortes para as características avaliadas. As doses de nitrogênio e a densidade de semeadura não alteraram a produtividade de grãos e de forragem, portanto a dose de 80 kg ha^{-1} e 400 sementes aptas m^{-2} permitiu alcançar a máxima produtividade de grãos. O manejo de cortes não alterou a produtividade nem o tamanho dos grãos. Entretanto, o segundo corte promoveu maior acúmulo de forragem e não reduziu a produtividade de grãos, e, portanto, viabiliza seu aproveitamento para duplo propósito. O teor de proteína bruta na forragem reduziu no segundo corte, porém foi superior a 22%.

Palavras-chave adicionais: integração lavoura-pecuária; produção de forragem; produtividade de grãos; *Triticum aestivum*.

Introduction

In southern Brazil, the forage availability and nutritional quality of pastures are reduced during the fall and early winter. During this period, summer species reduce growth and winter species have not grown yet. Due to this seasonality in forage production, winter cereals with longer vegetative cycle and forage aptitude have been used as a viable alternative for the use of areas that are normally occupied by grain production in the summer (Ferolla et al., 2010; Santos et al., 2011). This broader view of agricultural activity allows winter cereals with forage aptitude to be grown in order to provide green fodder in the autumn period and still produce grain. Winter cereals normally grown for the purpose of producing grain and fodder are white oat, black oat, rye, barley, triticale and wheat.

Dual-purpose wheat cultivars must have a long vegetative cycle and short reproductive cycle, in addition to high forage yield and regrowth capacity to recover the shoots that will support grain production (Scheffer-Basso et al., 2001). For some wheat cultivars, there may be a reduction in grain production after consecutive cuts, as well as in hectoliter weight and thousand grain weight. According to Bortolini et al. (2004), with a single cut in white oat, a considerable amount of forage can be removed without seriously affecting grain production. This behavior was not repeated in the two-cut management. Notwithstanding, Bortolini et al. (2005) observed that dual-purpose white oats, after being grazed for up to 4 weeks, had higher grain yield than non-grazed white oats due to lower lodging and lower apical meristem height.

In addition to the factors mentioned above, sowing density also directly influences the production of tillers and consequently the production of fodder and grains (Martin et al., 2010). The increase in sowing density may be a strategy adopted to anticipate cuttings, thus reducing the fall forage emptiness (Martin et al., 2010). Another aspect related to the regrowth and tillering ability is the nutritional status of the plant, especially with regard to nitrogen. In dual-purpose wheat, higher nitrogen doses can be used to increase forage and grain yield without presenting the risk of lodging due to the size reduction caused by cuts (Hastenpflug et al., 2011). Wheat grain yield is highly related to nitrogen management (Sangoi et al., 2007). Braz et al. (2006) found linear and quadratic increases or no effects on the yield of wheat grains treated with 0, 30, 60 and 120 kg ha^{-1} N, this response being variable with the predecessor crop. According to Espindula et al. (2010), the 40, 60, 80, 100 and 120 kg N ha^{-1} rates promoted a quadratic response in wheat grain yield, with a maximum point of 5.032 kg ha^{-1}, estimated at 96.8 kg N ha^{-1} rate. Hastenpflug et al. (2011) reported increased forage dry matter yield in dual-purpose wheat cultivars as a function of the application of nitrogen rates up to 120 kg ha^{-1}.

The use of dual-purpose winter cereals may contribute to the diversification of activities and farm profitability. The number of forage cuts depends on the region, as this is determined by phenological aspects of the crop and the cuts, in turn, are influenced by climatic and management variables, mainly nitrogen availability and sowing density. The joint assessment of these factors becomes important in establishing management indications for dual-purpose wheat. This work was based on the hypothesis that the wheat cultivar BRS Tarumã presents viability for forage production without reducing grain yield in the management with up to two cuts at the highest nitrogen doses. Therefore, the objective of this work was to evaluate forage production and grain yield in dual-purpose wheat cultivar BRS Tarumã under different sowing densities, nitrogen fertilization and numbers of cuttings.

Material and methods

The experiment was conducted in Capinzal (Santa Catarina State; 27°20' S and 51°36' W and altitude of 480 m) during the winter of 2016, in a no-tillage system in succession to the bean crop. The experimental design was completely randomized, with 4 replications, in which the treatments were distributed, in a factorial arrangement (sowing density x nitrogen doses), in the main plots, with subdivided plots (cutting managements). Sowing densities were 400 and 500 seeds m^{-2}. Nitrogen doses were 100% (80 kg ha^{-1}), 150% (120 kg ha^{-1}), 200% (160 kg ha^{-1}), 250% (200 kg ha^{-1}) and 300% (240 kg ha^{-1}) of the recommended dose for an expected yield of 4000 kg ha^{-1}, preceded by bean cultivation in no-tillage system (CQFS-RS/SC, 2004). The subplots were divided according to the cutting management (no cut, a single cut and two cuts). The cutting was performed when the wheat reached a height of 30 cm, leaving a residue of 10 cm. The experimental plot consisted of five rows with spacing of 17 cm between rows, by 5 m in length, and the useful area of the subplots was composed of three central rows of 1 m in length. The wheat cultivar used was BRS Tarumã. The initial soil analysis showed a clay content of 480 g kg^{-1} (densimeter method), organic matter of 19 g kg^{-1} (sulfochromic oxidation), soil CEC at pH 7.0 of 17.2 cmol$_c$ dm^{-3} and pH (water) of 5.7. The initial nutrient contents were Ca = 8.4 cmol$_c$ dm^{-3} (extracted with 1 mol/L KCl), Mg = 2.4 cmol$_c$ dm^{-3} (extracted with 1 mol/L KCl), P = 62.1 mg dm^{-3} (Mehlich-1), K = 163.0 mg dm^{-3} (Mehlich-1), H+Al = 6.0 cmol$_c$ dm^{-3}, and Al = = 0.0 cmol$_c$ dm^{-3} (extracted with 1 mol/L KCl). Sowing was done manually on 06/07/2016. Weed control and phytosanitary treatments followed the technical indications of the crop (CBPTT, 2015).

Nitrogen fertilization in coverage was divided as follows: in the subplot where there was no cut, the whole dose was performed in a single application, at the beginning of tillering. In the subplots regarding the one-cut management, the doses were applied in two equal splits, at tillering and immediately after the cut. In the subplot corresponding to the two-cut management, there were three equal splits applied at tillering and after each of the two cuts. Nitrogen doses in coverage were hand-spread, with urea (45% N) as the source of mineral N. All subplots received 20 kg ha^{-1} at sowing.

The useful area of each plot was cut to estimate the forage yield (kg ha^{-1}) when the plants reached approximately 30 cm in height, performing a manual cut at 10 cm from the soil surface. To determine the dry matter, the collected sample was oven-dried at 60 °C until constant weight. For the forage production, only the subplots that received the one- and two-cut managements were used. After harvesting, the following evaluations were carried out in the useful area of each subplot: ear mass (EM), thousand grain weight (TGW), grain mass per ear (GME), number of grains per ear (NGE), number of spikelets per ear (NSE), number of grains per spikelet (NGS), ear length (EL) and grain yield (GY). The yield components were determined from the random collection of 10 wheat ears per plot. Thousand grain weight was determined by the count of 200 grains. Grain yield was determined from the production of the useful area of the plots, corrected for 13% grain moisture.

The dry forage (DM) sample from the oven was ground to 1 mm in a Willey mill and packed in plastic bags for further determination of crude protein. The crude protein (CP) content was determined based on the total nitrogen content by the Kjeldahl method (AOAC, 1995), multiplied by the factor of 6.25.

The data were submitted to analysis of variance (F test) and when significant variations were detected, the means were compared by the Tukey test at 5% probability. For the quantitative factor (nitrogen rates), a regression analysis was performed at 5% probability.

Results and discussion

There was no significant effect of the interaction between nitrogen doses, sowing density and cutting management for the evaluated characteristics. This fact indicates that the wheat crop did not respond differently to the management effects tested. There was only a significant effect of cutting management on forage dry matter, forage protein content, and yield components, except for the thousand grain weight and grain yield (Table 1). Nitrogen doses and sowing density did not influence grain yield, forage yield and forage crude protein content.

Table 1 - Cuts management effect on grain yield and components yield of BRS Tarumã dual-purpose wheat.

Management	EL (cm)	EM (g)	NSE	NGE
Without CUT	4.74 A	0.82 A	15.11 A	23.74 A
1 cut	4.33 B	0.70 B	14.29 B	20.40 B
2 cuts	4.03 B	0.75 AB	13.72 B	20.08 B
CV (%)	15.11	24.77	9.84	19.64
$F_{(treatments)}$	11.42*	3.68*	9.80*	9.28*
Management	GME (g)	TGW (g)	NGS	GY (kg ha^{-1})
Without CUT	0.54 A	22.28 A	1.55 A	1956.6 A
1 cut	0.46 B	21.92 A	1.42 B	1831.3 A
2 cuts	0.49 AB	23.84 A	1.46 AB	1786.6 A
CV (%)	29.53	16.02	13.68	29.86
$F_{(treatments)}$	3.17*	3.14^{ns}	4.36*	1.01^{ns}

Means followed by same letters in the columns do not significantly differ by Tukey (P>0.05). ^{ns}Not significant. *Significant at 5% probability. Yield components: EL, ear length; EM, ear mass; NSE, number of spikelet per ear; NGE, number of grains per ear; GME, grains mass per ear; TGW, thousand grain weight; NGS, number of grains per spikelet; GY, grain yield.

Based on the number of cuts, the ear length, ear mass, number of spikelets per ear, number of grains per ear and grain mass per ear presented a differentiated response (Table 1). From a single cut, the wheat plants already showed reduced length, number of spikelets per ear and number of grains per ear. The smaller length resulted from the smaller number of spikelets per ear, observed in the treatments in which cuts were performed. With the reduction of the number of spikelets there was a reduction in the number of grains per ear. The thousand grain weight was not reduced, because this component is defined in the grain-filling stage and the number of grains per ear was smaller with the cuts.

Cutting reduces the leaf area and affects the photosynthesis and redistribution of photoassimilates that the plant uses in the reproductive phase (Bortolini et al., 2004). Moreover, the removal of the reproductive apex caused by cuts during elongation of the stems possibly reduced the size of the ears (Bortolini et al., 2004). Hence, defoliation promotes reduction in these yield components and this reduction is more severe the higher the number of cuts. According to Martin et al. (2010), despite the wheat BRS Tarumã being considered of dual aptitude, the production components and grain yield were drastically reduced, indicating that its recommendation as a dual-purpose cereal should be reviewed, or the cutting heights and the determination of the cutting time should be further evaluated.

Despite the reduction of the yield components with the cuts, with the exception of the thousand grain weight, grain production was not affected. Therefore, the forage can be removed without seriously affecting grain production. According to Bortolini et al. (2004), all the dual-purpose cereals tested showed a significant improvement in hectoliter weight when a single cut was performed, probably by reducing the lodging index, resulting in heavier grains. Scheffer-Basso et al. (2001) concluded that grain yield may be increased by reduction in lodging. According to Bartmeyer et al. (2011), defoliation can increase grain yield by reducing lodging, as long as grazing time and intensity are not severe. When lodging occurs in the grain-filling stage, it limits the translocation of photoassimilates in the plants to the grains. At maturation, the ears are closer to the soil, which leads to a decrease in hectoliter weight and germination or rotting of the grain, besides hindering the mechanized harvest (Zagonel & Fernandes, 2007).

Nitrogen fertilization did not significantly influence wheat dry matter production in the cuts performed. Sowing density did not affect the forage dry matter production. However, the number of cuts significantly increased the forage production of dual-purpose wheat (Table 2). The second cut presented a mean increase of 631.8 kg ha^{-1} in relation to the single cut management, regardless of nitrogen dose and sowing density.

Table 2 - Effect of cutting management on dry matter yield and crude protein content of dual-purpose wheat cultivar BRS Tarumã.

Management	Forage dry matter (kg ha^{-1})	Crude protein content (%)
1 cut	1,822.5 B	27.58 A
2 cuts (1st)	1,672.9 B	27.08 A
2 cuts (2nd)	2,379.5 A	23.95B
CV (%)	19.96	14.76
$F_{(treatments)}$	35.92*	19.90*

Means followed by same capital letters in the columns do not significantly differ by Tukey (P>0.05). ^{ns}Not significant. *Significant at 5% probability.

Such a result probably can be explained by the increase in regrowth capacity. According to Bortolini et al. (2004), the increase in forage yield is expressed by the high capacity of regrowth, induction activity in the formation of new tillers. Other authors found a similar result to this work. According to the results of Meinerz et al. (2012), wheat BRS Tarumã showed higher forage production in the second cut compared to the first one. Quatrin et al. (2017), evaluating the nutritional value of dual-purpose wheat BRS Tarumã in 3 grazing cycles, observed higher forage yield in the last grazing cycle (2,070 kg ha^{-1}).

The forage crude protein did not differ significantly in relation to the nitrogen doses and sowing density, but presented a difference in relation to the cutting management (Table 2). The second cut reduced the crude protein content, on average, by 3.38%. The crude protein values observed in the first cut were approximately 27%. Meinerz et al. (2011), evaluating wheat genotypes submitted to 3 cuts, observed average values between 24.2% (1st cut), 22.8% (2nd cut) and 15.6% (3rd cut) crude protein. Quatrin et al. (2017) observed values of 26.7, 27.8 and 27.6% crude protein for the 1st, 2nd and 3rd cuts, respectively. The contents observed were higher than those reported in oat by Cecato et al. (2001), who, when evaluating oat genotypes submitted to two cuts, observed average values between 15.94 and 19.66% crude protein. Roso & Restle (2000) found average values of 20.3% CP for the mixture of black oat and ryegrass under grazing, which are the most used winter forages in the southern Brazil. According to the reported values, dual-purpose wheat has a higher crude protein content, especially when compared to black oat and ryegrass. The crude protein values of this work are above the animal requirement, regardless of the animal category (NRC, 2001).

According to the regression analysis, there were no significant increases in the thousand grain weight and grain yield with increases in the nitrogen rate for the densities of 400 and 500 seeds m^{-2} (Table 3). Therefore, nitrogen rate higher than recommended for the crop did not increase grain size and yield even when submitted to 1 and 2 cuts. Regression analysis also did not indicate an increase in forage yield with the nitrogen doses for 400 and 500 seeds m^{-2}. Thus, nitrogen doses higher than 80 kg ha^{-1} did not promote increases in forage dry matter.

Table 3 - Regression analysis of thousand grain weight and grain yield of BRS Tarumã wheat, according to nitrogen levels and sowing density of 400 and 500 seeds m^{-2}.

400 seeds m^{-2}		500 seeds m^{-2}	
Equation	CV (%)	Equation	CV (%)
Without CUT			
TGW = 22.00 g	17.6	TGW = 22.55 g	23.4
GY = 1,867.0 kg ha^{-1}	30.0	GY = 2,046.2 kg ha^{-1}	29.2
1 cut			
TGW = 21.94 g	19.9	TGW = 21.91 g	16.0
GY = 1,791.6 kg ha^{-1}	28.7	GY = 1,870.9 kg ha^{-1}	36.9
2 cuts			
TGW = 23.7 g	12.0	TGW = 24.0 g	16.3
GY = 1,714.8 kg ha^{-1}	23.9	GY = 1,858.4 kg ha^{-1}	26.9

TGW - thousand grain weight; GY - grain yield.

This result can probably be explained by the biological N fixation and the higher decomposition rate with consequent release of nutrients, promoted by the predecessor crop (bean). According to Nunes et al. (2011) and Silva et al. (2015), the wheat response to the application of nitrogen is variable as a function of the predecessor crop. Braz et al. (2006) observed in a soil with 19 g dm^{-3} organic matter that, after pigeon pea cultivation, wheat grain yield was 3,647 kg ha^{-1}, obtained with the dose of 91 kg N ha^{-1}, and, after Stylosanthes cultivation, the maximum yield was 3,494 kg ha^{-1}, with 76 kg N ha^{-1}. Nonetheless, after Brachiaria and millet cultivation, the dose of 120 kg N ha^{-1} used in the study was not enough to reach the maximum wheat yield.

According to Penckowski et al. (2009), wheat yield was not affected by the increase of doses from 90 to 225 kg ha^{-1}, since the nitrogen supply to the cultivar was adequate with the lowest dose used. Zagonel & Fernandes (2007), evaluating 8 wheat cultivars, observed that only two of them responded to the increase of the nitrogen level in coverage regarding yield. According to the same authors, this fact occurred because even the lowest dose of nitrogen in coverage (50 kg ha^{-1}) met the needs of the cultivars. These results agree with those obtained in the present study, in which the lowest dose used (80 kg N ha^{-1}), allied to the predecessor crop (bean), met the needs of the cultivar, which did not respond to the increase of the nitrogen rate.

There were no increases in forage dry weight with the increasing nitrogen doses for 1 and 2 cuts in the sowing densities of 400 and 500 seeds m^{-2}. Therefore, the recommended dose for wheat grain (100%) does not affect forage production (Table 4). In triticale and ryegrass mixed pasture submitted to nitrogen rates from 0 to 450 kg ha^{-1} split in 5 applications after each cut, there were no increase in forage dry matter yield, with a mean value of 1,515 kg ha^{-1} (Soares & Restle, 2000). However, in a consortium of white oat, ryegrass and white clover, the use of 100, 200 and 300 kg N ha^{-1} provided an average increase of 13, 37 and 76% in the pasture dry matter accumulation, respectively.

Table 4 - Regression analysis of dry matter forage and crude protein of BRS Tarumã wheat, according to nitrogen levels, sowing density of 400 and 500 seeds m^{-2}.

400 seeds m^{-2}		500 seeds m^{-2}	
Equation	CV (%)	Equation	CV (%)
1 cut			
DM = 1,828.8 kg ha^{-1}	20.3	DM = 1,816.3 kg ha^{-1}	30.4
CP = 27.4 %	7.9	CP = 23.89* + 0.0197N* ; R^2 = 0.89	8.5
2 cuts (1st)			
DM = 1,738.5 kg ha^{-1}	24.0	DM = 1,610.7 kg ha^{-1}	29.7
CP = 28.2 %	25.5	CP = 26.0 %	12.2
2 cuts (2nd)			
DM = 2,415.1 kg ha^{-1}	14.0	DM = 2,343.5 kg ha^{-1}	12.0
CP = 23.3 %	8.1	CP = 22.1 %	19.2

DM - dry matter forage; CP - crude protein forage. *Significant at 5% probability at F Test.

The forage crude protein content increased as a function of the nitrogen rates in only one of the evaluated treatments. Hastenpflug et al. (2011) observed a similar result to this work regarding the average crude protein content for the cultivar BRS Tarumã and linear increases up to the nitrogen rate of 90 and 120 kg ha^{-1} in the forage dry matter production and crude protein content with 1 cut and 2 cuts, respectively. It should be noted that in the present study, the nitrogen rates evaluated were higher (80 to 240 kg ha^{-1}) and the lowest dose was sufficient for the cultivar to reach maximum forage and crude protein yield. Soares & Restle (2000) verified that the nitrogen rates did not interfere in the forage crude protein content, presenting an average value of 25.8%.

According to Balbinot Júnior et al. (2009), the correct adoption of the crop-livestock integration system promotes improvement of the soil quality by increasing the soil organic matter content and nutrient cycling, without the occurrence of compaction by animal trampling. According to Meinerz et al. (2012), BRS Tarumã presents a balance between forage and grain yield, and is indicated for dual-purpose management. The correct management of sowing density, nitrogen fertilization and number of cuts does not affect grain yield and may allow the use of dual-purpose wheat BRS Tarumã in crop-livestock integration systems in the southern region of Brazil.

Conclusion

The use of two cuts in the wheat cultivar BRS Tarumã increased forage production without affecting grain yield and, therefore, makes it feasible for dual-purpose production. The nitrogen rate of 80 kg ha^{-1} and 400 suitable seeds m^{-2} allowed to reach maximum grain yield. Nitrogen fertilization above that recommended for wheat did not increase grain and forage yield, nor did sowing density change grain and forage yield. The forage crude protein content decreased in the second cut, but was high and may be an important source in animal production during the autumn-winter period for the southern Brazil.

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