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Influence of wheat populations arrangement on growth characteristics and grain yield

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The arrangement of plants in paired spacing is one of the management practices being used in some crops resulting in increased yield. Aiming to evaluate the arrangements and plant density on agronomic characteristics, yield components and yield of two wheat cultivars, one experiment was carried out on a Haplic Cambisol Tb typical dystrophic soil, with two cultivars, in the city of Ponta Grossa, PR,. The design experimental was randomized blocks in a factorial design 2×4, with four replications. The treatments consisted of two plant arrangements (single and paired spacing) and four plant densities (45, 60, 75 and 90 plants m^{-1}), applied in two wheat cultivars (Marfim and BRS-Tangara). At Paired spacing the number of spikes per square meter and yield were lower than single spacing, even with higher grain weight in both wheat cultivars. The paired spacing did not result in increased yield for both wheat cultivars.

Key words: *Triticum aestivum*, tillage, paired spacing.

INTRODUCTION

There is a growing demand for wheat derivatives in Brazil, such as bread, cereals and biscuits, although most of the wheat is imported leading to the necessity of the country to move from the importer scenario and become self-sufficient (Smanhotto et al., 2006). In Brazil around 47 million hectares are devoted to agriculture, of which around 4% is used for the wheat fields, insufficient area to meet domestic demand, which explains why half of domestic grain consumption is imported (Sober, 2010).

The reduced of plant area has lead to the need of maximizing the yield, encouraging the usage of intensive management, which includes an adoption of practices such as sowing at the recommended time, fertilizer rate and appropriate application timing for diseases and pests control, decreased plant lodging, arrangement and plant density (Rodrigues et al., 2003).

Plant arrangement can be modified by varying plant density, spacing between rows and between plants within the row, changing the growing area available for each plant, which is reflected in an intraspecific differentiated competition by nutrients, sunlight and water (Rambo et al., 2003).

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The interception of solar radiation photosynthetically has a major influence on crop yield when other environmental factors are favorable (Brachtvogel et al., 2009). One way to increase the radiation interception, and consequently, grain yield is through proper plant arrangement.

Paired spacing is a modification in the conventional plant arrangement where every three rows planted, one is left empty; as a result, we have 33% reduction in the number of rows. This modification can improve plants' water usage due to lower interspecific competition and consequently greater water supply during critical periods. It also allows greater solar radiation penetration inside the canopy, increased air flow and also improves pesticide application quality, especially fungicides (Weiner et al. 2001).

It was observed on barley that paired spacing causes a reduction in plant height, increasing yield and grain weight (Teixeira and Rodrigues, 2003), although wheat response and viability has not been studied with the use of this plant arrangement. Paired spacing studies for crops such as cotton, sorghum and maize are found in the literature, being necessary to study the effect of this arrangement in different populations on agronomic characteristics and wheat yield.

For wheat there is an optimal plant density set by the research, even with the capability of sprouting and adjusting the number of pods according to the density. However, in paired spacing there is no recommendation on density increasing or reduction, but due to the fact of this spacing the number of seeds per area is reduced making it necessary to verify the need for seed density adjustment on the line when adopted.

Thus, this study aims to determine if the plant arrangement in paired rows affects the yield of wheat cultivars and verify if there is a proper combination of plant arrangements and different density in wheat yield.

MATERIALS AND METHODS

The experiment was carried out in 2012 on a Haplic Cambisol Tb typical dystrophic soil (Embrapa, 2006) in Campos Gerais region, Ponta Grossa, Parana State, Brazil. The experimental design was randomized blocks in a factorial scheme (2 × 4) with four replications. Treatments in the experiment consisted of simple spacing (0.17 m between rows) and paired (every three rows spaced 0.17 m one was not sown, resulting in a 0.34 m spacing to the next double row), plant populations of 45, 60, 75 and 90 plants by meter row. The cultivars used were Marfim and BRS-Tangara. The plots were 5.0 m long by 3.0 m wide and floor area of 4.0 × 2.0 m.

All rows were planted in single rows with plant density of 90 viable seeds per row meter. At 17 days after sowing thinning was done in order for each plot be with a specific number of plants (45, 60, 75 and 90 plants.m^{-1}) and with proper spacing (single or paired). In paired spacing was thinned the whole row.

Wheat was grown at no tillage system with soybean as the previous crop. The sowing was done on July 6th 2012 and plant emergence occurred on July 16th of the same year. As fertilization 300 kg ha^{-1} of N:P:K 14:34:00 was carried out at the sowing time. At the beginning of the tilling stage, 90 kg ha^{-1} of nitrogen as urea was applied as coverage fertilization.

Seed treatment, pest, disease and weed control, were conducted with products registered for wheat crop (AGROFIT, 2012). At crop anthesis stage the number of tillers and ground height to the base of the ear were evaluated. When the grains have reached the mature stage, hand sickles were used to harvest the plants, and meter of plant row was sampled for the assessment of yield components. From the meter of plant row per plot was evaluated the number of ears; the number of spikelets per spike and grain per spikelet; diameter ten stems from mother plants were randomly collected and measured through a digital caliper as well as the thousand grain weight.

From the plants collected, 10 were selected to determine the plants harvest index (HI), where not only grains, but also stems, leaves and plant rachis were placed in a forced ventilation oven at temperature of 65°C for 48 to 72 h. The HI was determined by dividing the grains mass by total above-ground production of biomass (grain weight, dry weight of leaves and stems rachis) according to the following formula:

$$HI\ (\%) = \frac{Grains\ mass\ (g)}{Biomass\ (g)} x100$$

Harvest was done on March 3rd and 5th for Marfim and BRS-Tangara cultivars, respectively. The yield was determined by the useful production area of each plot, and its moisture corrected to 13% being the value converted into kilograms per hectare.

Data were subjected to analysis of variance by F test and the differences among the averages of spacing were compared by Tukey test at 5% probability (p> 0.05) (Table 1). The plant densities were analyzed by polynomial regression (Banzatto and Kronka, 2006).

RESULTS AND DISCUSSION

For plant height attributes, in both cultivars there were no significant interactions between spacing and plant densities (Table 2). The plants height is an important feature for wheat crop, once it is directly linked with plant lodging (Pinthus, 1973). In the current experiment lodging was not observed on wheat cultivars, as a consequence of mild weather without strong winds and cultivars of medium height, the effects of plant height in the lodging could not be evaluated (Figure 1).

The BRS-Tangara height was greater in the paired spacing compared to simple, to Marfim plant height was not affected by the change in spacing and was not affected by the change in plant densities in both cultivars. This result as noted by others authors (Fioreze and Rodrigues, 2014). Plant height can be affected by plant population and generally higher in larger populations as the interspecific competition caused plants etiolating. However, this response varies by cultivar.

There were no interactions between row spacing and plant density related to tillers numbers in both cultivars (Table 3). To the Marfim cultivar, the number of tillers was not affected by spacing variation. Although when assessed, the effect of increasing plant density in the tillers production quadratic response was observed, with highest number of tillers in lower densities and a strong decrease in density of 90 plants.m^{-1} (Table 3).

Table 1. Summary analysis of variance: Values of "F" for height (HEI), tillers (TIL), spikelets per spike (SPS), grains per spikelet (GPS), spike per square meter (SPSM), thousand grain weight (TGW), Yield (Yield) and harvest index (CI) of BRS-Tangara and Marfim cultivars (Ponta Grossa, 2013).

Source of variation	GL	BRS-Tangará							
		HEI	TIL	SPS	GPS	SPSM	TGW	YIELD	HI
Spacing row (S)	1	63.2*	246.8*	0.1^{ns}	0.1^{ns}	11.6*	21.6*	94.0*	1.5^{ns}
Seeding rate (R)	3	0.6^{ns}	4.1^{ns}	6.8*	2.4^{ns}	11.7*	13.5*	1.7^{ns}	0.9^{ns}
S x R	4	0.5^{ns}	0.3^{ns}	1.2^{ns}	0.3^{ns}	1.9^{ns}	0.7^{ns}	1.5^{ns}	2.7^{ns}
C.V (%)		3.0	10.8	6.4	8.7	9.3	2.2	10.4	9.6
Source of variation	**GL**	**Marfim**							
		HEI	**TIL**	**SPS**	**GPS**	**SPSM**	**TGW**	**YIELD**	**HI**
Spacing row (S)	1	0.1^{ns}	0.1	6.5**	0.1^{ns}	11.6*	94.2*	13.3*	0.5^{ns}
Seeding rate (R)	3	2.3^{ns}	23.5*	4.1**	10.1*	11.7*	15.9*	2.8^{ns}	2.5^{ns}
S x R	4	0.2^{ns}	1.0^{ns}	15.3*	2.2^{ns}	1.9^{ns}	0.6^{ns}	1.5^{ns}	1.9^{ns}
C.V (%)		3.0	10.8	6.4	8.7	9.3	2.2	1.1	13.4

Table 2. Plant height of wheat cultivars Marfim and BRS-Tangara due to row spacing and seeding rate (Ponta Grossa, PR 2012).

Row	Marfim	BRS-Tangará
	Plant height (cm)	
Simple spacing	64.0^{a}	64.0^{b}
Paired spacing	64.1^{a}	69.7^{a}
Plants.m^{-1}	Marfim	BRS-Tangará
45	65.1	67.6
60	63.3	66.8
75	64.4	63.3
90	63.6	66.9
Regression	Ns	Ns

Means followed by the same lower case letter in columns are not significantly different by Tukey test (p <5%); Ns = not significantly different.

To the BRS-Tangará cultivar the number of tillers per plant was higher in the paired spacing compared to simple and with an increasing plant density; a decreasing linear response was observed in the number of tillers (Table 3).

The highest number of tillers in paired spacing can be explained by the greater distance between rows, which represent a reduction of 33% of rows less than the single spacing and the wheat's capability to compensate for the lack of plants in issuing a greater number of tillers. Valerio et al. (2008) in studies with several cultivars and years of growth observed a linear decrease in tiller numbers with an increasing plant density. A reduction of tiller numbers at high densities can be explained due to the severe decrease of photosynthetically active radiation intensity and water competition between plants (Almeida and Mundstock, 2001; Evers et al., 2006). According to Valerio et al. (2008), tillering is related to wheat genotype, therefore generally there is no standard methodology for choosing the most appropriate plant density to cultivars, a fact observed in this current study where the response was different among cultivars. However, it was observed that a reduction in the number of tillers with an increase of plant density, where only BRS-Tangará cultivar was influenced by spacing variation, showing that there is not a direct relationship between spacing variation and seeding density, being the obtained response related to the cultivar used.

Significant interactions between spacing and densities, for both cultivars, were observed for the number of ears per square meter (Table 4). To the Marfim cultivar at densities of 45, 60 and 75 plants per meter observed lower number of ears per square meter at paired spaced, in relation to simple spaced, and at density of 90 plants per meter results were similar between the spaces. To BRS-Tangará cultivar the number of ears per square meter in paired spacing was lower compared to single spacing in all plant densities (Table 4).

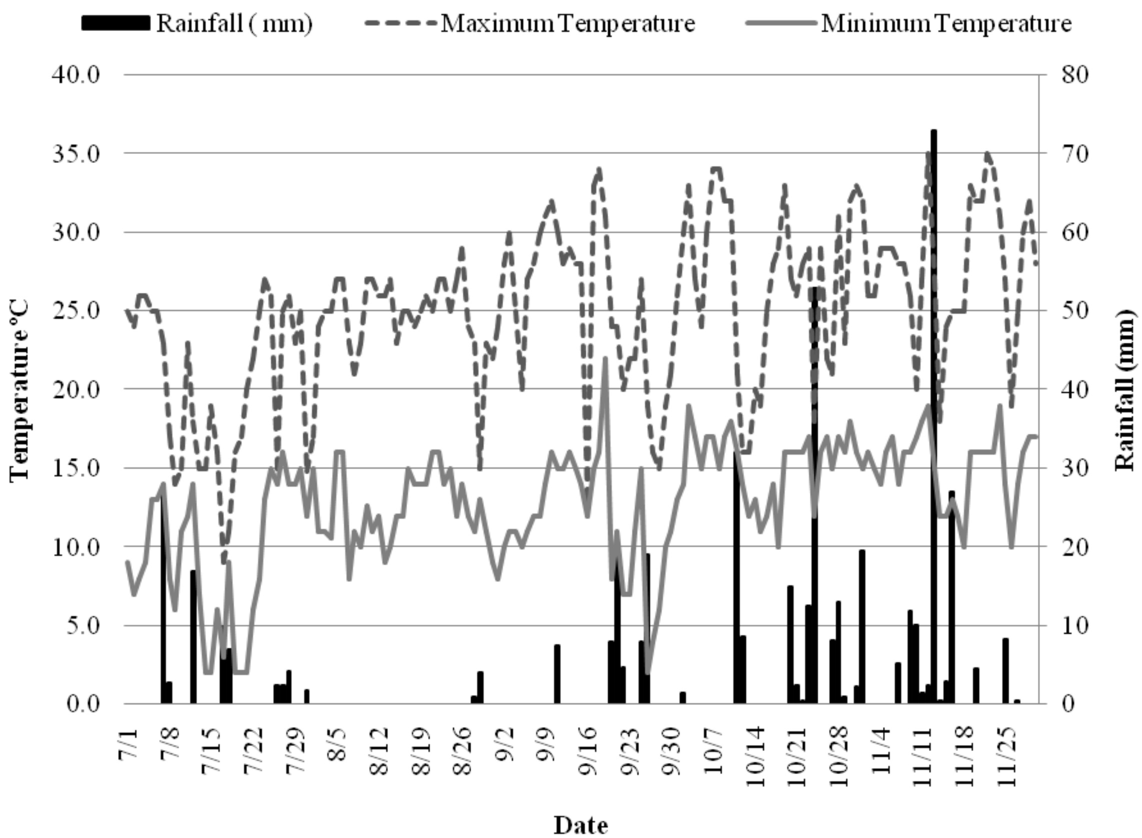

Figure 1. Temperature Analysis, maximum and minimum, and rainfall in the municipality of Ponta Grossa, PR. Brazil. 2012. (Source: IAPAR).

Table 3. Tillers numbers of wheat cultivars Marfim and BRS-Tangara due spacing between rows and average plant populations (Ponta Grossa, PR).

Row	Marfim	BRS-Tangará
	Tillers numbers	
Simple spacing	1.9[a]	2.3[b]
Paired spacing	1.9[a]	4.2[a]
Plants.m⁻¹	Marfim	BRS-Tangará
45	2.6	3.6
60	2.3	3.2
75	2.1	3.1
90	1.0	3.1
Regression	Q	L

Means followed by the same lower case letter in columns are not significantly different by Tukey test (p <5%); L: linear; Q: Quadratic; Number of tillers Marfim cultivar: $Y = 0.675000 + 0.079167x - 0.00833x^2$ ($R^2 = 96.53$); Tillers numbers of Marfim Cultivar: $Y = 4.026125 - 0.011600x$ ($R^2 = 79.17$).

Regards to sowing density, cultivar Marfim showed a quadratic response for the number of ears per square meter as the density increased in single and paired spacing (Table 4). For BRS- Tangará cultivar the number of ears per square meter increased linearly with the plant density in both spacing. In an experiment conducted by Zagonel et al. (2002) it was observed that with increasing plant density the number of ears per square meter was also increased. According to the authors, the increase in density is directly related to the larger number of ears per

Table 4. Ears per square meter of wheat cultivars Marfim and BRS-Tangara in relation to spacing between rows and plant populations. Ponta Grossa, PR, 2012.

Row	Marfim			
	Plants.m⁻¹			
	45	60	75	90
Simple spacing	361[a]	421[a]	406[a]	406[a]
Paired spacing	279[b]	308[b]	313[b]	442[a]
Row	**BRS-Tangará**			
	Plants.m⁻¹			
	45	**60**	**75**	**90**
Simple spacing	389[a]	415[a]	464[a]	474[a]
Paired spacing	261[b]	319[b]	323[b]	403[b]

Plants.m⁻¹	Marfim		BRS-Tangará	
	Simple spacing	Paired spacing	Simple spacing	Paired spacing
45	361	279	389	261
60	421	308	420	319
75	408	313	450	323
90	406	442	481	403
Regression	Q	Q	L	L

Means followed by the same lower case letter in columns are not significantly different by Tukey test ($p < 5\%$); L: linear; Q: Quadratic; Spikes / meter cultivate Marfim single space: $Y= 49{,}8265 + 10{,}141367x - 0{,}069172x^2$ ($R^2 = 82{,}76$); Ears/meter for cultivar Marfim at paired space: $Y = 591.774313 - 11.807738x + 0.111893x^2$ ($R^2 = 93.27$); Ears/meter for cultivar BRS-Tangará simple space: $Y = 299.178750 + 2.022083x$ ($R^2 = 94.82$); Ears/meter for cultivar BRS-Tangará paired space: $Y= 133.67625 + 2.861125x$ ($R^2 = 90.71$).

meter, but the production of these ears is dependent on the environmental conditions, which means that not always an increase on the ears number will result in higher yield. In the current study, at paired spacing occurred a lower ears number per square meter compared to single-spaced, because they had 33% less lines and tillering was not enough to fulfill the unseeded rows. For Marfim and BRS-Tangará the differences in the number of ears per square meter between the spacing were 25 and 26% respectively, less at paired spacing when compared to simple. Theoretically wheat should make a difference around 33% of ears per square meter, but once we observed a higher tillering at paired spaced this difference was smaller.

Insignificant interactions between spacing and plant densities were detected for the number of spikelet per ear of the Marfim cultivar, being observed at a smaller number of spikelets per ear in single spacing and density of 90 plants per meter (Table 5). Regards to plant density variation, the cultivar responded quadratic to single space with a tendency to decrease at higher densities with a maximum point with 61 plants per meter. For impaired space the response decreased linearly (Table 6). To BRS-Tangará cultivar there were no differences in the number of grains per spikelet with spacing variation, but on this cultivar the response was linear and decreasing for the number of spikelet per ear with increasing plant density.

Variations in plant density could change the canopy morphology resulting in an increase or a decrease in the number of spikelets. At high plant densities, the number of spikelets per ear may decrease due to competition between wheat plants, though the increase in the number of grains per spikelet can compensate for this factor. According to Zagonel et al. (2002), when the wheat plants are subjected to variations in plant density there is a tradeoff between yields components, which can have any one of them increase, but tradeoff is related to climate and cultivar. Results obtained by Penckowski et al. (2009) also showed that yield components, including the grain number per ear, tends to compensate itself by climate change, but this compensation also varies by cultivar. For thousand grain weight, yield and harvest index there were no significant interactions between spacing and plant densities for both cultivars.

With the change in spacing, the thousand grain weight (TGW) was greater for spacing paired in both cultivars (Table 7). By increasing plant density, the TGW behavior showed to be decreasing quadratically and linearly in Marfim and BRS-Tangará respectively, with a trend of decreasing TGW as we increased density. For both cultivars the highest TGW was achieved with the density of 45 plants per meter (Table 7). Some authors stand that under normal weather conditions, the TGW is more affected by the number of grains per area, tending to increase or decrease with decreasing or increasing the number of grains, being behavior dependent on the cultivar (Valério et al., 2008), these results match with the

Table 5. Number of grains per spikelet and spikelets by ear of wheat cultivars Marfim and BRS-Tangará in relation to spacing between rows and average plant populations (Ponta Grossa, PR, 2012).

Row	Marfim				
	Number of grains per spikelet	Spikelets by ear			
	Mean	Plants.m⁻¹			
		45	60	75	90
Simple spacing	2.2[a]	16.9[a]	14,5[a]	14,1[a]	12,7b
Paired spacing	2.2[a]	16.5[a]	14,7[a]	15,1[a]	15,5[a]
Row spacing	**BRS-Tangará**				
	Number of grains per spikelet	**Spikelets by ear**			
	Mean	**Mean**			
Simple spacing	2.2[a]	14.5[a]			
Paired spacing	2.3[a]	14.6[a]			

Means followed by the same lower case letter in columns are not significantly different by Tukey test (p <5%).

Table 6. Grains per spikelet for cultivar BRS-Tangará wheat according to plant density and average of two spacings between rows (Ponta Grossa, PR, 2012).

Plants.m⁻¹	Marfim		
	Number of grains per spikelet	Spikelets by ear	
		Simple spacing	Paired spacing
45	2.3	16.9	16.5
60	2.3	14.5	15.7
75	2.3	14.1	15.1
90	1.9	15.5	12.7
Regression	Q	Q	L
Plants.m⁻¹	**BRS-Tangará**		
	Number of grains per spikelet	**Spikelets by ear**	
45	2.3	15.3	
60	2.2	15.2	
75	2.2	14.6	
90	2.1	13.4	
Regression	Ns	L	

ns: No significance; L, linear; Q, Quadratic; Grains / spikelet cultivar Marfim: $Y= 0.663813 + 0.055029x - 0.000451x^2$ (R^2 = 82.78); Spikelets/ear cultivar Marfim single space: $Y= 35.310375 - 0.600408x + 0.004231x^2$ (R^2= 99.89); Spikelets/ear cultivar Marfim paired space: $Y = 19.681000 - 0.072700x$ (R^2 = 81.26); Spikelets/ear cultivar BRS-Tangará: $Y = 17.415625 - 0.041500x$ (R^2 = 87.38)

ones found on the current study, where both cultivars showed a similar behavior to variation in plant density, with reduced TGW increasing density and lower TGW in single spacing, when plants density is higher.

For both cultivars lower yield, was observed in paired spacing (Table 7). Abunyewa (2008), working with simple and paired spacing on sorghum crop observed different behaviors related to spacing variation depending on environment condition. In the absence of water deficit, grain yield was lower in paired spacing, but with a severe water deficit higher yield was observed in paired spacing compared to simple. In the current study there was no water deficit along the critical crop stages, such as flowering and grain filling, results showing that paired spacing for wheat may not be feasible in same climate the conditions on which the current experiment was carried out, which is without major water deficit.

The yield was not influenced by increase in plant density for both cultivars (Table 8). Some authors have seen absence on yield change due to plant density variation (Thomason et al., 2009), a result that might be related with wheat capability in sprouting, compensating the absence of plants, as well the yield components, which end up maintaining the same yield index (Holen et al.,

Table 7. Thousand grain weight (TGW), yield and harvest index (HI) of wheat cultivars Marfim and BRS-Tangará due the spacing between rows and average plant populations (Ponta Grossa, PR 2012).

Row	Marfim		
	TGW (g)	**Yield (kg/ha)**	**HI (%)**
Single spacing	39.6[b]	3.674[a]	50.5[a]
Paired spacing	43.0[a]	3.458[b]	51.5[a]
Row	**BRS-Tangará**		
	TGW (g)	**Yield (kg/ha)**	**HI (%)**
Single spacing	42.2[b]	3.810[a]	48.5[a]
Paired spacing	43.8[a]	2.959[b]	49.9[a]

Means followed by the same lower case letter in columns are not significantly different by Tukey test (p <5%).

Table 8. Thousand grain weight (TGW), yield and harvest index (HI) in wheat cultivars Marfim and BRS-Tangará due to plant density and average of two spacings between rows (Ponta Grossa, PR, 2012).

Plants.m⁻¹	Marfim		
	TGW (g)	**Yield (kg/ha)**	**HI (%)**
45	42.4	3.555	54.5
60	41.8	3.586	51.6
75	41.2	3.680	49.2
90	39.6	3.442	48.7
Regression	Q	Ns	Ns
Plants.m⁻¹	**BRS-Tangará**		
	TGW (g)	**Yield (kg/ha)**	**HI (%)**
45	44.4	3.265	49.3
60	43.4	3.312	50.5
75	42.8	3.454	49.1
90	41.4	3.505	47.8
Regression	L	Ns	Ns

Ns, Not significant; L, linear; Q, Quadratic; TGW Marfim cultivar: $Y = 38.06113 + 0.176442 x 0.001808 x^2$ (R^2=98.84); TGW BRS-Tangará cultivar:$Y= 47.238 - 0.062766 x$ ($R^2 = 97.23$).

2001). In this study, a yield component that had a positive influence on maintaining productivity was the thousand grain weight (Tables 6 and 7) which was higher in paired spacing and at low plant densities.

There were no response for harvest index (HI) with spacing and density variation for both wheat cultivars (Table 8). According to Ahmad et al. (2007), the HI values observed in the current study are between the acceptable levels, which vary between 0,40 to 0,55 for wheat. Lower values mean that the cultivar in conjunction with the management techniques, are not resulting in a maximization of assimilates usage at grain yield.

Conclusions

For wheat cultivars, Marfim and BRS-Tangará increasing plant density reduced the number of tillers, number of spikelets per ears and thousand grain weight, without affecting yield. At paired spaced the number of ears per square meter and productivity were lower compared to single-spaced, even with higher grain weight in both wheat cultivars. The use of paired spacing towards greater yield depends on the crop, cultivar and plant density, but environmental conditions are likely to have substantial effect on this behavior. Due to wheat tillering capacity, all plant densities adjusted to the simple and paired spacing, resulting in no yield difference in the conditions under which the experiment was carried out.

Conflict of Interests

The authors have not declared any conflict of interests.

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REFERENCES

Abunyewa AA (2008). Efficient Utilization of Water and Nitrogen Resources for Grain Sorghum under Rainfed Conditions. Theses, Dissertations, and Student Research in Agronomy and Horticulture.Agronomy and Horticulture Department.University of Nebraska – Lincoln.

AGROFIT (2012). Sistema de Agrotóxicos Fitossanitários - Ministério da Agricultura, Pecuária e Abastecimento. Available at: http://extranet.agricultura.gov.br/agrofit_cons/principal_agrofit_cons>.

Ahmad R, Hassan B, Jabran K (2007). Improving crop harvest index. Down Group of newspapers, v.18.

Almeida ML, Mundstock CM (2001). O afilhamento da aveia afetado pela qualidade da luz em plantas sob competição. Cienc. Rural pp. 393-400.

Banzatto DA, Kronka SN (2006). Experimentação agrícola. 4. ed. Jaboticabal: FUNEP, 237 p.

Brachtvogel EL, Pereira FR, Da S, Cruz SCS, Bicudo SJ (2009). Densidades populacionais de milho em arranjos espaciais convencional e equidistante entre plantas. Ciênc. Rural (UFSM. Impresso). pp. 2334-2339.

Embrapa (2006). Empresa Brasileira de Pesquisa Agropecuária. Sistema Brasileiro de Classificação de Solos. Brasília: Embrapa.

Evers JB, Vos J, Andrieu B, Struik PC (2006). Cessation of Tillering in Spring Wheat in Relation to Light Interception and Red: Far-red Ratio. Ann. Bot. pp. 649-658.

Fioreze SL, Rodrigues JD (2014). Componentes produtivos do trigo afetados pela densidade de semeadura e aplicação de regulador vegetal. Semina: Ciênc. Agrárias. pp. 39-54.

Holen DL, Bruckner PL, Martin JM, Carlson GR, Wichman DM, Berg JE (2001). Response of winter wheat to simulated stand reduction. Agron. J. pp. 364-370.

Penckowski LH, Zagonel J, Fernandes EC (2009). Nitrogênio e redutor de crescimento em trigo de alta produtividade. Acta Sci. Agron. pp. 473-479.

Pinthus MJ (1973). Lodging in wheat barley and oats: The phenomenon its causes and preventive measures. Adv. Agron. pp. 210-256.

Rambo L, Costa JÁ, Pires JLF, Parcianello G, Ferreira FG (2003). Rendimento de grãos de soja em função do arranjo de plantas. Ciênc. Rural Santa Maria. pp. 405-411.

Rodrigues O, Didonet AD, Teixeira MCC, Roman ES (2003). Reguladores de crescimento. Boletim de Pesquisa e Desenvolvimento. n. 14.

Smanhotto A, Nóbrega LHP, Opazo MAU, Prior M (2006). Características físicas e fisiológicas na qualidade industrial de cultivares e linhagens de trigo e triticale. Revista Brasileira de Engenharia Agrícola e Ambiental. pp. 867-872.

Sober (2010). Políticas governamentais e a coordenação da cadeia do trigo no Brasil. Disponível em: http://www.sober.org.br/palestra/15/952.pdf.

Teixeira MCC, Rodrigues O (2003). Efeito da adubação nitrogenada, arranjo de plantas e redutor de crescimento no acamamento e em características de cevada. Boletim de Pesquisa e Desenvolvimento.

Thomason WE, Brooks WS, Griffey CA, Vaughn ME (2009). Hulless Barley Seeding Rate Effects on Grain Yield and Yield Components. Crop Sci. pp. 342-346.

Valério IP, Carvalho FIF, Oliveira AC (2008). Desenvolvimento de afilhos e componentes do rendimento em genótipos de trigo sob diferentes densidades de plantas. Pesqui. Agropecu. Bras. pp. 319-326.

Weiner J, Griepentrog HW, Kristensen L (2001). Suppression of weeds by spring wheat *Triticum aestivum* increases with crop density and spatial uniformity. J. Appl. Ecol. pp. 784-790.

Zagonel J, Venancio WS, Kunz RP, Tanamati H (2002). Doses de nitrogênio e densidades de plantas com e sem um regulador de crescimento afetando o trigo, cultivar OR-1.Ciênc. Rural pp. 25-29.