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Scientific Article

Agronomic and bromatological characteristics of forage wheat under different fertilization managements and densities

Características agronômicas, fisiológicas e bromatológicas do trigo forrageiro em diferentes manejos de adubação e densidades

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ABSTRACT - The objective of the present study was to evaluate the wheat crop as a forage potential subjected to different fertilization and sowing densities in the semi-arid region of Minas Gerais, Brazil. The design used was randomized blocks in a 3 x 4 factorial scheme with 3 replications, with 3 fertilization managements (without fertilization, organomineral fertilization and mineral fertilization) and 4 sowing densities (200, 350, 500 and 650 seeds m^2). The chosen wheat cultivar was MGS Brilhante. For agronomic characteristics, a greater plant height was observed in the fertilized treatments, with an average of 111.28 cm, regardless of the type of fertilizer. For fresh matter and dry matter production, the mineral fertilization treatment showed a 19.76% and 18.99% higher production, respectively, compared to the others. Regarding the leaf percentage variable, there was an average reduction of 25.65% in the treatment without fertilization compared to those with fertilization. Concerning the bromatological composition, there was only a difference in neutral detergent fiber, with an average increase of 6.32% with organomineral fertilization compared to the other treatments. The use of broadcast mineral fertilizer promotes superior results in terms of dry matter yield (5.55 t ha^{-1} compared to organomineral fertilizer (4.63 t ha^{-1}). Increasing sowing density does not affect crop yield.

Keywords: Semi-arid region. *Triticum aestivum.* Cereal. Succession.

RESUMO - Objetivou-se com o presente estudo avaliar a cultura do trigo como potencial forrageiro submetido a diferentes adubações e densidades de semeadura no semiárido Mineiro. O delineamento utilizado foi o de blocos casualizados em esquema fatorial 3 x 4 com 3 repetições, sendo 3 manejos de adubações (sem adubação, adubação organomineral e adubação mineral); e 4 densidades de semeadura (200, 350, 500 e 650 sementes m^2). A cultivar de trigo utilizada foi a MGS Brilhante. Para as características agronômicas, observou-se maior altura de planta nos tratamentos com adubação, com média de 111,28 cm, independentemente do tipo de adubo. Para produção de matéria natural e matéria seca, o tratamento com adubação mineral apresentou produção superior de 19,76% e 18,89% respectivamente aos demais. Para a variável porcentagem de folha observou-se redução média de 25,65% no tratamento sem adubação em relação aos com adubação. Para composição bromatológica, houve diferença apenas para a fibra em detergente neutro, com aumento médio de 6,32% com adubação organomineral em relação aos demais tratamentos. A utilização de adubo mineral a lanço propiciou resultados superiores de produtividade de matéria seca (5,55 t ha^{-1}), em relação ao organomineral (4,63 t ha^{-1}). O aumento da densidade de semeadura não afeta a produtividade da cultura.

Palavras-chave: Semiárido. *Triticum aestivum.* Cereal. Sucessão.

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INTRODUCTION

In Brazilian semi-arid regions, farmers face daily challenges in their crops. Even with fertile land, the high salinity of the soil, high temperatures and strong winds, which are typical of these places, can result in physiological stress to the plant, hindering its development. The northern region of the State of Minas Gerais has all these characteristics; however, several public and private irrigation projects have enabled the cultivation of various plant species.

Wheat (*Triticum aestivum* L.) forage can be an alternative in succession to other crops traditionally used in the summer in this region (VIEIRA et al., 2022). Due to the drop in pasture production during winter, it is necessary to adopt strategies to optimize land use on properties and reduce the effects caused by the forage deficit in this period. Therefore, to mitigate the effects of the dry season, the use of wheat is an alternative to optimize the use of existing irrigated land, also obtaining the benefit of crop rotation, such as reducing the incidence of diseases, weeds and pests and promoting physical, chemical and biological improvements in the soil (SANTOS et al., 2019). Wheat is a dual-purpose crop that has characteristics of a quality forage, such as good nutritional value, grazing tolerance, good tillering capacity, good adaptation and production during periods of scarcity of tropical forages (HASTENPFLUG et al., 2011).

Alternative sources of fertilizers are becoming increasingly attractive due to the high costs of production using conventional fertilization. Organomineral fertilizers have been shown to be satisfactory in the addition of organic matter to the soil and in the fertilization of crops. Their continuous use increases the organic matter content in the soil, which, therefore, benefits its physical attributes, improving its water retention capacity, decreasing erosion, improving aeration and creating better conditions for the development of soil microbiota. With proper management, it is possible to efficiently replace mineral fertilizers, partially or even fully.The association of inorganic fertilizers with a high nutrient content with an organic matrix results in organomineral fertilizer (KOMINKO; GORAZDA; WZOREK, 2017).

Among the procedures for planting wheat, we can highlight the quality of seeds and the density of sowing. Obtaining appropriate plant stands is essential for the cultivar to express its maximum genetic potential in yield, as well as increasing its production stability in the face of climatic adversities (FOLONI; BASSOI; SILVA, 2016). Increasing sowing density is the main way to improve wheat yield (GAO et al., 2021). According to Wang and Li (2008), sowing density can directly affect the final production, as it acts significantly on the effect of the emergence and survival of plant tillers and also on the ability to maintain plant structure and architecture, in order to obtain a good efficiency of radiation use, mainly by the flag leaf, converting it into photoassimilates for the development of the plant throughout its cycle.

In view of the above, the objective of this study was to determine the agronomic, physiological and bromatological characteristics of ‘MGS Brilhante’ wheat subjected to different fertilization managements and sowing densities.

MATERIAL AND METHODS

The experiment was conducted from May to August 2021 in the experimental area of the Institute of Agricultural Sciences of the Federal University of Minas Gerais (UFMG), located in the city of Montes Claros, MG. Montes Claros is located in the northern region of Minas Gerais, Brazil, and its geographical coordinates are 16° 44’ 06” S and 43° 51’ 43” W and altitude of 624 m. According to Köppen (ALVARES et al., 2013), the climate is dry tropical, with annual precipitation between 1000 and 1300 mm, with dry winter and average temperature of 22.7 °C.

The soil of the experimental area is classified as *Argissolo Vermelho Amarelo eutrófico típico* (Ultisol). The cultivation was conventional and the soil was prepared with plowing and harrowing (medium harrow). Soil sampling was performed at a depth of 0-20 cm one month before wheat sowing, using a shovel. The samples were sent for chemical analysis at the Soils Laboratory of the Agricultural Sciences Institute (ICA)/UFMG. The results of the soil chemical analysis can be seen in Table 1.

Table 1. Chemical analysis of the soil in the experimental area in the 0-20 cm profiles, April/2021.

Layer	pH H_2O	P	K	Ca	Mg	Al	H + Al	SB	CEC	V	OM
(cm)	-	--mg dm^{-3} --		----------------------- $cmol_c$ dm^{-3} ----------------------						(%)	dag kg^{-1}
0-20	6.6	3.2	108	5.1	1.1	0	1.8	6.5	8.3	78	2.3

P, K = (0.05 mol L^{-1} HCl + 0.0125 mol L^{-1} H_2SO_4); available P (Mehlich-1 extractant); Ca, Mg, Al (1 mol L^{-1} KCl); H+Al(Buffer solution – SMP at pH 7.5); SB = sum of bases; CEC = cation exchange capacity; V = base saturation; OM = organic matter. Source: ICA Soil Analysis Laboratory /UFMG.

The genetic material used was provided by the Agricultural Research Company of Minas Gerais (Epamig), the wheat cultivar MGS Brilhante, with potential as a forage crop. Its selection is due to its wide use and existing studies in the savannah region of Minas Gerais state, as well as its resistance to drought and heat, early cycle, moderate lodging resistance, and absence of awns, structures that cause minor injuries in cattle's rumen. The experiment was conducted in a randomized block design in 3 x 4 factorial, with three replications, consisting of three managements (without fertilization, mineral fertilizer and organomineral fertilizer) and four sowing densities (200, 350, 500 and 650 seeds m^{-2}), totaling 36 plots. The plots consisted of a 10 m² (5 x 2) area and the usable area was 2 m². Before sowing, broadcast fertilization was performed. 100 kg ha^{-1} of P_2O_5 were applied for the organomineral fertilizer (05-26-00) and 100 kg ha^{-1} of P_2O_5 for the mineral fertilizer (MAP- 12-54-00); no fertilization was applied to the control group.

The wheat seeds were sown broadcast and fertilized in the field on May 21, 2021. For this, after harrowing, with the aid of a graduated tape, the plots were divided for subsequent fertilization and sowing of the inputs previously measured and weighed in the amount established for the treatments. After fertilization, sowing was carried out with seed incorporation using a rake. Planting densities were 200-350-500-650 seeds per m^2 distributed among the plots at random.

At 30 days after emergence, topdressing fertilization was applied using 40 kg/ha of nitrogen and 10 kg/ha of potassium for the fertilized treatments, following the recommendations of the Joris et al. (2022). The plants were harvested when the grains were in the soft but dry dough stage (Feekes Maturation Stage 11.2), described by LARGE (1954). For this, they were cut close to the ground with a sickle and a 0.5 m^2 square. The square was randomly thrown at four points within each plot, totaling a usable area of 2 m^2 of forage. The collected samples were weighed on a portable digital scale to determine the green weight of the plot.

The variables evaluated in this trial were plant height (cm), fresh matter yield (t ha^{-1}) and total dry matter (t ha^{-1}), total tillers (nº), total plant weight (g), % leaf, % stem, % spike and physiological characteristics such as chlorophyll, net photosynthetic rate (µmol m^{-2} s^{-1}), transpiration (E) (mmol of H_2O m^{-2} s^{-1}), stomatal conductance (gs) (gs mol m^{-2} s^{-1}) and internal CO_2 concentration (Ci) (µmol mol^{-1}). For the physiological evaluations, we used an Infrared Gas Analyzer (IRGA), model LCpro-SD Marconi/ADC.

After obtaining the fresh weight, 20 plants selected at random from the usable area were collected, weighed and dried in a forced aeration oven, at a temperature of 55 °C to 60 °C for 72 h. Subsequently, the percentage of forage dry matter was determined. Dry matter yield was estimated by means of the fresh weight of the plots multiplied by the percentage of dry matter. The average weight was transformed into t ha^{-1}.

Plant height was obtained by averaging 20 plants measured from their base to the apex of the spikes, with the aid of a measuring tape graduated in centimeters at harvest.

To determine the number of tillers, an area of 1 m² was randomly marked. In each plot, the evaluations were carried out in two stages: the first evaluation at 15 days after germination and the second after 25 days. The number of tillers per plant was obtained by manually counting them in a non-destructive manner.

The nitrogen status of the plants was monitored weekly, throughout the wheat development stages, using an AtLeaf® chlorophyll meter. Readings were performed on 15 plants considering the youngest leaf of the plant whorl.

To determine the percentages of spike, stem and leaf in the green matter, the total weight of the green matter per plot was initially determined. Subsequently, the spikes, stems, and leaves from ten plants of each plot were weighed, and then their percentages were determined. Subsequently, the samples were analyzed for dry matter (DM) (INCT-CA G-001/1 and G -003/1), crude protein (CP), neutral detergent fiber (NDF) (INCT-CA F-001/1), acid detergent fiber (ADF) (INCT-CA F -008/1), mineral matter (MM) (INCT-CA M-001/1) and organic matter (OM), following the recommendations of DETMANN et al. (2021). The flag leaves of 20 plants were collected in the plots at the time of bottling for foliar macronutrient (NPK) analysis, according to the Embrapa (2009) methodology.

Data were subjected to analysis of variance and, when significant, to the Scott-Knott test at a 5% significance level, using the SISVAR software version 5.6 (FERREIRA, 2019). Subsequently, Pearson's simple correlation analysis was performed in order to know the intensity with which the variables influence and are influenced.

RESULTS AND DISCUSSION

The summary of the analyses of variance for the agronomic characteristics of wheat at different sowing densities (200-350-500-650 seeds per m^2) and fertilization managements (mineral, organomineral and without fertilization) are presented in Table 2. Only the fertilization managements caused significant effects on the characteristics plant height, fresh matter yield, dry matter yield and percentage of leaves. The other agronomic traits were not affected by any of the treatments.

Table 2. Analysis of variance summary for total tillers (TT), plant height (PH), fresh matter yield (FMY), dry matter yield (DMY), plant weight (PW), leaf percentage (% Leaf), stalk percentage (% stalk) and spike percentage (% spike) of wheat subjected to different fertilization managements and sowing densities.

S.V.	DF	Mean squares							
		TT (n°)	PH (m)	FMY (t ha^{-1})	DMY (t ha^{-1})	PW (g)	% leaf	% stalk	% spike
Blocks	2	180340.33	545.02	31.24	5.85	0.06	29.23	8.30^{ns}	11.83^{ns}
Fertilization (F)	2	42609.45^{ns}	191.14*	32.53*	4.00*	0.06^{ns}	72.18*	15.05^{ns}	27.78^{ns}
Densities (D)	3	52128.10^{ns}	6.38^{ns}	1.07^{ns}	0.41^{ns}	0.242^{ns}	7.86^{ns}	8.80^{ns}	6.99^{ns}
F x D	6	14912.58^{ns}	19.24^{ns}	5.59^{ns}	0.79^{ns}	0.207^{ns}	4.31^{ns}	6.45^{ns}	5.88^{ns}
Error	22	27352.69^{ns}	33.06^{ns}	8.39^{ns}	0.89^{ns}	0.12^{ns}	9.18^{ns}	26.92^{ns}	31.35^{ns}
Total	35								
Means		266.08	108.87	12.70	4.88	2.67	18.63	48.48	32.88
C.V. (%)		62.16	5.28	22.80	19.44	15.40	16.27	10.70	17.03

S.V. – sources of variation; CV - coefficient of variation; D.F. - degrees of freedom; Int. – interaction; **, * – significant at 5% probability; ns – not significant by F-test.

When comparing the fertilization treatments, plant height was lower in the control treatment compared to those with fertilization, regardless of the fertilizer source (Table 3). Plots with organomineral (110.26 cm) and mineral (112.31 cm) fertilizers did not differ statistically for plant height, but were superior to the treatment without fertilization.

Table 3. Mean results for plant height (cm), fresh matter yield (t ha^{-1}), dry matter yield (t ha^{-1}) and leaf percentage (%) of wheat subjected to different fertilization managements and sowing densities.

Fertilization	Plant height (cm)	Fresh matter (t ha^{-1})	Dry matter (t ha^{-1})	Leaf percentage (%)
Control	104.67 b	11.75 b	4.46 b	15.79 b
Organomineral	110.26 a	11.87 b	4.63 b	19.02 a
Mineral	112.31 a	14.72 a	5.55 a	20.66 a

Means with the same lowercase letter in the column belong to the same grouping, according to the Scott-Knott test at 5% significance level.

Fertilization management had significant effects on fresh matter and dry matter yield. The plot without fertilization (4.46 t ha^{-1}) and the organomineral treatment (4.63 t ha^{-1}) were similar, while the treatment with mineral fertilization (5.55 t ha^{-1}) showed a higher value (Table 3). For the percentage of leaves, it was noted that the plots without fertilization (15.79%) had lower numbers, statistically different from the treatments with organomineral (19.02%) and mineral (20.66%) fertilization (Table 3).

For the bromatological characteristics, there was a significant difference only as a function of fertilization management for the variable neutral detergent fiber (Table 4).

For the neutral detergent fiber (NDF) content, a significant effect of fertilization management was observed.

Table 4. Analysis of variance summary for chemical composition based on crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), dry matter (DM), mineral matter (MM) and organic matter (OM) in wheat subjected to different fertilization managements and sowing densities.

S.V.	DF	Mean squares					
		DM (%)	MM (%)	OM (%)	NDF	ADF	CP (%)
Blocks	2	6.49	0.48	3.46	104.05	17.86	4.27
Fertilization (F)	2	7.54 ^{ns}	0.85 ^{ns}	13.35 ^{ns}	54.37 *	28.69 ^{ns}	0.93 ^{ns}
Densities (D)	3	6.27 ^{ns}	0.91 ^{ns}	5.00 ^{ns}	11.87 ^{ns}	10.77 ^{ns}	0.05 ^{ns}
F x D	6	4.97 ^{ns}	0.47 ^{ns}	3.01 ^{ns}	13.96 ^{ns}	13.87 ^{ns}	0.50 ^{ns}
Error	22	5.76	1.07	4.97	12.67	16.46 ^{ns}	1.21
Total	35						
Means		87.41	6.21	81.20	54.22	32.93	4.99
C.V. (%)		2.74	16.64	2.75	6.56	12.32	22.08

S.V.- sources of variation; CV- coefficient of variation; D.F- degrees of freedom; Int.- interaction; **,* - significant at 5% probability level; ns- not significant by F-test.

The plot without fertilization (53.54%) and the mineral treatment (52.52%) were similar, while the treatment with organomineral fertilization (56.61%) showed a higher NDF content (Table 5).

No difference was observed for the variables chlorophyll, net photosynthetic rate (A) (µmol m^{-2} s^{-1}), transpiration (E) (mmol H_2O m^{-2} s^{-1}), stomatal conductance (gs mol m^{-2} s^{-1}), internal concentration of CO_2 (Ci) (µmol mol^{-1}) (Table 6).

Table 5. Chemical composition based on crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), dry matter (DM), mineral matter (MM) and organic matter (OM) in wheat subjected to different fertilization managements and sowing densities.

Fertilization	DM (%)	MM (%)	OM (%)	NDF	ADF	CP (%)
Control	32.68 a	6.52 a	80.02 a	53.54 b	32.83 a	8.01 a
Organomineral	34.36 a	6.02 a	82.48 a	56.61 a	34.07 a	8.22 a
Mineral	32.84 a	6.10 a	81.48 a	52.52 b	33.72 a	8.73 a

Means with the same lowercase letter in the column belong to the same grouping, according to the Scott-Knott test at 5% significance level.

Table 6. Summary of analysis of variance for the variables chlorophyll (Chlo), net photosynthetic rate (A) (µmol m^{-2} s^{-1}), transpiration (E) (mmol of H_2O m^{-2} s^{-1}), stomatal conductance (gs mol m^{-2} s^{-1}), and internal CO_2 concentration (Ci) (µmol mol^{-1}).

SV	DF	Mean Squares				
		Chlo	*A*	*E*	gs	Ci
Blocks	2	1.79	1.47	0.66	0.01	26318.77
Fertilization (F)	2	19.99^{ns}	30.13^{ns}	0.14^{ns}	0.01 ^{ns}	43.1450^{ns}
Densities (D)	3	19.36^{ns}	35.12^{ns}	0.02^{ns}	0.01 ^{ns}	9997.20^{ns}
F x D	6	13.93^{ns}	18.54^{ns}	0.36^{ns}	0.01 ^{ns}	7231.71^{ns}
Error	22	15.73	20.79	0.32	0.01	8138.76
Total	35					
Means		57.51	13.84	1.60	0.16	230
CV (%)		6.90	69.50	35.24	48.86	39.14

S.V. – sources of variation; CV - coefficient of variation; D.F. - degrees of freedom; Int. – interaction; **, * – significant at 5% probability level; ns – not significant by F-test at 5% significance according to Scott-Knott test.

No difference was observed in the contents of nitrogen, phosphorus and potassium in the flag leaf of wheat subjected to different fertilization managements and sowing densities (Table 7). Regardless of the treatments, the average leaf contents of nitrogen, phosphorus and potassium described in Table 7 are within the appropriate ranges cited by Embrapa (2009).

Table 7. Analysis of variance summary for the macronutrients N, P and K in the flag leaf in wheat subjected to different fertilization managements and sowing densities.

S.V.	DF	Mean squares		
		N (dag kg^{-1})	P (dag kg^{-1})	K (dag kg^{-1})
Blocks	2	0.13	0.02	0.45
Fertilization (F)	2	0.81 ^{ns}	0.01 ns	0.22 ns
Densities (D)	3	4.13 ^{ns}	0.01 ns	0.07 ns
F x D	6	1.11 ^{ns}	0.00 ns	0.42 ns
Error	22	31.14	0.00	0.29
Total	35			
Means		4.07	0.31	1.65
C.V. (%)		29.22	27.24	32.40

S.V. – sources of variation; CV - coefficient of variation; D.F. - degrees of freedom; Int. – interaction; **, * – significant at 5% probability level; ns – not significant by F-test.

When analyzing the Pearson's correlations, it was possible to notice that the most strongly correlated positive characteristic was the fresh and dry matter yield, as expected (r = 0.97). For the total production of tillers, a positive correlation was observed between dry matter (r = 0.53) and fresh matter (r = 0.49) and also for the phosphorus content of the flag leaf (P) (r = 0.43). For plant height, there was a positive correlation with the dry (r = 0.49) and fresh (r = 0.52) matter yield variables. A significant negative correlation of low magnitude was observed between leaf percentage and ear percentage (r = -0.47). There was also a negative correlation of high magnitude (r = -0.71) between stem and spike percentages, which shows the dilution effect of these fractions with the increase in the forage portion of the plant. A positive correlation was also observed between net photosynthetic rate and transpiration (r = 0.52) (Tables 8 and 9).

The experiment was conducted using irrigation for crop development due to the absence of rain during the period. Average temperatures during the development of the wheat crop were in the range of 18-24 °C. As reported by Santos et al. (2022), it is important to sow in the months of April/May in that region, in addition to the need for irrigation. The yields obtained in the present study (Table 3) were higher than those reported by Vieira et al. (2022). Theses authors, when evaluating the productive performance of Panaty wheat in the Municipality of Janaúba, MG, reported values of 3.05 t ha^{-1} of forage DM.

Plant height is an agronomic indicator of yield. Phosphorus has important functions in plant development, participating in photosynthesis, cell division and growth, consequently leading to a greater supply of energy (ATP), resulting in greater growth and development, especially in plant roots (VIEIRA; WEBER; SCARAMUZZA, 2015). The highest height of fertilized plants has great similarity with the results found by MARQUES et al. (2014), with black oats and ryegrass. This can be related to better fertility conditions that the evaluated fertilizers provided for the soil, making more nutrients available in the soil solution to be used by the wheat plants, which resulted in greater plant growth. Therefore, fertilization must be carried out for productive purposes of wheat, regardless of the fertilizer source used (CQFS-RS/SC - Comissão de Química e Fertilidade do Solo, 2016).

Table 8. Pearson correlations involving variables in wheat. Total Tillers (TT), Dry Matter Yield (DMY), Fresh Matter Yield (FMY), Total Plant Yield (TPY), Leaf Percentage (LE), Stem Percentage (ST), Spike Percentage (SPI) considering wheat submitted to different fertilization and sowing densities.

Correlations	Height	FMY	DMY	TPY	LE	ST	SPI
TT	0.15 ns	0.49*	0.53*	0.10 ns	-0.25 ns	-0.09 ns	0.27 ns
Height		0.49*	0.52*	0.31 ns	0.03 ns	0.10 ns	-0.11 ns
FMY			0.97 **	0.27 ns	-0.20 ns	-0.16 ns	0.30 ns
DMY				0.30 ns	-0.23 ns	-0.17 ns	0.33 ns
TPY					-0.01 ns	-0.17 ns	-0.15 ns
LE						0.29 ns	-0.47 *
ST							-0.71 **

* Significant at 5% significance by t-test; - ** Significant at 1% significance by t-test; - ns Not significant at 5% significance by t-test.

Table 9. Pearson correlations involving variables in wheat Stem Percentage (ST), Spike Percentage (SPI), Chlorophyll (Chlor), Net photosynthetic rate (NFR), transpiration (TRANS), stomatal conductance (SC), Nitrogen (N), Phosphorus (P) and Potassium (K), considering wheat submitted to different fertilization and sowing densities.

Correlations	Chlor	NFR	TRANS	SC	CO2	N	P	K
SPI	-0.21 ns	-0.01 ns	0.26 ns	0.15 ns	-0.19 ns	0.01 ns	0.11 ns	-0.14 ns
Chlor		-0.07 ns	0.07 ns	0.04 ns	0.16 ns	0.00 ns	0.02 ns	-0.27 ns
NFR			0.52 *	0.41 ns	-0.21 ns	-0.30 ns	-0.10 ns	-0.04 ns
TRANS				0.91 **	0.17 ns	-0.29 ns	-0.16 ns	0.42 *
SC					0.23 ns	-0.14 ns	0.37 ns	0.80**
N						0.03 ns	0.60 **	0.39 ns
P							0.61 **	0.40 ns
K								0.40 ns

* Significant at 5% significance by t-test; - ** Significant at 1% significance by t-test; - ns Not significant at 5% significance by t-test.

Later irrigated planting may have provided better conditions for wheat development with mineral fertilizer. Possibly mineral fertilization favored the accumulation of dry matter more due to the greater chemical reactive potential of the fertilizer when compared to the organomineral fertilizer. A disadvantage of organomineral fertilizers is their slower cycling of nutrients from elements such as phosphorus bound to an organic source. This becomes more evident when working with short-season crops such as wheat. Another issue is that the broadcasted phosphorus added to the soil had less reaction in the organomineral fertilizer. Broadcast phosphate fertilization in soils with low concentration of this nutrient makes phosphorus a limiting resource, mainly due to the low mobility of this element in clayey soils as in this study. In such soils, as the buffering power is higher, the ability to extract phosphorus decreases (SOBRAL et al., 2015). Highly weathered soils have a great relationship with mineralogical constituents, making most of the phosphorus adsorbed and unavailable to plants. Furthermore, the phosphorus added to the soil surface together with the broadcast seeds and subsequent incorporation possibly reduced the fertilizer efficiency. Furthermore, the excess Ca described in the soil analysis (Table 1) favors greater P adsorption and, in turn, plant metabolism.

Grohskopf et al. (2020), in a study comparing organomineral fertilizers (chicken litter plus granulated phosphorite and swine manure plus MAP in fluid form) with other mineral fertilizers (granulated MAP and triple super phosphate, and MAP diluted in water), observed in clayey soils higher levels of assimilable phosphorus for soluble phosphates. The authors also highlighted that phosphorus release is faster from soluble sources, since the availability of the organic fraction of the element in the soil, with the use of organomineral fertilizers, requires that the organic matter be first mineralized.

The organomineral fertilizer, compared to the mineral one, has a relatively lower reactive chemical potential. On the other hand, its solubilization is gradual over the period of crop development, when agronomic efficiency can become greater when compared to soluble mineral fertilizers. According to Sivojiene et al. (2021), the continuous use of organomineral fertilizers reduces the need for large volumes of fertilizer over time, as it stimulates the proliferation of organisms responsible for mineralizing soil nutrients, making them available throughout the plant cycle. In addition, it reduces losses from nitrogen volatilization and leaching, phosphorus fixation and precipitation and potassium leaching.

The significant reduction in the leaf area of plants cultivated under phosphorus deficiency has been identified as one of the main factors responsible for the reduction in plant growth due to the reduction of the surface responsible for CO_2 capture (TRINDADE; ARAÚJO; TEIXEIRA, 2010). The number of leaves is related to the production of tillers, which is largely responsible for the production of the crop. Leaves are photosynthetic organs where light is captured and used for chemical reactions that are vital to the plant. Phosphorus in leaf tissue probably entered the metabolic compartment of plants, stimulating photophosphorylation and ATPASE activity and, consequently, ATP biosynthesis, ensuring greater use of light, photosynthetic rates and cell division and expansion. This promoted an increase in plant growth and biomass production, as verified in the present study (Table 3). These results were higher than those found by Carletto et al. (2020), who observed plant height of 75.6 cm without fertilization at 115 days after planting.

Valério et al. (2008), in a study to assess the development of tillers in different wheat genotypes under different plant densities, observed that genotypes that have low tillering potential are more dependent on plant population for a high yield.

NDF and ADF contents are indicative of the quantity and quality of forage fiber. Lower values of ADF contents are a good indicator of improvement in the nutritional value of silage, as there is a negative correlation between ADF contents and food degradability.

The variation in cellulose and hemicellulose contents may be related to the determination of NDF and ADF, as such contents are obtained by the difference between these fractions. Hemicellulose can be determined by the difference between NDF and ADF contents. Hemicellulose is a group of substances that closely follow the formation of the cell wall of plants and is mainly composed of pentoses (xylose and arabinose), hexoses (glucose, mannose and galactose), uronic acids and acetyl group. Considering that NDF is composed of cellulose, hemicellulose and lignin and is related to food intake by cattle and ADF is composed of cellulose and lignin and its higher content is related to lower digestibility, we can conclude that the portion with organomineral fertilization, despite having a higher NDF content, may have better digestibility of the fibrous fraction, in view of the higher

NDF/ADF ratio with greater participation of hemicellulose. When studying different wheat cultivars for forage, Vieira et al. (2022) found digestibility values between 31.21 and 43.94% for NDF and between 21.99 and 35.21% for ADF.

The production of tillers has a positive relationship with yield and the phosphorus content of the flag leaf, a result that demonstrates the importance of phosphorus fertilization. The flag leaf is considered the primary source for grain filling, due to the short distance from the spike. Leaves located in the upper portion of the stem are responsible for most of the production of photoassimilates responsible for grain production (SOUZA et al., 2013). Tillering capacity has a compensatory character throughout the phenological development of plants and, given its strong influence on the number of spikes per plant, it is important to regulate tiller survival. Self-sufficient and photosynthetically active tillers tend to contribute with increased grain yield (FIOREZE; RODRIGUES, 2012).

Increases in plant height contribute to increased biomass yield. This was expected, since taller plants can produce more biomass volume if the leaf, spike and grain fractions are also high. Domingues et al. (2013) obtained correlations of 0.80 for the same variables, a factor that made these authors indicate the possibility of indirect selection of taller plants aiming at higher yield. According to Tavares et al. (2014), taller plants can make the genotype more susceptible to lodging, and sometimes it may not be suitable for cultivation in places with high intensity of winds and very fertile soils.

This was probably because the plants were harvested at Feekes' 11.2 maturity stage. Falqueto et al. (2009) argued that yield is strongly influenced by the efficiency of plants in directing their assimilates to specific structures, as well as by the ability to modify this transport throughout their phenological stages under different environmental conditions.

The photosynthetic rate was positively correlated with the production of dry matter (r = 0.42), fresh matter (r = 0.42), plant height (r = 0.48) and total plant weight (r = 0.55). This positive correlation between production and photosynthesis in wheat is probably due to the greater availability and absorption of light. The photosynthetic rate is directly related to photosynthetically active radiation and indirectly related to factors associated with gas exchange and water availability. Xiao et al. (2012) observed that the biomass yield was higher at high post-anthesis photosynthetic rates, considering that much of the photosynthesis produced during the post-anthesis period is directed to the sinks. Therefore, increases in the photosynthetic rate and stomatal conductance of modern cultivars, mainly after anthesis, can be important tools to increase the yield potential in wheat. With that, it can be affirmed that the wheat crop has a positive correlation, as higher photosynthetic rate may result in increase in yield. Studies claim that the positive correlation between production and photosynthetic rate probably only exists for crops in which most of the plant is harvested.

For transpiration, a strong positive correlation was observed with stomatal conductance (r = 0.91). About 95% of the water absorbed by the plant is used to maintain the thermal balance through transpiration. When plants face water shortages, leaf transpiration decreases, causing a reduction in stomatal conductance. In addition to stomatal closure, the decrease in transpiration can also cause insufficient leaf cooling, which leads to an increase in leaf temperature. This result demonstrates that transpiration and stomatal conductance (gs) are directly correlated.

According to Catuchi et al. (2012), the ratio between photosynthetic rate and transpiration results in greater efficiency in the use of water by plants, which is another physiological parameter that quantitatively expresses the momentary behavior of gas exchange in the leaf, and which varies between species. This indicates the plant's ability to regulate gas exchange, reducing proportionally more the stomatal conductance and, consequently, transpiration, than the assimilation of CO_2, which preserves water for each assimilated molecule of CO_2, since the partial reduction of stomatal conductance proportionally limits transpiration more than the entry of CO_2 into the leaf.

CONCLUSION

The use of broadcast MAP mineral fertilizer provides higher dry matter yield results than the organomineral fertilizer and the control at the evaluated doses.

The cultivar MGS Brilhante shows good adaptation to the semi-arid region of Minas Gerais, with great tillering capacity. However, the increase in the number of seeds at the time of sowing does not affect the production attributes of the plant.

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