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Growth and production of wheat cultivars under water tensions in Cerrado soil[1]

Crescimento e produção de cultivares de trigo sob tensões de água em solo de Cerrado

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HIGHLIGHTS:
A soil water tension of 5 kPa promotes higher growth and production of wheat cultivars.
Cultivar BRS 254 showed the lowest production increasing soil water tension.
Cultivar BRS 264 showed less dependence on water for growth and production.

ABSTRACT: Brazil is not self-sufficient for the production of wheat (*Triticum aestivum* L.), and the expansion of cultivation to the Cerrado in the State of Mato Grosso, in an irrigated system, is an alternative solution to increase wheat production. This study aimed to evaluate the effects of soil water tension on the growth and production of wheat cultivars cultivated in the Cerrado Oxisol. The treatments were arranged in a 3 × 5 factorial scheme, with three wheat cultivars (BRS 254, BRS 394, and BRS 264) and five water tensions in soil (5, 15, 25, 35, and 45 kPa), using a randomized block design with four replications. Wheat growth and production exhibited a better response at a tension of 5 kPa. Cultivar BRS 254 showed the lowest production of spikes and grains per spike with increasing soil water tension. Among the cultivars, BRS 264 produced the highest number of grains per spike at tensions of 35 and 45 kPa. The wheat cultivars BRS 254, BRS 394, and BRS 264 have high water requirements. However, BRS 264 presented greater growth and production under conditions of restricted water in the soil, being able to be cultivated with an irrigation system activated less frequently, with less expenditure of water and energy.

Key words: *Triticum aestivum* L., BRS 394, BRS 264, BRS 254, water availability

RESUMO: O Brasil não é autossuficiente na produção de trigo (*Triticum aestivum* L.) e a expansão do cultivo para o cerrado mato-grossense, em sistema irrigado, constitui alternativa para aumentar a produção desse cereal. Assim, objetivou-se avaliar os efeitos das tensões de água no solo no crescimento e na produção de cultivares de trigo sob Oxisol de Cerrado. Os tratamentos foram arranjados em um esquema fatorial 3 × 5, com três cultivares de trigo (BRS 254, BRS 394 e BRS 264) e cinco tensões de água no solo (5, 15, 25, 35 e 45 kPa), usando um delineamento em blocos casualizados, com quatro repetições. O crescimento e produção do trigo mostraram melhor resposta na tensão de 5 kPa. A cultivar BRS 254 apresentou maior redução na produção de espigas e de grãos por espiga com o incremento das tensões de água no solo. Entre as cultivares, a BRS 264 produziu maior número de grãos por espiga nas tensões de 35 e 45 kPa. As cultivares de trigo BRS 254, BRS 394 e BRS 264 possuem alto requerimento de água. Entretanto, a cultivar BRS 264 apresenta maior crescimento e produção em condições de restrição de água no solo, podendo ser cultivada com um sistema de irrigação acionado com menor frequência, com menor gasto de água e energia.

Palavras-chave: *Triticum aestivum* L., BRS 394, BRS 264, BRS 254, disponibilidade hídrica

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Introduction

Wheat (*Triticum aestivum* L.) is one of the most important food crops (Li et al., 2022) and Brazil is among the world's largest consumers. However, wheat production in Brazil has not yet reached self-sufficiency. Wheat production in Brazil was 6.2 million tons in 2020. The southern region of Brazil is the main producer of grain (5.47 million tons) (CONAB, 2020). However, consumption of this cereal in the same period was approximately 12 million tons (CONAB, 2020), which represents a deficit of more than 5.8 million tons supplied through cereal imports.

The expansion of wheat cultivation to the central-west region is an alternative to increasing production. The development of cultivars adapted to the Cerrado, combined with management techniques, has enabled the cultivation of wheat in the Cerrado region of Mato Grosso (Oliveira et al., 2021). Irrigated wheat cultivars occupy a majority of the area cultivated in the Cerrado, with productivity up to three times greater than that of dryland cultivars (EMBRAPA, 2018a).

The need for irrigation for wheat production in the Cerrado increases its production costs. Therefore, it is necessary to identify cultivars that present better use of irrigation water to convert it into production, which would make the production system more efficient. The objective of the present study was to evaluate the growth and production of three irrigated wheat cultivars (BRS 254, BRS 394, and BRS 264) under different soil water tensions in a Cerrado Oxisol.

Material and Methods

The experiment was conducted from May to August 2018 at the Universidade Federal de Mato Grosso, Rondonópolis, Brazil, in a greenhouse located at 16° 27' 50.9" S, 54° 34' 50.0" W, and an altitude of 284 m. The average annual temperature and relative humidity inside the greenhouse were 27 °C and 57%, respectively (Figure 1).

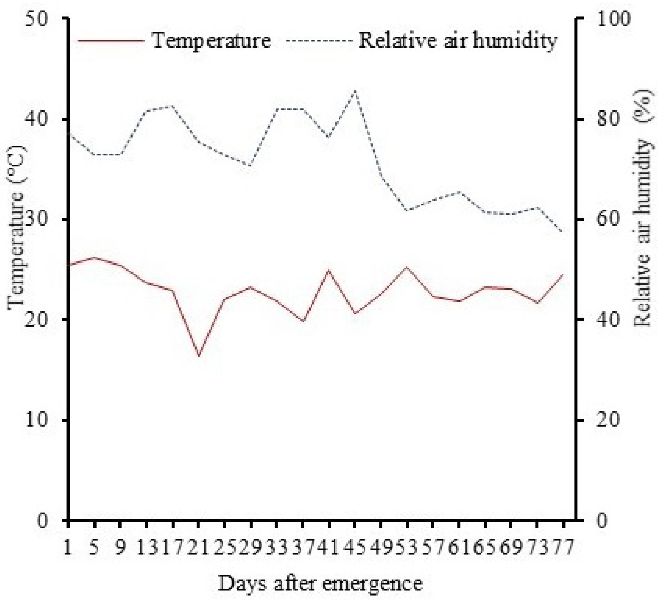


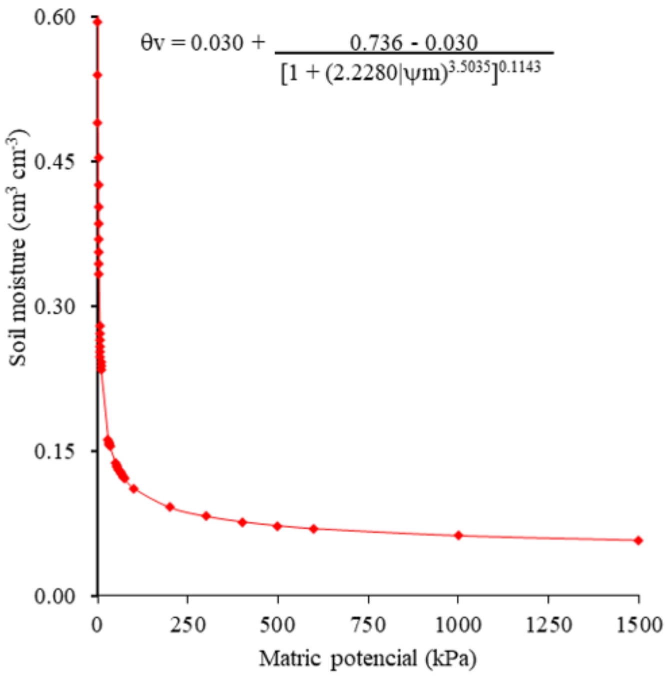
Figure 1. Mean daily temperature and relative air humidity observed during the conduction of the experiment inside the greenhouse

The experimental design used was randomized blocks in a 3 × 5 factorial scheme with three wheat cultivars (BRS 254, BRS 394, and BRS 264), combined with five soil water tensions (5, 15, 25, 35, and 45 kPa), with four replicates each, for a total of 60 experimental units. To determine the soil water tension used in the study, the maximum water retention capacity in the pot was initially obtained and the soil moisture at that point was determined. From the soil water retention curve (Figure 2), the matrix potential was determined at the maximum retention capacity, which in the present study was 5 kPa, whereas the other tensions were used to induce water stress in wheat cultivars.

Plants were grown for 75 days after emergence in pots with a capacity of 5 dm^3 of soil. The wheat cultivars used were BRS 254, BRS 394, and BRS 264, which are recommended by the Brazilian Agricultural Research Company (EMBRAPA) for irrigated cultivation in Brazilian Cerrado soils and are considered to have a high productive potential for the region.

The soil used was classified as Oxisol (United States, 2014) which corresponds to Latossolo Vermelho in the Brazilian Soil Classification System (EMBRAPA, 2018b). Soil was collected in an area under Cerrado vegetation in the 0–0.20 m layer and had the following chemical and granulometric characteristics (EMBRAPA, 2017): pH 4.1 ($CaCl_2$); P: 2.4 mg dm^{-3}; K: 28 mg dm^{-3}; Ca: 0.3 $cmol_c$ dm^{-3}; Mg: 0.2 $cmol_c$ dm^{-3}; H: 4.2 $cmol_c$ dm^{-3}; Al: 1.1 $cmol_c$ dm^{-3}; CEC: 5.9 $cmol_c$ dm^{-3}; V: 9.8%; OM: 22.7 g dm^{-3}; sand: 549 g kg^{-1}; silt: 84 g kg^{-1}; and clay: 367 g kg^{-1}.

Soil acidity was corrected by incorporating dolomitic limestone (PRNT = 80.3%) to increase base saturation to 60%. The soil was incubated with limestone for 30 days, and soil moisture was maintained at 60% of the maximum water-holding capacity of the soil. The maximum water retention capacity in the pots was determined using pots of the same shape and volume as those used in the experiment. The pots



θv – Soil moisture (cm^3 cm^{-3}); ψm – Matric potential (kPa)

Figure 2. Soil water retention curve according to the van Genuchten model

were filled with 5 dm^3 dry soil and weighed. They were then placed in trays and filled with water up to two-thirds of the height of the vessels, so that they were saturated with water by capillarity. After saturation, the pots were kept on a support to drain excess water. When drainage ceased, the pots were weighed again and the maximum water retention capacity in the soil was determined by the weight difference.

In the planting fertilization, 300 mg dm^{-3} of phosphorus and 74.56 mg dm^{-3} of potassium were applied to the soil, in the forms of simple superphosphate and potassium chloride, respectively (Carvalho et al., 2016). Micronutrients were also added: 0.5 mg dm^{-3} of boron, 0.8 mg dm^{-3} of copper, and 10.8 mg dm^{-3} of zinc, in the forms of boric acid, copper sulfate, and zinc sulfate, respectively (Carvalho et al., 2016). After fertilization, 20 wheat seeds (cultivars: BRS 254, BRS 264, or BRS 394) were distributed in each pot, maintaining six plants per pot after thinning. The nitrogen application rate was 200 mg dm^{-3} (top dressing), divided into three applications (15, 22, and 32 days after emergence), using urea as the source.

For irrigation management, the soil water retention curve was used and determined in the 0–0.10 m layer. Thus, the results were applied to the mathematical model proposed by van Genuchten (1980) using the software Soil Water Retention Curve (SWRC) version 2.0 (Dourado-Neto et al., 2000) to obtain the soil water retention curve (Figure 2). Irrigation was performed manually and calculated to increase the values of water tension in the soil to field capacity (5 kPa) for treatments when set tensions (treatments) were achieved.

Thus, it was possible to correlate the volumetric soil moisture (cm^3 cm^{-3}) throughout the crop cycle with the soil matrix potential (kPa). Monitoring of the water content in the soil was carried out using tensiometers, installed at a depth of 0.10 m. Tension readings were performed using a digital tensimeter, daily, in two periods: morning (between 7:00 and 8:30 a.m.) and afternoon (between 3:30 and 5:00 p.m.).

The time to irrigation was established when the readings obtained from the tensiometers reached the tensions proposed for each treatment. Irrigation was manually performed and the volume of water to be added was calculated using the difference between the moisture (corresponding to the tension) of each treatment and the moisture obtained at the time of reading (corresponding to the tension). Thus, the soil water tension was maintained for each treatment.

Thirty days after the emergence of the wheat plants, the following variables were evaluated: number of leaves, number of tillers, and plant height. The number of leaves per pot was determined by manually counting leaves with an exposed ligule. The number of tillers per pot was determined by manually counting the tillers. For plant height, the vertical distance between the soil surface and insertion point of the last leaf was measured using a graduated ruler. At 45 days after emergence, the length of the flag leaves of the main plants was determined using a graduated ruler. At harvest (86 days after emergence), the number of spikes, grains, and grains per spike per pot were evaluated. The number of grains per spike was determined as the ratio of the number of grains to the number of spikes per experimental unit.

Statistical analysis was performed using the SISVAR program (Ferreira, 2017). The results were subjected to an analysis of variance by the F-test. The analysis of variance (ANOVA) residues were tested for normality, independence, and homogeneity. The wheat cultivars and soil water tension were subjected to Tukey's test and regression analysis, respectively, at a probability of 0.05.

Results and Discussion

There was no significant interaction ($p > 0.05$) between wheat cultivars and soil water tension for the number of leaves, number of tillers, flag leaf length, and number of grains for the BRS 254, BRS 394, and BRS 264 wheat cultivars. However, these factors had an isolated effect on these variables. Conversely, there was a significant interaction between wheat cultivar and soil water tension for plant height, number of spikes, and number of grains per spike (Table 1).

At 30 days after emergence (DAE), there were significant independent effects of wheat cultivar and soil water tensions on the number of leaves. Among the cultivars studied, BRS 264 showed the highest number of leaves (57.65 leaves per pot) but did not differ statistically from the cultivar BRS 394 (Table 2). The greater number of leaves in the cultivar BRS 264 may have occurred because of its phenological characteristics. This greater number of leaves compared to the cultivars BRS 394 and BRS 254 may reflect an increase in grain production because the leaves are responsible for photosynthesis (Delfin et al., 2021).

At 30 DAE, the number of tillers showed significant independent effects on wheat cultivars and soil water tensions. Cultivar BRS 264 had the highest number of tillers (16.91 tillers per pot). This tiller production corresponds to 34.65% more than the tillers of cultivar BRS 254, which produced the lowest number of tillers (11.05 tillers per pot) (Table 2). This difference may be due to differences in the tillering capacity, as each cultivar may be genetically expressed. This greater

Table 1. Summary of analysis of variance for the effects of wheat cultivars, soil water tension, and their interaction on the growth and production of wheat

Variables	F-value			CV (%)
	Wheat cultivars	Soil water tension	Interaction	
Number of leaves	6.02*	3.88**	0.71^{ns}	22.1
Number of tillers	34.35***	66.19***	2.06^{ns}	15.91
Plant height	14.02***	4.95**	2.64*	10.17
Flag leaf length	7.65**	4.37**	1.26^{ns}	27.89
Number of spikes	23.76***	281.91***	6.68***	7.96
Number of grains	11.56***	52.13***	0.14^{ns}	23.08
Number of grains per spike	29.69***	104.1***	3.6**	46

ns, *, **, and *** - Indicate not significant, significant at ≤ 0.05, 0.01, and 0.001, respectively

Table 2. Means and Tukey's test for the number of leaves, number of tillers, flag leaf length, and number of grains for BRS 254, BRS 394, and BRS 264 wheat cultivars

Wheat cultivars	Leaves	Tillers	Flag leaf length (cm)	Grains (Number per pot)
	(Number per pot)			
BRS 254	47.65 b	11.05 c	19.65 b	488.42 b
BRS 394	55.20 ab	14.95 b	24.22 a	596.95 a
BRS 264	57.65 a	16.91 a	17.29 b	695.42 a

Means with different letters in the column indicate significant differences ($p \leq 0.05$) according to Tukey's test tillering in wheat plants has an impact on grain production because tillers can contribute on average 32% to the yield of wheat grown under irrigation (Xue-jing et al., 2021).

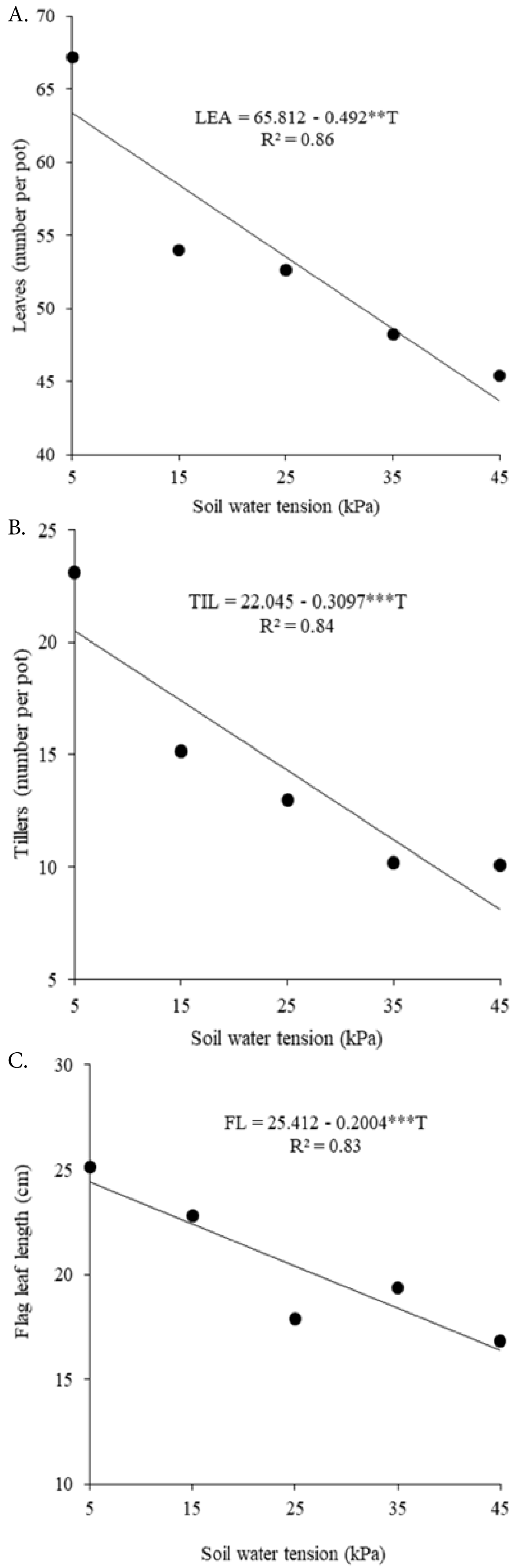
The flag leaf length of wheat plants showed significant independent effects on wheat cultivars and soil water tensions. The highest flag leaf length (24.22 cm) was observed in the cultivar BRS 394, was approximately 1.4 times that of the cultivar BRS 264 (Table 2). The flag leaf is of great importance in grain production because it is the last leaf to emerge before the formation of panicles, making it an important contributor of photosynthates to the developing cereal grain (Liu et al., 2021; Xue-jing et al., 2021). In a study of wheat cultivars, Xue-jing et al. (2021) observed a strong correlation between flag leaf length and wheat yield.

The number of grains was significantly influenced by wheat cultivar and soil water tension. Cultivars BRS 394 and 264 had a higher number of grains (596.95 and 695.42 grains per pot, respectively) than cultivar BRS 254. A 1.4-fold increase in grain production was observed when comparing cultivar BRS 264 with cultivar BRS 254 (Table 2). As previously discussed, the highest number of leaves and tillers may reflect grain production (Delfin et al., 2021; Xue-jing et al., 2021), as observed in the present study. The cultivars BRS 394 and BRS 264 presented the highest number of leaves and tillering, and consequently the highest number of grains.

Cultivar BRS 264 showed the highest production of leaves, tillers, and grains, independent of soil water tension (Table 2), indicating the genetic potential of this cultivar to obtain high wheat yields in the Brazilian Cerrado. This cultivar is characterized by a super early cycle and resistance to high temperatures, and is recommended for cultivation in the states of Mato Grosso, Minas Gerais, Distrito Federal, and Goiás. BRS 264 has high productive potential, superior to BRS 254, showing good response in production for all environmental conditions; thus, it has general adaptability (Albrecht et al., 2007).

For soil water tension, a linear decrease of 31.06% was observed for the number of leaves of wheat plants when compared to low soil water tension (5 kPa) with the maximum water deficit (45 kPa). Soil moisture at field capacity (equivalent to 5 kPa) provided the highest number of wheat leaves (Figure 3A). Under conditions of reduced water availability, plants tend to respond mainly by reducing the number and size of leaves, in addition to closing stomata and mechanisms to reduce the loss of water through transpiration (Delfin et al., 2021), which may have occurred in the present study. The lowest number of wheat leaves under water deficit conditions (45 kPa) corroborates the results of Hammad & Ali (2014), who observed that leaf production was negatively affected when wheat plants were subjected to water stress (irrigation after 80% depletion of available soil water). Haque et al. (2020) also found a lower number of leaves in wheat plants grown under water stress (30% field capacity).

Soil water tension was adjusted to the linear regression model and the maximum water deficit (45 kPa) provided a 60.43% decrease in tiller production compared to the higher water availability, equivalent to the field capacity of the soil (5 kPa) (Figure 3B). In wheat, the reduction in the number of



LEA - Leaves; TIL - Tillers; FL - Flag leaf length; T- Soil water tension. ** - Significant at 0.01 probability; *** - Significant at 0.001 probability

Figure 3. Number of leaves (A) and number of tillers (B) at 30 days after emergence (DAE); and flag leaf length of wheat, at 45 DAE, as a function of soil water tensions

leaves and leaf area in response to water stress also affects the tillering pattern of the plant, reducing the size and number of tillers before anthesis (Delfin et al., 2021), as observed in the present study, in which water deficit was applied throughout the crop cycle.

For soil water tension, a significant decrease of 32.83% was observed in the flag leaf length of wheat plants when compared to the leaves of plants under high soil water availability (soil field capacity of 5 kPa) with maximum water deficit (45 kPa) (Figure 3C). The reduction in the length of flag leaves when subjected to low water availability in the soil is associated with a reduction in the net rate of CO_2 assimilation in the flag leaves during the greatest water restriction (Liu et al., 2021; Xue-jing et al., 2021).

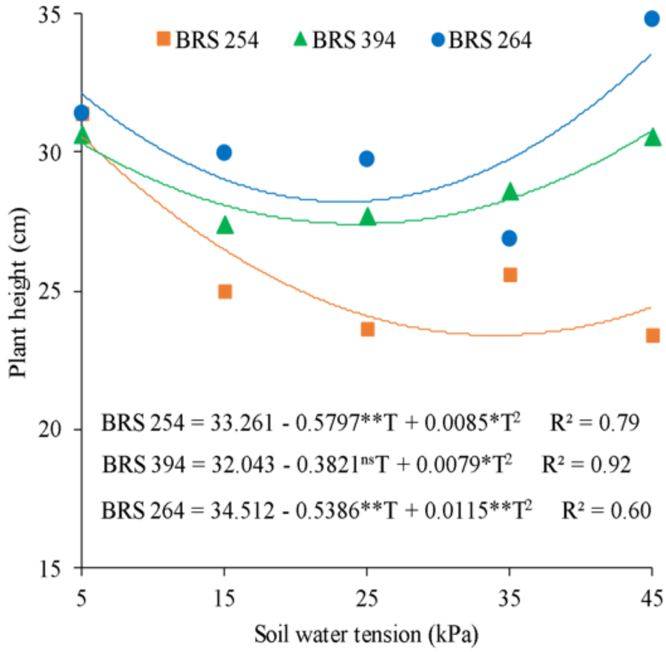
At 30 DAE, there was a significant interaction between wheat cultivar and soil water tension. At 5 kPa of tension (soil field capacity), there was no difference in plant height between the three wheat cultivars. Cultivars BRS 264 and 394 showed higher plant heights (34.76 and 30.57 cm, respectively) than cultivar BRS 254 at the lowest water availability (45 kPa), which indicates that cultivar BRS 254 was more sensitive to water deficit (Table 3).

Cultivar BRS 254 showed a reduction in plant height with increasing soil water restriction, and 23.39 cm was the minimum plant height found under a soil water tension of 34.07 kPa. Conversely, the plant height of cultivar BRS 264 showed a minimum value (23.44 cm) in the soil water tension of 28.20 kPa and when there was an increase in soil water restriction to 45 kPa, the plant height was increased to 33.54 cm (Figure 4). Plants subjected to reduced water availability (45 kPa) increased their stature as a morphophysiological response and increased leaf senescence (Xue-jing et al., 2021), as observed in the present study (Figure 3A).

Wheat cultivars BRS 254, BRS 394, and BRS 264 had similar potentials for plant height when grown in soil with moisture at field capacity (5 kPa). However, when there was high soil water restriction (45 kPa), cultivar BRS 254 was more sensitive, with fewer plants than BRS 264 and BRS 394. Thus, the low tolerance of this cultivar to water deficit may be due to differences in the genetic characteristics of the genotypes, as reported by Liwani et al. (2019). Additionally, it is possible to prove that a water deficit causes low plant growth. This may be attributed to physiological and biochemical disturbances that affect the regulation of stomatal opening and chlorophyll biosynthesis, which are essential for photosynthesis (Aurangzaib et al., 2021). These results corroborate those of Chen et al. (2021), who found that wheat plants had a lower height when there was soil water restriction. On the other hand, the plant height of the other studied genotypes, BRS 264 and BRS 394, was stimulated by soil water deficit (45 kPa). This overgrowth, which generally decreases the stem diameter, did not provide a higher yield (number of spikes and number of grains per spike) and can cause lodging and affect the wheat harvest (Jiang et al., 2020).

The number of spikes in wheat plants showed a significant interaction between cultivar and soil water tension. Under conditions of low soil water availability (35 and 45 kPa), higher production of spikes was observed in cultivars BRS 394 (16.25 and 12.75 spikes per pot, respectively) and BRS 264 (14.50 and 11.50 spikes per pot, respectively) than in BRS 254. There was no significant difference in the number of spikes among the wheat cultivars under the lowest water tension in the soil (without water restriction) (Table 4). The number of spikes was closely related to the number of early tillers and the extent of tiller degeneration, which is in agreement with the results of the present study, in which the number of spikes maintained the same trend as the tillering data for the wheat cultivars (Figure 3B).

Overall, the increase in soil water restriction resulted in low spike production in wheat cultivars, with the minimum



T - Soil-water tension; ** and * - Significant at 0.01 and 0.05 probability, respectively; ns - Not significant

Figure 4. Plant height of wheat as a function of interaction between wheat cultivars (BRS 254, 394 and 264) and soil water tensions at 30 DAE

Table 3. Plant height of wheat cultivars as a function of soil water tensions at 30 days after emergence

Soil water tension (kPa)	Plant height (cm)		
	Wheat cultivars		
	BRS 254	BRS 394	BRS 264
5	31.41 a	30.63 a	31.41 a
15	24.97 a	27.38 a	29.91 a
25	23.61 b	27.70 ab	29.74 a
35	25.54 a	28.61 a	26.85 a
45	23.41 b	30.57 a	34.76 a

Means with different letters in the row indicate significant differences according to Tukey's test ($p \leq 0.05$)

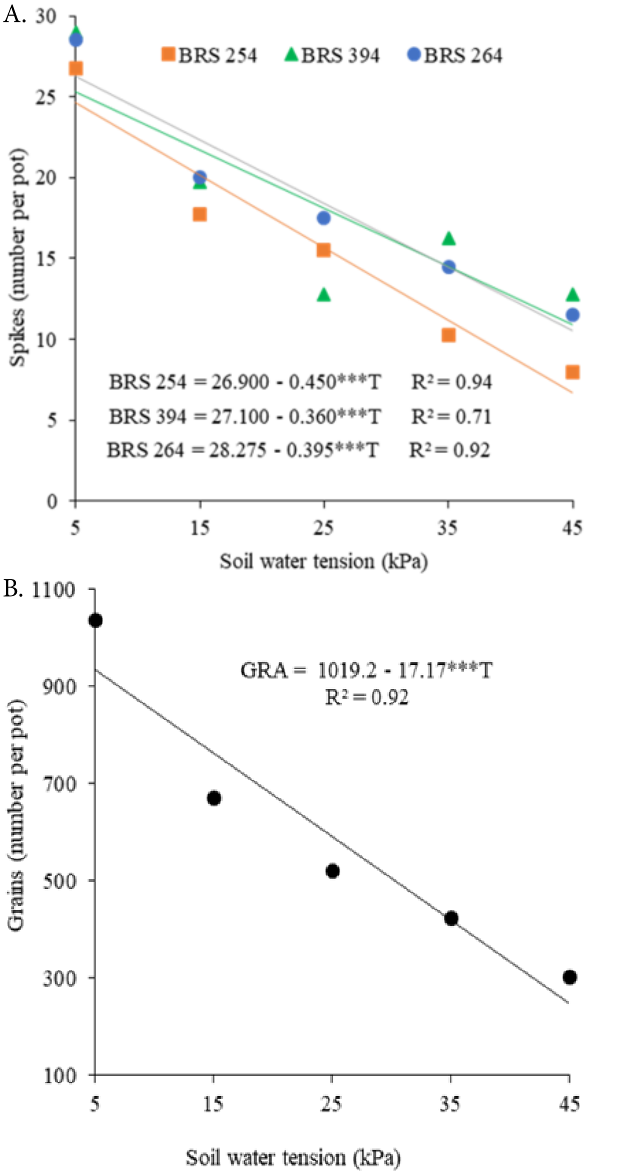
Table 4. Number of spikes of wheat cultivars as a function of soil water tensions at 75 days after emergence

Soil water tension (kPa)	Spikes (number per pot)		
	Wheat cultivars		
	BRS 254	BRS 394	BRS 264
5	26.75 a	29.00 a	28.50 a
15	17.75 a	19.75 a	20.00 a
25	15.50 a	12.75 b	17.50 a
35	10.25 b	16.25 a	14.50 a
45	8.00 b	12.75 a	11.50 a

Means with different letters in the row indicate significant differences ($p \leq 0.05$) according to Tukey's test values found at a tension of 45 kPa. The increase in soil water tension resulted in a decrease of 73, 60, and 57% in the number of spikes of wheat cultivars BRS 254, BRS 264, and BRS 394, respectively, compared to the highest soil water tension (45 kPa) and the highest availability of water in the soil (5 kPa) (Figure 5A).

There was a 73.6% reduction in the number of grains when compared to soil water tension at field capacity (5 kPa) with the lowest water availability in the soil (45 kPa) (Figure 5B). Low water availability (45 kPa) can significantly inhibit the grain filling of wheat and induce grain abortion, which reduces the number of effective grains, and therefore, reduces the yield of wheat (Xue-jing et al., 2021).

For the number of grains per spike, there was a significant interaction between the wheat cultivars and soil water tensions. At a soil water tension of 15 kPa and 35 kPa, BRS 264 showed higher grain production per spike than BRS 254, providing a 22.4 and 9.44% increase, respectively. On the other hand, in the soil water tension with high water availability (5 kPa), there was no significant difference in grain production per spike between wheat cultivars (Table 5).



GRA - Number of grains; T - Soil water tension; *** - Significant at 0.001 probability

Figure 5. Number of spikes (75 DAE) (A) and number of grains (86 DAE) (B) of wheat, as a function of interaction between wheat cultivars (BRS 254, 394, and 264) and soil water tensions

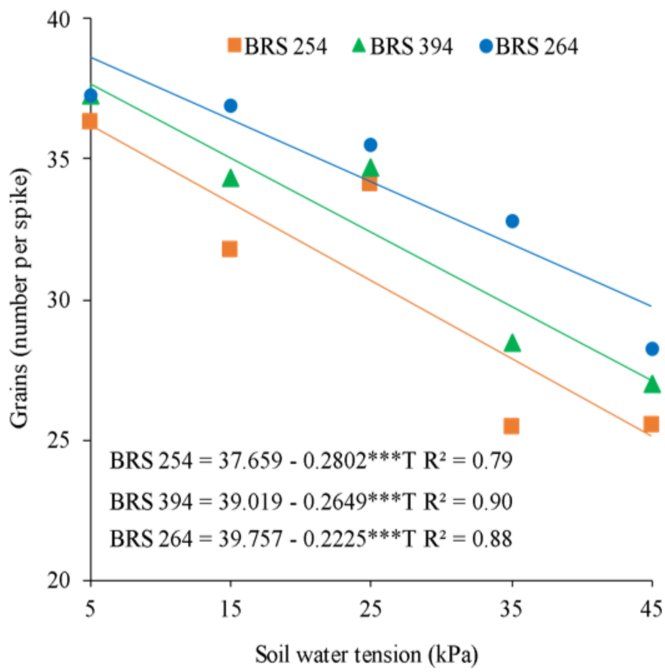
Table 5. Number of grains per spikes of wheat cultivars as a function of soil water tensions at 86 days after emergence

Soil water tension (kPa)	Grains (number per spike)		
	Wheat cultivars		
	BRS 254	BRS 394	BRS 264
5	36.36 a	37.33 a	37.33 a
15	31.77 c	34.40 b	36.96 a
25	34.16 a	34.72 a	35.57 a
35	25.49 c	28.49 b	32.85 a
45	25.59 b	27.04 ab	28.26 a

Means with different letters in a row indicate significant differences according to Tukey's test ($p \leq 0.05$)

The increase in soil water tension provided low grain production per spike in the three wheat cultivars (BRS 254, BRS 394, and BRS 264), and the lowest value of grain number per spike was found in the highest water restriction (45 kPa). There was a reduction of 30.69, 28.12, and 23.03% in the number of grains per spike in wheat cultivars BRS 254, BRS 394, and BRS 264, respectively, when compared to low soil water tension (5 kPa) with a high water deficit in the soil (45 kPa) (Figure 6). The number of grains per spike is closely related to the differentiation of flower primordium and pollination of wheat spikes. The marked water reduction (45 kPa) that occurs during the development and filling of the grain stage can partially block the biosynthesis and transport of photosynthetic products during the grain-filling stage (Xue-jing et al., 2021).

Overall, wheat cultivars responded better to growth and production when they were cultivated in soil with moisture at field capacity (5 kPa). These results indicate that the cultivars developed for irrigated cultivation in the Brazilian Cerrado have a high water requirement to express their maximum



T - Soil water tension; *** - Significant at 0.001 probability

Figure 6. Number of grains per spikes of wheat, as a function of interaction between wheat cultivars (BRS 254, 394, and 264) and soil-water tensions, at 84 DAE

productive potential. These results corroborate those found by Soares et al. (2021), who observed that cultivars with biotypes for irrigated cultivation (BRS 264 and BRS 254) showed high production in the highest water regimes (equivalent to 100 and 83% of the crop's evapotranspiration).

For the three wheat cultivars (BRS 254, BRS 394, and BRS 264), there was a reduction in production (number of spikes and number of grains per spike) with increasing soil water tensions. Several studies have reported that decreased water availability for plants leads to low wheat yields (Agami et al., 2018; Adrees et al., 2020; Pour-Aboughadareh et al., 2020; Soares et al., 2021). Grain filling is the developmental stage most sensitive to water stress, and the response depends on the exposure time and stress severity (Barros et al., 2021). In this study, wheat plants were exposed to soil moisture levels throughout their developmental cycle, including the vegetative and reproductive periods. In the vegetative stage, the low availability of water for plants, due to the increase in water tension in the soil, led to reduced soil nutrient absorption and photosynthetic activity and, therefore, caused decreased plant growth. During the reproductive stage, there is inefficient translocation of photoassimilates which affects wheat development and yield. Therefore, grain filling in plants under high water stress is restricted (Aurangzaib et al., 2021).

The number of spikes is positively correlated with wheat grain yield, even under different soil water levels; therefore, it can be used as a criterion for selecting more productive wheat genotypes (Soares et al., 2021). Among the three wheat cultivars (BRS 254, BRS 394, and BRS 264), cultivar BRS 264 had a higher spike production and a higher number of grains per spike, with a decrease in water availability for the plants (35 and 45 kPa). Considering its high adaptability, this cultivar has a higher grain yield in any environment, including soils with a water deficit (Albrecht et al., 2007). Therefore, it can be inferred that the cultivar BRS 264 showed a higher efficiency in the use of water, proving to be more viable for optimizing the use of water and energy resources, especially in situations of water scarcity for irrigation.

Conclusions

1. Wheat cultivars BRS 254, BRS 394, and BRS 264 have high water requirements (5 kPa, water tension in the soil equivalent to field capacity) to express their maximum productive potential (growth and production) in Cerrado soil.

2. The cultivar BRS 264 presented higher growth and production under conditions of water restriction in the soil than the cultivars BRS 394 and BRS 254, indicating better water use efficiency of this wheat genotype.

3. The cultivar BRS 264 can be grown with an irrigation system activated less frequently, with less water and energy expenditure.

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