

Plant arrangement and its effects on yield and bromatological quality of wheat submitted to different cutting systems

Arranjo de plantas e seus efeitos na produtividade e qualidade bromatológica de trigo submetido a diferentes sistemas de corte

Disposición de las plantas y sus efectos sobre el rendimiento y la calidad bromatológica del trigo sometido a diferentes sistemas de corte

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Abstract

This was aimed to evaluate the effects of plant arrangements and cutting systems on the yield and quality of dual purpose wheat. The present study was conducted in the years 2015, 2016 and 2017 in Frederico Westphalen, belonging to the state of Rio Grande do Sul. The dual purpose wheat genotype used was BRS Tarumã. For this, five sowing densities were used, namely: 75, 150, 225, 300 and 375 seeds per square meter. The analysis of variance revealed significance for the interaction sowing density x cutting systems x chemical quality for the variables dry matter per hectare, lipids, digestible fiber in acid detergent, lignin, cellulose, mineral matter, total carbohydrates and non-fibrous carbohydrates. The positive effects on yield and bromatological quality of the forage are obtained by arranging plants and cutting systems through the sowing density of 300 to 375 seeds per meter with the practice of up

to two cuts in dual purpose wheat. Superior dry matter per unit area was observed in the second cut, which was defined by the stimulation of tillering, regrowth and split nitrogen fertilization. Since, the superior bromatological quality is determined by the magnitude of non-fibrous carbohydrates in the forage.

Keywords: *Tritium aestivum*; Plant architecture; Production; Forage quality.

Resumo

Objetivou-se avaliar os efeitos de arranjos de plantas e sistemas de corte sobre a produtividade e qualidade do trigo de duplo propósito. O presente estudo foi realizado nos anos de 2015, 2016 e 2017 no município de Frederico Westphalen, Rio Grande do Sul. O genótipo de trigo de duplo propósito utilizado foi o BRS Tarumã. Para isso, foram utilizadas cinco densidades de semeadura, a sendo: 75, 150, 225, 300 e 375 sementes por metro quadrado. A análise de variância revelou significância para a interação densidade de semeadura x sistemas de corte x qualidade química para as variáveis matéria seca por hectare, lipídios, fibra digestível em detergente ácido, lignina, celulose, matéria mineral, carboidratos totais e carboidratos não fibrosos. Os efeitos positivos no rendimento e na qualidade bromatológica da forragem são obtidos pelo arranjo de plantas e sistemas de corte por meio da densidade de semeadura de 300 a 375 sementes por metro com a prática de até dois cortes em trigo de duplo propósito. A matéria seca superior por unidade de área foi observada no segundo corte, definido pela estimulação do perfilhamento, rebrota e fertilização com nitrogênio parcelado. Sendo assim, a qualidade bromatológica superior é determinada pela magnitude dos carboidratos não fibrosos na forragem.

Palavras-chave: *Tritium aestivum*; Arquitetura da planta; Produção; Qualidade da forragem.

Resumen

Este tenía como objetivo evaluar los efectos de los arreglos de plantas y los sistemas de corte en el rendimiento y la calidad del trigo de doble propósito. El presente estudio se realizó en los años 2015, 2016 y 2017 en Frederico Westphalen, perteneciente al estado de Rio Grande do Sul. El genotipo de trigo de doble propósito utilizado fue BRS Tarumã. Para ello se utilizaron cinco densidades de siembra, a saber: 75, 150, 225, 300 y 375 semillas por metro cuadrado. El análisis de varianza reveló significancia para la interacción densidad de siembra x sistemas de corte x calidad química para las variables materia seca por hectárea, lípidos, fibra digestible en detergente ácido, lignina, celulosa, materia mineral, carboidratos totales y carboidratos no fibrosos. Los efectos positivos sobre el rendimiento y la calidad bromatológica del forraje se obtienen ordenando plantas y sistemas de corte a través de la densidad de siembra de 300 a 375 semillas por metro con la práctica de hasta dos cortes en trigo de doble propósito. En el segundo corte se observó materia seca superior por unidad de área, que se definió por la estimulación del macollamiento, rebrote y fertilización con nitrógeno fraccionado. Dado que, la calidad bromatológica superior está determinada por la magnitud de los carboidratos no fibrosos en el forraje.

Palabras clave: *Tritium aestivum*; Arquitectura vegetal; Producción; Calidad del forraje.

1. Introduction

Wheat (*Triticum aestivum* L.) is considered an annual cycle plant, of great economic importance among winter crops (Mendes et al., 2015), ranked as the second most produced cereal in the world for the purpose of foraging and obtaining flour (Zocche, et al., 2018). Accounting for approximately one fifth of the world demand for food. The growing of wheat demonstrates its relevance in terms of supplying food needs, in the scope of bakery and animal production. In addition, wheat is an important component in crop succession and rotation systems, maximizing the potential to generate wealth per soil area in the winter period (Mendes, et al., 2018).

With the population increasing, an increment in agricultural production is necessary, at the same time as the preservation of natural resources and biodiversity must be taken into account (Trewavas, 2002). In this agenda, crop-livestock integration emerges, which are based on the premise of the sustainability of production systems (Santos et al., 2011). With the use of minimal tillage or reduced soil preparation, generating increased efficiency in the use of natural resources and land (Faria, et al., 2015). The advancement of research in genetic improvement and in the management of the crop has enabled genotypes of dual purpose to be obtained, so not only is grain production aimed, but also the ability to provide quality fodder to animals (Bartmeyer et al., 2011; Carvalho, 2016a).

Dual-purpose wheat is characterized as a dual-purpose cereal for providing fodder in the growing season, and subsequently providing grain harvesting (Carvalho et al., 2018). It should have, as main characteristics: high dry matter yield,

tolerance to grazing or cutting and high grain yield (Santos, et al., 2015; Bartmeyer et al., 2011; Del Duca et al., 2000). Fontaneli et al. (2011), points out that this material can be sown only for grazing (two or more times), for grain production or even, for grazing (one or two) and grain production, as has occurred in several countries, among these, the United States of America, Australia, Uruguay and Argentina, as an economic alternative in agricultural growing systems.

This species, according to Pires et al. (2011), allows to offer forage during autumn/winter, a period of lower growth rate and, therefore, the need for a larger extension of areas with pastures, to supply the demand of the growing herd, allowing them to be sown 20 to 40 days before the period indicated for traditional grain cultivars. In this way, wheat genotypes of dual purpose, come to minimize the effects of food scarcity during periods of forage void, by enabling early sowing, fast establishment, tolerance to trampling, high forage production and good bromatological quality. (Soares et al., 2016)

The dual purpose wheat needs a longer extension in its vegetative phase, to then provide a greater increase in forage due to the increase in the number of cuts, however, it is necessary that the reproductive period be relatively short (Carvalho et al., 2019). Thus, the management of cuts in dual purpose cereals generates a greater increase in the leaf area, due to the stimulus in the emission of tillers, allowing a high interception of solar radiation (Santos et al., 2011). Coming to indirectly reduce lodging, apical dominance and plant height (Bortolini et al., 2004; Carvalho, 2016a).

The magnitude of tillers per plant reflects the number of ears per unit area, number and mass of grains per plant and consequently the grain yield of the genotype, as long as these are self-sufficient and do not present themselves as a drain of assimilates (Valério et al., 2009; Carvalho, 2016a). Wheat tillering can be controlled by genetic, hormonal effects through auxins and cytokinins, characteristic of the growing environment, water and nutritional demand, and the arrangement of plants in the canopy (Valério et al., 2009; Carvalho, 2016a).

However, pasture-based animal production is complex, since plants and animals share the same space, and it has the need to maintain leaf area to perform photosynthesis while maintaining its active metabolism. In contrast, the animals need to remove the leaves to feed, that is, the animal-plant interaction is of important knowledge. Thus, it is important to carry out a correct maintenance of the pasture, with excellent fertilization and soil correction, emphasizing the use of nitrogen fertilizers after the removal of the forage, to maximize its regrowth, placement of tillers, as well as the recovery of the plant to allow subsequent grain production, generating a greater increase in the economic and sustainable scope of the agricultural system. (Demari et al., 2016). This work aimed to evaluate the effects of plant arrangements and cutting systems on the yield and quality of dual purpose wheat.

2. Methodology

The present study was conducted in the years 2015, 2016 and 2017 in Frederico Westphalen, belonging to the state of Rio Grande do Sul. Located under the coordinates 27°39'54" S and 53°42'94" W, with an altitude in relation to the level of the sea of 490 meters. The local climate is characterized according to Köppen as Subtropical (Cfa) (Moreno, 1961), with soil characterized as Ferric Red Latosol (Oxisol). The experiment was carried out in a randomized block design organized in a factorial scheme of cutting systems x sowing densities, with treatments arranged in 15 repetitions.

The dual purpose wheat genotype used was BRS Tarumã. For this, five sowing densities were used, namely: 75, 150, 225, 300 and 375 seeds per square meter. And three cutting systems (first cut, second cut and third cut). As an evaluation criterion, the plant stand height was used. These were evaluated when they reached an average height of 0.30 m from the ground level, until the flag leaf was fully developed, leaving a residual of 0.10 m after making the cuts. The evaluations were carried out on the central lines of each plot, disregarding 0.50 m of each one at its ends, in order to reduce the border effects. Each plot had 4.76 m², obtaining twelve lines, with a spacing of 0.17 m in width and 2.00 m in length. The treatments were

sown under no-tillage system (NTS), with basic fertilization following technical recommendations, based on soil sampling. 250 kg ha⁻¹ of N-P-K were used in the formulation (10-20-20) as base fertilization and 90 kg ha⁻¹ of nitrogen in the form of urea for topdressing. These are divided into vegetative phases of full tillering (V3-V4), and after each cut. Previous control of diseases and insect pests was carried out.

The evaluated characters were: dry matter per hectare (DMH); Percentage of hemicellulose (HEM); Cellulose (CEL); Mineral matter (MM); Neutral detergent fiber (NDF); Acid detergent fiber (ADF); Lignin (LIG); Total carbohydrates (TC); Non-fibrous carbohydrates (NFC); Crude protein (CP) and Lipids (LIP). The collected samples were submitted to drying in a forced air oven, at a temperature of 65 °C, for seven days. After the materials were completely dried, they were weighed on a precision scale, and the results obtained were adjusted to kg ha⁻¹ of dry matter per hectare (DMH). The percentages of hemicellulose (HEM), cellulose (CEL) and mineral matter (MM), were determined using the methodologies proposed according to Silva and Queiroz (2006). To obtain the percentages of neutral detergent fiber (NDF), the methodology of Senger et al. (2008) was used. The percentages of acid detergent fiber (ADF) were obtained from the NDF residue according to the methodology of Senger et al. (2008). The percentages of lignin (LIG) were measured using the methodology proposed by Robertson and Van Soest (1981). To obtain the percentages of total carbohydrates (TC) and non-fibrous carbohydrates (NFC), the methodology proposed by Sniffen et al. (1992) was used. The percentages of crude protein (CP) were obtained through the methodology proposed by Nogueira and Souza (2005). And the percentages of lipids (LIP) were carried out using the methodological technique proposed by Bling and Dyer (1959).

The data obtained were submitted to the assumptions of the statistical model, after the analysis of joint variance for the three years of growing was performed, the diagnosis of the interaction between cutting systems x sowing densities at 5% probability was performed by the F test. The significant interactions were broken down to the simple effects for the qualitative effects of the cutting systems, for the quantitative effects aimed at the sowing densities, the test of the highest significant degree of the polynomial was performed at a 5% probability for the t test. Afterwards, a polynomial regression model was estimated for each level of the qualitative factor.

3. Results and Discussion

The analysis of variance (Table 1) revealed significance for the interaction sowing density x cutting systems x chemical quality for the variables dry matter per hectare, lipids, digestible fiber in acid detergent, lignin, cellulose, mineral matter, total carbohydrates and non-fibrous carbohydrates. The variables digestible fiber in neutral detergent and hemicellulose showed no interaction between the factors. The character of dry matter yield per hectare (DMH) showed direct dependence on sowing densities in relation to the cutting systems (Table 2; Table 5). It is evident that in the first cut, the increase in sowing density enabled an abrupt increase in yield per unit area. While the dual purpose wheat management is intended for only one cut, it is recommended to use 375 seeds per square meter, so that an increase of 729 kg ha⁻¹ of forage is then obtained.

Table 1: Summary of the analysis of variance for the cutting system (CS) x sowing densities (SD) of dual purpose wheat.

| SV | MS* | | | | | | | | | | | |
|---------|-----|------------|-------|----------|---------|-------|----------|---------|--------|-------|--------|---------|
| | DF | DMH | LIP | NDF | ADF | LIG | HEM | CEL | MM | CP | TC | NFC |
| CS | 2 | 91166251,9 | 54,72 | 7759,17* | 1273,41 | 22,25 | 2637,91* | 1046,40 | 89,03 | 3,24 | 331,23 | 5119,60 |
| SD | 4 | 414144,3 | 2,34 | 12,46 | 2,84 | 1,01 | 12,20 | 18,26 | 36,17 | 6,35 | 32,32 | 40,57 |
| CS x SD | 8 | 739453,8* | 3,82* | 8,41 | 14,52* | 1,14* | 2,63 | 7,33* | 11,73* | 5,85* | 31,32* | 40,69* |
| BLOCKS | 14 | 470038,7 | 4,22 | 21,04 | 15,34 | 0,51 | 8,30 | 14,02 | 6,84 | 1,96 | 6,13 | 13,01 |
| RESIDUE | 196 | 206403,6 | 1,18 | 10,28 | 5,60 | 0,52 | 10,17 | 2,62 | 5,25 | 2,70 | 9,91 | 19,55 |

* significant at 5% probability by the F test. DF:degrees of freedom; MS: mean square; SV: source of variation; DMH: dry matter yield per hectare in kg ha⁻¹; LIP: percentage of lipids; NDF: percentage of fibers in neutral detergent; ADF:percentage of fibers in acid detergent; LIG: percentage of lignin; HEM: percentage of hemicellulose; CEL: percentage of cellulose; MM: percentage of mineral matter; CP: percentage of crude protein; TC: percentage of total carbohydrates; NFC: percentage of non-fibrous carbohydrates. Source: Authors.

In situations where the grower wishes to make the second cut based on the premises of the dual purpose wheat ideal point, the rate of seed increase per square meter will result in only 171 kg⁻¹ of dry matter per hectare of forage added to the first cut. In contrast, in management with three cuts, the trends are reversed. The strategy of seeking maximum forage yield per unit area in a dual purpose crop should be related to the strategic planning of the number of cuts to be made, since the largest extractions of forage are obtained in the early stages of crop development, next to this, nitrogen fertilizers are carried out, efficient while these quantitative effects last in the first until the second grazing. Based on the specific effects of each sowing density (Table 2), it is revealed that the first cut is quantitatively inferior to the second cut, due to the grower making the optimal nitrogen management after each cut, thus favoring the increase in the contribution of tillers in the plant, generating an increase in vegetative production at each cutting system successively (Ferrari et al., 2016).

The percentage of lipids (LIP) character differed statistically in terms of cutting systems and sowing densities, not showing direct dependence on densities, but on the cutting system. The first cut showed an increase higher than the others, not differing statistically in relation to the sowing densities (Table 2). The maximum point of the percentage of lipids (5.73%) was observed with the density of 375 seeds per square meter. There was a decrease in the percentage of lipids for the second cut, with the percentages differing statistically from each other due to the different sowing densities (Demari et al., 2018). It has an increasing straight line, with its highest lipid percentage with a density of 350 seeds per square meter, showing a decrease of 1.42% (Table 2) when compared to the first cut. The third cut showed a decrease in percentage, in relation to the increase in plant population density per square meter. Therefore, it is recommended to use 375 seeds per square meter, which will increase 0.94% if compared to the density of 75 seeds per square meter, with up to two cutting systems (Table 2; Table 5).

The character digestible fiber in acid detergent (ADF), did not obtain significant difference between the sowing densities, however, it differed statistically between the cutting systems, showing an abrupt increase in the percentage directly correlated to the cutting sequence. On the other hand, lower levels of fiber are preferable for the animals' diet in order to maximize forage intake. Thus, if only this character were evaluated, the ideal would be to make only from one to two cuts, but for maximum yield per area, the third cut can be made, since it is in good/tolerable levels of fiber. Thus, the percentage of digestible fiber in acid detergent shows that the best sowing density is situated in the amount of 375 seeds per square meter (Table 2; Table 5).

Table 2: Means for the interaction between the effects of cutting systems x sowing densities for the variables percentage of dry matter per hectare (DMH), percentage of lipids (LIP), percentage of acid detergent fiber (ADF), percentage of lignin (LIG).

| DMH | | | |
|---------------------------------------|-----------|------------|-----------|
| Sowing densities (s m ⁻²) | First cut | Second cut | Third cut |
| 75 | 642,89 B | 2940,05 A | 3251,38 A |
| 150 | 933,62 B | 2949,73 A | 2988,53 A |
| 225 | 1288,21 B | 3144,48 A | 3000,34 A |
| 300 | 1324,50 B | 2979,52 A | 2925,78 A |
| 375 | 1372,01 B | 3111,60 A | 2927,20 A |
| CV (%) | 19,04 | | |
| R ² | 0,82 | | |
| LIP | | | |
| Sowing densities (s m ⁻²) | First cut | Second cut | Third cut |
| 75 | 4,78 A | 3,31 B | 3,53 B |
| 150 | 5,43 A | 4,48 B | 3,61 B |
| 225 | 4,56 A | 4,14 A | 3,77 A |
| 300 | 5,05 A | 4,13 AB | 3,62 B |
| 375 | 5,73 A | 4,30 B | 2,55 C |
| CV (%) | 25,94 | | |
| R ² | 0,47 | | |
| ADF | | | |
| Sowing densities (s m ⁻²) | First cut | Second cut | Third cut |
| 75 | 41,65 C | 57,45 B | 62,60 A |
| 150 | 42,75 C | 57,37 B | 64,01 A |
| 225 | 43,95 C | 57,44 B | 62,49 A |
| 300 | 43,27 C | 57,12 B | 61,83 A |
| 375 | 44,36 C | 57,66 B | 63,62 A |
| CV (%) | 5,88 | | |
| R ² | 0,88 | | |
| LIG | | | |
| Sowing densities (s m ⁻²) | First cut | Second cut | Third cut |
| 75 | 0,46 B | 2,19 A | 1,90 A |
| 150 | 1,16 A | 1,52 A | 1,74 A |
| 225 | 0,61 B | 1,63 A | 1,74 A |
| 300 | 0,77 B | 1,31 AB | 1,51 A |
| 375 | 0,56 B | 1,61 A | 1,41 A |
| CV (%) | 53,90 | | |
| R ² | 0,38 | | |

* averages followed by the same capital letter (for the purposes of the cutting systems) in the line do not differ statistically by Tukey at 5% probability. CV (%): coefficient of variation; R²: R square. Source: Authors.

The percentage of lignin (LIG) showed a significant difference for the first and second cuts, in relation to population densities. The first cut showed an increase in the percentage up to the density of 150 seeds per square meter, demonstrated its peak, with a relative decrease in the percentage due to the increase in the density of seeds. The second cut showed high levels of lignin in the density of 75 seeds per square meter, with 2.19% (Table 2), with a relative drop from this to the density of 225

seeds per square meter, with an increase from this, obtaining 1.61% (Table 2) of lignin at maximum density. The third cut shows a decrease in the percentage of lignin, presenting 1.41% (Table 2) in the density of 375 seeds per square meter. In this way, grazing can be extended to the third cut when the character in question is lignin, since it tends to decrease with the advance of cuts, allowing optimal values with the sowing density of 375 seeds per square meter (Table 2; Table 5).

The percentage of cellulose (CEL) has a direct correlation, and an abrupt increase with the increase in sowing densities, as well as with the cutting systems, which demonstrated statistical significance among themselves (Table 3). Thus, when using the maximum density, an increase of 3.24% is obtained in the first cut, and 6.20% of increase when using three cuts, in relation to the use of 375 seeds per square meter. This increase is due to the greater insertion of tillers by the plant, which are stimulated at each cut, and also due to nitrogen fertilization. Thus, the use of 375 seeds per square meter is indicated, with the possibility of making three cuts (Table 5).

There was a significant difference between the cutting systems, as well as the sowing densities (Table 3) for the percentage of mineral matter (MM). The first cut showed a decrease in the percentage of mineral matter due to the increase in population density. The second cut showed an increase in the percentage to its optimum point, which is between 150 to 225 seeds per square meter, 10.79% to 8.35% respectively. There is a decrease in the percentage due to the continuation of cuts, as well as the increase in sowing density, obtaining the lowest percentages in the density of 375 seeds per square meter in both cuts (Table 5).

The percentage of crude protein (CP) does not reveal statistical difference for the first cut (Table 3), however it is possible to show its highest percentage in the density of 375 seeds per square meter, with 8.13%. The second and third cuts showed a significant difference in relation to sowing densities, showing a decrease in protein with an increase in population density (Table 5).

Table 3: Means for the interaction between the effects of cutting systems x sowing densities for the variables percentage of cellulose (CEL), percentage of mineral matter (MM), percentage of protein (CP), percentage of total carbohydrates (TC) and percentage of non-fibrous carbohydrates (NFC).

| CEL | | | |
|---------------------------------------|-----------|------------|-----------|
| Sowing densities (s m ⁻²) | First cut | Second cut | Third cut |
| 75 | 14,51 C | 21,72 B | 23,47 A |
| 150 | 15,96 C | 21,74 B | 23,59 A |
| 225 | 17,22 C | 21,58 B | 23,57 A |
| 300 | 17,13 C | 21,66 B | 23,70 A |
| 375 | 17,75 B | 23,21 A | 23,96 A |
| CV (%) | | 7,81 | |
| R ² | | 0,82 | |
| MM | | | |
| Sowing densities (s m ⁻²) | First cut | Second cut | Third cut |
| 75 | 9,51 A | 8,20 AB | 6,85 B |
| 150 | 8,67 B | 10,79 A | 7,67 B |
| 225 | 9,34 A | 8,35 A | 6,14 B |
| 300 | 9,77 A | 9,52 A | 8,57 A |
| 375 | 8,54 A | 6,46 B | 6,16 B |
| CV (%) | | 27,60 | |
| R ² | | 0,33 | |
| CP | | | |

| Sowing densities (s m ⁻²) | First cut | Second cut | Third cut |
|---------------------------------------|-----------|------------|-----------|
| 75 | 5,91 A | 6,22 A | 5,99 A |
| 150 | 6,28 A | 6,65 A | 6,21 A |
| 225 | 5,77 A | 6,64 A | 6,22 A |
| 300 | 5,76 A | 5,73 A | 5,76 A |
| 375 | 8,13 A | 6,37 B | 5,77 B |
| CV (%) | | 26,38 | |
| R ² | | 0,16 | |

| TC | | | |
|---------------------------------------|-----------|------------|-----------|
| Sowing densities (s m ⁻²) | First cut | Second cut | Third cut |
| 75 | 79,79 B | 82,25 AB | 83,61 A |
| 150 | 79,59 B | 78,06 B | 82,50 A |
| 225 | 80,30 B | 80,86 B | 83,86 A |
| 300 | 79,41 A | 80,59 A | 82,04 A |
| 375 | 77,58 B | 82,86 A | 85,49 A |
| CV (%) | | 3,87 | |
| R ² | | 0,36 | |

| NFC | | | |
|---------------------------------------|-----------|------------|-----------|
| Sowing densities (s m ⁻²) | First cut | Second cut | Third cut |
| 75 | 38,13 A | 24,79 B | 21,00 C |
| 150 | 36,84 A | 20,69 B | 18,49 B |
| 225 | 36,34 A | 23,41 B | 21,37 B |
| 300 | 36,13 A | 23,47 B | 20,20 B |
| 375 | 33,22 A | 25,19 B | 21,87 B |
| CV (%) | | 16,53 | |
| R ² | | 0,74 | |

* averages followed by the same capital letter (for the purposes of the cutting systems) in the line do not differ statistically by Tukey at 5% probability. CV (%): coefficient of variation; R²: R square. Authors.

The percentage character of total carbohydrates (TC) showed a statistical difference for the first and second cut, in relation to the increase in the sowing density. It is evident the increase in the percentage of total carbohydrates from the second and third cut, with its optimum points in the density of 375 seeds per square meter with 82.86% and 85.49%, respectively (Table 3), thus adding up to 0.60 % when performing the management of 375 seeds with two cuts, and 1.88% when using the maximum density at the third cut, both increments in relation to the population density of 75 seeds per square meter. Therefore, it is recommended to use the sowing density of 375 seeds per square meter, as well as the grazing can be extended to the third cut, resulting in an increase of 7.91% in total carbohydrates compared to the first cut (Table 3; Table 5).

According to the percentage of non-fibrous carbohydrates (NFC), the highest percentage was obtained in the first cut, with a decrease to the point where the sowing density increases, but does not differ statistically between them. The second and third cuts show increasing lines according to the increase in population density, with the highest percentages in the density of 375 seeds per square meter. The first cut presented percentages higher than the others, so compared to the third cut, in the density of 375 seeds per square meter, a decrease of 11.34% is observed (Table 2; Table 5).

Regarding the means for the interaction between the effects of the cutting system x sowing densities for the variables dry matter per hectare (DMH), lipids (LIP), acid detergent fiber (ADF) and lignin (LIG). The dry matter per hectare character did not show any statistical difference between the sowing densities within each cut. Even so, it can be seen that for the first cut, there was a greater increase in dry matter in the sowing density of 375 seeds per square meter, with 1372.01%. The second cut presented a greater increase in the density of 225 seeds per square meter, with 3144.48%, as well as the highest production occurred in the density of 75 seeds per square meter with 3251.38% in the third cut. The second cut presented a greater

increase in dry matter per hectare, it is worth noting that the second and third cut did not show any significant difference, and the first was shown to be inferior to the others.

The percentage of lipids obtained a significant difference between the cutting systems, the first one was higher, as well as a difference between the sowing densities for the second and third cut. For the first cut, even though there was no significant difference between sowing densities, the density of 375 seeds showed a higher percentage than the others with 5.73%. The second cut presented the best percentage with 150 seeds per square meter with 4.48%, as well as 3.77% for the third cut under the density of 225 seeds.

The character digestible fiber in acid detergent showed statistical variation between the cutting systems (Table 2), with a continuous increase in the percentage according to the cuts. The sowing densities did not differ between the cutting systems, however we can evidence that the density 375 seeds per square meter obtained better results for the first and second cut, with 44.36% and 57.66%, respectively, and better density management obtained with 150 seeds per square meter for the third cut, with a percentage of 64.01%. Lignin showed a significant difference for sowing densities of 150 seeds per square meter in the first cut, with 1.16% and 75 seeds per square meter for the second and third cut with 2.19% and 1.90%, respectively.

Table 3 shows the averages for the interaction between the effects of cutting systems x sowing densities for the variables cellulose (CEL), mineral matter (MM), protein (CP), total carbohydrates (TC) and non-fibrous carbohydrates (NFC).

The cellulose character showed a statistical difference between the cutting systems, obtaining a greater increase in the third cut, second cut and first cut, respectively. The first and second cuts showed statistical variation between the sowing densities, the density of 375 seeds per square meter showed a higher percentage, with 17.75% and 23.21% respectively. The third cut showed no statistical difference for the treatment of sowing density, however, a greater increase in the percentage in the density of 375 seeds per square meter can be observed, presenting 23.96%.

The mineral matter character showed variation between the sowing densities, the best percentages were obtained in the first and second cut. For the first and second cut, the density of 300 seeds per square meter obtained the highest percentage with 9.77% and 8.57% respectively. The second cut presented the best result in the density of 150 seeds, with a percentage of 10.79% of mineral matter (Silva et al., 2019).

The crude protein showed significant differences only for the second and third cuts. The first cut obtained the best result with the management of 375 seeds per square meter, obtaining 8.13% of protein. The second cut had the best percentage with the sowing density per square meter of 150 seeds, with 6.65% and the third cut had the best result with the density of 225 seeds per square meter, with a protein percentage of 6.22%.

The total carbohydrates showed a statistical difference between the densities for the first and second cuts. The density of 225 seeds per square meter was higher in the first cut, with 80.30%. For the second and third cut, the best percentages were obtained with the maximum sowing density of 375 seeds per square meter, with 82.86% and 85.49% respectively.

Non-fibrous carbohydrates showed no significant difference between sowing densities for the first and second cut. However, it can be seen in both that the best results were obtained in the density of 75 seeds per square meter with 38.13% and 24.79% respectively. The third cut, on the other hand, obtained the best parameter in the density of 375 seeds per square meter, with 21.87%, and for this treatment there was a significant difference between the sowing densities.

Pearson's linear correlation performed for 11 characters (Table 4) revealed 43 associations, all significant. Regarding the dry matter per hectare (DMH), positive correlation coefficients are revealed with NDF ($r=0.82$), ADF ($r=0.75$), LIG ($r=0.49$), HEM ($r=0.69$), CEL ($r=0.82$), TC ($r=0.32$), and negative with the characters LIP ($r = -0.44$), MM ($r = -0.19$), NFC ($r = -0.75$).

The percentage of lipids shows a positive correlation coefficient with the character NFC ($r = 0.32$), and negative for the characters NDF ($r = -0.48$), ADF ($r = -0.45$), LIG ($r = -0.24$), HEM ($r = -0.40$), CEL ($r = -0.45$), TC ($r = -0.46$). Regarding the percentage of neutral detergent fibers (NDF), positive correlations can be observed with the character ADF ($r = 0.85$), LIG ($r = 0.49$), HEM ($r = 0.89$), CEL ($r = 0.89$), TC ($r = 0.42$), and negative for MM ($r = -0.29$), NFC ($r = -0.91$). For the percentage character of acid detergent fiber (ADF), positive correlations were obtained for LIG ($r = 0.45$), HEM ($r = 0.60$), CEL ($r = 0.85$), TC ($r = 0.34$), and negative correlations for MM ($r = -0.23$) and NFC ($r = -0.77$).

The percentage of lignin (LIG) showed positive correlations for the characters HEM ($r = 0.44$), CEL ($r = 0.44$), TC ($r = 0.13$), and negative correlations for the character NFC ($r = -0.48$). Regarding the percentage of hemicellulose, it showed positive correlations for CEL ($r = 0.70$), TC ($r = 0.34$), and negative correlations for MM ($r = -0.22$) and NFC ($r = -0.83$). According to Campos et al. (2001) and Carvalho (2016a), the constitution of lignin, cellulose and hemicellulose are related to the forage species, stage of plant tissue development and climatic conditions, the increase in the magnitude of these characters is inversely proportional to the digestibility of ruminants.

The character percentage of cellulose showed a positive correlation for TC ($r = 0.39$), and negative correlations for MM ($r = -0.28$) and NFC ($r = -0.80$). The character percentage of mineral matter showed a negative correlation with the character TC ($r = -0.80405$). The percentage of crude protein showed negative correlations with TC ($r = -0.55$) and NFC ($r = -0.18$). The characters total carbohydrates and non-fibrous carbohydrates did not obtain positive or negative correlations with the other percentages.

The neutral detergent fiber (NDF) and hemicellulose (HEM), showed significant differences (table 6), as well as direct interaction for the treatment of cutting systems, which showed a continuous increase with the continuation of cuts. The third cuts showed the best results for neutral detergent fiber and hemicellulose, with 62.91% and 37.75%, respectively. And following the same train of thought, for the second cut with percentages of 57.41% and 34.62%, and the first cut with 43.20% and 26.28% respectively. (Carvalho et al., 2016b)

From the data presented above, we can evidence that the best results were obtained with higher seed densities per square meter, ranging from 300 to 375 the optimal seed density per square meter. A greater increase was observed during the cutting systems for the characters dry matter per hectare, fiber in acid detergent, lignin, cellulose and total carbohydrates, digestible fiber in neutral detergent and hemicellulose. The reverse was observed for the characters lipids, mineral matter and non-fibrous carbohydrates. That is, the results obtained showed an increase in the characters related to structural carbohydrates, since they are contained in the fraction of digestible fiber in neutral detergent, thus, they tend to increase according to the number of cuts due to the greater tillering, as well as with the aging of plants. Thus, the best way to maintain a balance between nutritional quality and yield is the use of only two cutting systems, so that structural carbohydrates are not excessively elevated, as well as good levels of non-structural carbohydrates are maintained.

Table 4: Estimates of the linear correlation of 11 bromatological and forage characters in five dual purpose wheat genotypes.

| | DMH | LIP | NDF | ADF | LIG | HEM | CEL | MM | CP | TC | NFC |
|-----|-----|--------|--------|--------|--------|--------|--------|--------|----|--------|--------|
| DMH | . | -0,44* | 0,82* | 0,75* | 0,49* | 0,69* | 0,82* | -0,19* | | 0,32* | -0,75* |
| LIP | | . | -0,48* | -0,45* | -0,24* | -0,40* | -0,45* | | | -0,46* | 0,32* |
| NDF | | | . | 0,85* | 0,49* | 0,89* | 0,89* | -0,29* | | 0,42* | -0,91* |
| ADF | | | | . | 0,45* | 0,60* | 0,85* | -0,23* | | 0,34* | -0,77* |
| LIG | | | | | . | 0,40* | 0,44* | | | 0,13* | -0,48* |
| HEM | | | | | | . | 0,70* | -0,22* | | 0,34* | -0,83* |
| CEL | | | | | | | . | -0,28* | | 0,39* | -0,80* |
| MM | | | | | | | | . | | -0,80* | |
| CP | | | | | | | | | . | -0,55* | -0,18* |
| TC | | | | | | | | | | . | |
| NFC | | | | | | | | | | | . |

* significant linear correlation coefficient (n = 225) at 5% probability by t test. DMH: dry matter yield per hectare in kg ha⁻¹; LIP: percentage of lipids; NDF: percentage of fibers in neutral detergent; ADF: percentage of fibers in acid detergent; LIG: percentage of lignin; HEM: percentage of hemicellulose; CEL: percentage of cellulose; MM: percentage of mineral matter; CP: percentage of crude protein; TC: percentage of total carbohydrates; NFC: percentage of non-fibrous carbohydrates. Source: Authors.

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Table 5: Equations obtained by specific polynomial linear regression for each level of the effect.

| Cutting systems | Equations |
|-----------------|---|
| | DMH |
| First | $\hat{y}: 557,51+2,46x$ R ² :0,24 |
| Second | $\hat{y}: 2913,21$ R ² :0,01 |
| Third | $\hat{y}: 557,51+2,46x$ R ² :0,24 |
| | LIP |
| First | $\hat{y}: 2,94+0,03x-0,002x^2+0,0000003x^3$ R ² :0,11 |
| Second | $\hat{y}: 3,58$ R ² :0,03 |
| Third | $\hat{y}: 2,69+0,01x-0,00003x^2$ R ² :0,10 |
| | ADF |
| First | $\hat{y}: 15,01+0,009x$ R ² :0,19 |
| Second | $\hat{y}: 24,05$ R ² :0,02 |
| Third | $\hat{y}: 25,15$ R ² :0,000001 |
| | LIG |
| First | $\hat{y}: -6,52+0,16x-0,001x^2+0,000003x^3-0,000000004x^4$ R ² :0,14 |
| Second | $\hat{y}: 2,81-0,01x+0,00001x^2$ R ² :0,11 |
| Third | $\hat{y}: 2,03$ R ² :0,04 |
| | CEL |
| First | $\hat{y}: 14,22+0,01x$ R ² :0,22 |
| Second | $\hat{y}: 21,11$ R ² :0,03 |
| Third | $\hat{y}: 23,33$ R ² :0,01 |
| | MM |
| First | $\hat{y}: 9,42$ R ² :0,002 |
| Second | $\hat{y}: -24,48+0,80x-0,006x^2+0,00001x^3-0,00000002x^4$ R ² :0,25 |
| Third | $\hat{y}: -17,77+0,63x-0,005x^2+0,00001x^3-0,00000002x^4$ R ² :0,18 |
| | CP |
| First | $\hat{y}: 2,86+0,06x-0,0003x^2+0,0000006x^3$ R ² :0,19 |
| Second | $\hat{y}: 6,50$ R ² :0,003 |
| Third | $\hat{y}: 6,26$ R ² :0,008 |
| | TC |
| First | $\hat{y}: 80,71$ R ² :0,03 |
| Second | $\hat{y}: 119,08-0,87x+0,006x^2-0,00001x^3+0,00000001x^4$ R ² :0,20 |
| Third | $\hat{y}: 107,00-0,59x+0,004x^2-0,00001x^3+0,0000000x^4$ R ² :0,18 |
| | NFC |
| First | $\hat{y}: 39,30+0,01x$ R ² :0,11 |
| Second | $\hat{y}: 22,44$ R ² :0,01 |
| Third | $\hat{y}: 19,55$ R ² :0,01 |

DMH: dry matter yield per hectare in kg ha⁻¹; LIP: percentage of lipids; NDF: percentage of fibers in neutral detergent; ADF: percentage of fibers in acid detergent; LIG: percentage of lignin; HEM: percentage of hemicellulose; CEL: percentage of cellulose; MM: percentage of mineral matter; CP: percentage of crude protein; TC: percentage of total carbohydrates; NFC: percentage of non-fibrous carbohydrates. Source: Authors.

Table 6: Comparison of means for the effects of cutting systems.

| NDF | | | |
|-----------------|-----------|------------|-----------|
| Cutting systems | First cut | Second cut | Third cut |
| | 43.20 c | 57.41 b | 62.91 a |
| HEM | | | |
| Cutting systems | First cut | Second cut | Third cut |
| | 26.28 c | 34.62 b | 37.75 a |

* CS: cutting systems; NDF: digestible fiber in neutral detergent; HEM: hemicellulose. Averages followed by the same lowercase letter on the line do not differ statistically from tukey at 5% probability. Source: Authors.

4. Final Considerations

The positive effects on yield and bromatological quality of the forage are obtained by arranging plants and cutting systems through the sowing density of 300 to 375 seeds per meter with the practice of up to two cuts in dual purpose wheat.

Superior dry matter per unit area was observed in the second cut, which was defined by the stimulation of tillering, regrowth and split nitrogen fertilization. Since, the superior bromatological quality is determined by the magnitude of non-fibrous carbohydrates in the forage.

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