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Spacing and plant density effect on reproductive development of herbaceous cotton

Espaçamento e densidade populacional no desenvolvimento reprodutivo no algodoeiro herbáceo

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The aim of this work was to evaluate the influence of spacing and plant density for cotton plant on reproductive structures and productivity. The work was conducted at the Mato Grosso State University (UNEMAT) experimental field, Tangara da Serra Campus, latitude 14°37'10 "S, longitude 57°29'09" W and altitude 320 m, in the 2008/2009 season. It was used a randomized block delineation in a 4x4 factorial scheme with 16 treatments and 4 replicates, consisting of four row spacings: 0.36, 0.45, 0.75 and 0.90 m, and four densities: 8, 10, 12 and 14 plants per meter, using the cultivar FMT-701® for planting. After the evaluation it was concluded that the cotton crop was influenced by the spacing on number of flower buds per plant, number of bolls and productivity. The smaller spacings provided smaller number of flower buds and lower productivity. The spacings of 0.75 and 0.90 m between rows had presented higher yields. Have not checked the effect of the interaction of row spacing x plant density on the crop.
Keywords: cotton; density; productivity

O objetivo deste trabalho foi avaliar a influência do espaçamento e da densidade de plantas para o algodoeiro quanto às estruturas reprodutivas e a produtividade. O trabalho foi realizado na área experimental da Universidade do Estado de Mato Grosso (UNEMAT), *Campus* de Tangará da Serra MT, latitude 14°37’10” S, longitude 57°29’09” W e altitude de 320 m, na safra 2008/2009. O delineamento experimental utilizado foi o de blocos casualizados, em esquema fatorial 4 x 4, constituindo-se de quatro espaçamentos entrelinhas (0,36, 0,45, 0,75 e 0,90 m), quatro densidades (8, 10, 12 e 14 plantas por metro linear), com quatro repetições, e utilizada a cultivar FMT-701®. Foram contabilizados: número de maçãs e botões florais por planta e produtividade por hectare. Após a avaliação Verificou-se que o espaçamento influencia a cultura do algodoeiro quanto ao seu número de botões florais por planta, número de maçãs e produtividade. Os menores espaçamentos apresentaram menor número de botões florais e menor produtividade. Os espaçamentos de 0,75 e 0,90 m entre linhas apresentaram maior produtividade. Não foi verificado o efeito da interação espaçamento *x* densidade sobre a cultura.
Palavras-clave: algodão; adensamento; produtividade

1. INTRODUCTION

The migration of the cotton crop to the Cerrado was due to several technical and macroeconomic factors, and its expansion has occurred mainly due to research and implementation of new technologies, making the area extremely competitive (BUAINAIN, 2007) [1].

The planted area in Brazil that was in decline from 1,0774 million hectares (2007/2008) to 843.2 (2008/2009) and 835.7 (2009/2010) has estimate of 1,304.7 for the 2010/2011 season, an increase of 56.1%. Highlight to Mato Grosso State, the greatest producer, that is estimated in 669.100 hectares, an increase of 56.3% over the previous crop (CONAB, 2011) [2].

However, cotton production has a high economic risk due to high costs of production, the need of investment in equipment, and the instability of prices paid to farmers. Therefore the search for high productivity and reduction of production costs has become a constant [3], and among the main management proposals for that, has highlighted the high density system, a technique brought from the United States which had intensive research from the 2008/2009 season.

The technique has already been used in Argentina on 65 to 75% of the cultivated area in the 2009/2010 season, in Brazil, the first experiments were conducted in small areas in the 2009/2010 season. The demand for the high density technology in the country has been towards enable the winter crop season in Mato Grosso with cotton culture, and although results are variable yet, the tendency is that Brazilian farmers to invest in this new technology (ABRAPA, 2009) [4]. There is about 50,000 hectares planted for the 2010/2011 season in Brazil, where most improving companies should identify cultivars of early and medium cicle, best suited for use in this system as well as perform more conclusive tests on equipment, supplying producers with more consistent information to decide which system to use (ABRAPA, 2010) [5].

The adoption of a standard spacing for various crops such as soybeans, corn, sunflower, beans, sorghum and cotton, can maximize the use of machinery (SILVA et al., 2009) [6] which consequently improves the time on cultural practices, making planting, spraying, fertilizing and harvesting more efficient.

Therefore it is clear the need for studies that support the planting configuration adopted by producers to reduce costs and improve profits consolidating management techniques and thereby stimulating the cultivation. Within this context, this work aim evaluated the influence of spacing and plant density on the incidence of flower buds, number of bolls and cotton productivity.

2. MATERIAL AND METHODS

The experiment was conducted in the Mato Grosso State University (UNEMAT) experimental field, Tangará da Serra Campus, located at 14° 37'10 "S and 57° 29'09" W, at an altitude of 320 m, in the 2008/2009 season.

The soil was classified as a clayey-texture Typic Eutrorthox, argillaceous texture (Embrapa, 2006) [7], and its chemical analysis as described in Table 1.

The experimental delineation used was the randomized blocks in factorial 4 x 4 scheme, containing four spacings (0.36, 0.45, 0.75 and 0.90 meters between lines) and 4 densities (8, 10, 12 and 14 plants per meter) with four replicates, totaling 16 treatments.

The parcels consisted of four rows five m long. The area used for evaluation of each parcel was the two central rows, discarding 0.5 m from the border.

Soil tillage was conducted in October 2008, with scarification and harrowing to incorporate the lime. It was used lime with neutralizing value 85, applied over the total area before tilling the soil, at a rate of 1.65 Mg ha^{-1} to raise the base saturation to 60%, according to crop need.

At the seed treatment for fungal diseases control, it was used a product from the benzimidazole chemical group with carbendazim as active ingredient at a dose of 80 ml for 100 kg of seeds.

Sowing was done manually on December 11, 2008, using the late-maturing variety FMT 701®. At 30 days after emergence (DAE) it was performed the thinning of seedlings, obtaining the desired density in accordance with the spacing for each parcel.

Table 1: Chemical characterization of the LVdf 0-20 cm before place the experiment.

Depth	P resin	M.O	pH	K^+	Ca^{2+}	Mg^{2+}	H+Al	Al^{3+}	S.B	V	S-SO_4
	mg dm^{-3}	g dm^{-3}	$CaCl_2$			———— mmol$_c$ dm^{-3} ————				%	mg dm^{-3}
0 – 20 cm	8	55	5,1	1,9	23	15	50	1	40	45	5

The fertilizer recommendations (macronutrients) for sowing and top dressing were done according to crop need. For the treatments spacing 0.75 and 0.90 m it was applied at sowing 25, 80 and 30 kg ha^{-1} of N, P_2O_5 and K_2O respectively. Top dressing fertilization was done parceled at 35 and 50 DAE, applying 35 kg ha^{-1} N and 30 kg K_2O ha^{-1} in the first period and over 35 kg N ha^{-1} in the second period. By 35 DAE it was done a broadcast application of 0.5, 0.5, 1.5, 0.1 and 1.5 kg ha^{-1} of the micronutrients B, Cu, Mn, Mo and Zn, respectively [8].

For the treatments spacing 0.36 and 0.45 m it was applied at sowing 18.5, 60 and 22 kg ha^{-1} of N, P_2O_5 and K_2O. Top dressing fertilization was done parceled at 35 and 50 DAE, applying 26 kg ha^{-1} N and 18.5 kg ha^{-1} K_2O in each two applications. By 35 DAE it was done a application of 0.4, 0.4, 1.1, 0.08 and 1.1 kg ha-1 of the micronutrients B, Cu, Mn, Mo and Zn, respectively [9].

It was used as source for N, P_2O_5 and K_2O, urea, simple superphosphate (18% phosphorus pentoxide) and potassium chloride, respectively.

The weed control was done with hand weeding at 30 and 60 DAE for spacing 0.75 and 0.90 m, due to the non-shading by the culture had provided favorable environment for weeds, and for the spacing 0.36 and 0.45 m there were no need for weeding due the canopy closure before their emergence. By 80 DAE it was applied a growth regulator with active ingredient mepiquat chloride at a dose of 50 g of active ingredient per hectare via foliar using manual sprayer at medium flow rate as recommended by the manufacturer.

There was a preventive applying of fungicide from the triazoles chemical group for control of alternaria and ramularia and insecticide from the pyrethroid chemical group.

Three reproductive parameters of the culture were evaluated, namely: number of flower buds (at 90 DAE), number of bolls (at 125 DAE), and productivity by 149 DAE for high densities (0.36 and 0.45 m) and 178 DAE for conventional densities (0.75 and 0.90 m).

The results were subjected to analysis of variance and when the F test was significant at 1 or 5% probability, it was applied the Tukey test at 5% probability for comparison of averages and regression for the quantitative parameters, using the computational Program Sisvar [10].

3- RESULTS AND DISCUSSION

According to Table 2 the number of flower buds and number of bolls per plant, associated with the spacing and population density, the cotton crop was influenced by spacing on its gronomic characteristics: number of flower buds, bolls per plant and productivity. The density of plants has influenced only the number of flower buds. It was verified no effect in the interaction spacing *x* plant density on the culture, however, Brito et al. (2005) [11] have evaluated the spacing *x* plant density interaction indicating that the increase of distance between plants in the row, associated to the reduction in spacing between rows, promote the increase in the yield of cotton seed.

Table 2: Number of flower buds (90 DAE), and bolls (125 DAE) per plant and productivity related to spacing and density of cotton plant, cultivar FMT 701.

Spacings	**Flower buds**	**Bolls**	**Productivity**
(cm)			kg ha^{-1}
0,36	4,28 c	1,06 a	1856,77 c
0,45	5,66 b	1,07 a	2354,94 b
0,75	6,30 b	0,98 a	3147,00 a
0,90	8,29 a	0,67 b	3174,81 a
Densities (plants m^{-1})			
8	5,82b	0,93 a	2529,59a
10	6,9 a	1,03 a	2769,56a
12	6,01b	0,90 a	2630,47a
14	5,89b	0,92 a	2603,90a
Spacings (S)	0,01**	0,01**	0,00**
Densities (D)	0,01**	0,55^{ns}	0,2461^{ns}
Interaction (SxD)	0,85^{ns}	0,32^{ns}	0,9905^{ns}
CV %	12,32	28,24	12,75
MSD	0,71	0,25	316,05

(**) Significant at 1% of probability by F test (*); Significant at 5% probability by F test; (ns) not significant. Averages followed by the same lowercase letter in column do not differ by Tukey test at 5% of probability. CV = *coefficient of variation. MSD* = minimum significant difference.

In Figure 1 it is presented data on the number of flower buds per plant in relation to the evaluated spacings. The regression equation showed a linear function for flower buds responses to interval of space between rows. It was verified that the smaller spacing provided lower number of flower buds per plant, thus the opposite is also true, the largest flower buds production had occurred in the treatment which was used greater spacing.

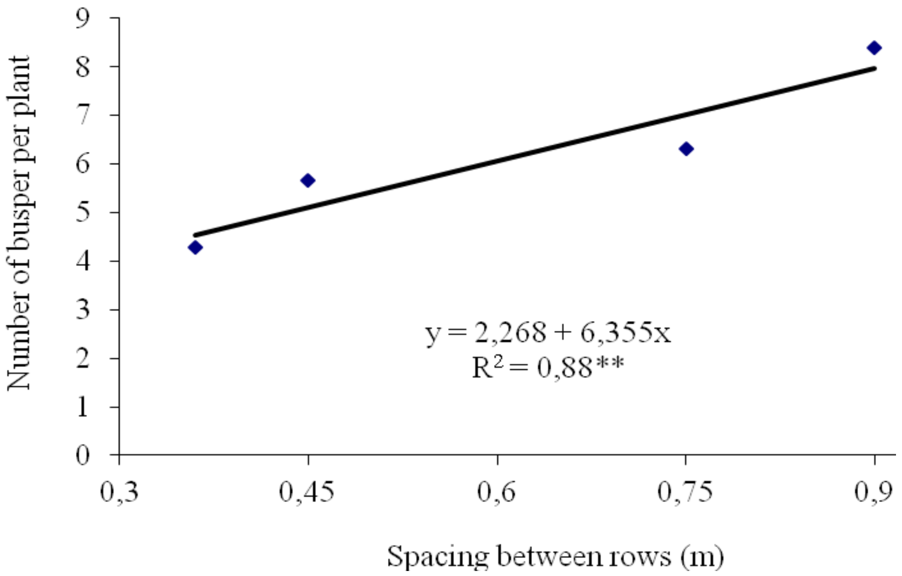

Figure 1: Effect of spacing between rows on the number of flower buds.
Figura 1: Efeito do espaçamento sobre o número de botões florais por planta na cultura do algodoeiro.

Discordant results were found by Silva et al. (2006) [6], evaluating the effect of row spacings (0.38, 0.76, 0.95 m) and plant densities (5, 8, 11, and 14 per meter) of the IAC 23 cultivar, found that production of seed cotton was 12% and 8.4% higher at spaced ultra-dense and high dense, respectively, compared to the conventional.

For the result of fewer flower buds and consequently lower productivity, two hypotheses can be raised. The first one refers to the fall and/or abortion of flower buds, and the second is the decrease in actual production of reproductive organs, which can occur due to competition for light between plants.

According to Rosolem (2006) [12] the drop or abortion of flower buds is a natural phenomenon of the culture, however, this effect can be enhanced due to the imbalance between ethylene and sugar content in the tissues, while any factor that determine photosynthetic decline or excessive metabolic expenditure will result in senescence of reproductive structures. The same author describes that one of the factors that culminates in this situation is the self-shading caused by the plants themselves.

For the second situation, Martin (2006) [13] indicates that competition for light provides increased plants etiolation and thus increase the internodes range resulting in decreased of reproductive branches, thereby producing fewer flower buds and in both cases the luminosity is the fundamental factor.

The effect of spacing about the number of bolls (Figure 2) was observed by quadratic model regression. The number of bolls was reduced in the greater spacing and the response was similar in the other spacing.This effect was expected due to the time of assessment to be within a period of transition from the stage F (referring to the flower) to the stage M (referring to boll) according to the phenological scale adapted from Marur and Ruano (2001) [14]. In this case occurred simply the cycle anticipation in smaller spacing, which justifies the higher number of bolls, however, it was observed that this effect was not return higher productivity.

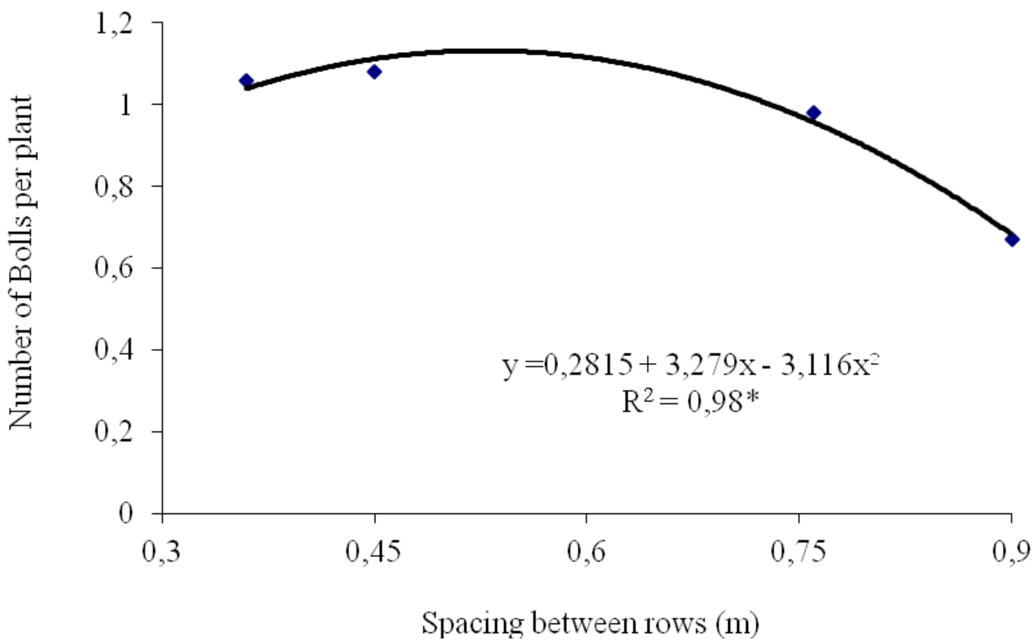

Figure 2: Effect of spacing between rows on the number of bolls.
(Figura 2: Efeito do espaçamento sobre o número de maçãs por plantas de algodão).

Cotton production showed linear growth from the smallest spacing, 0.36 m, up 0.75 m not differing the from this. Another factor that must be taken into account on the productivity of cotton is the position of the capsule in relation to the main stem. Rosolem (2001) [15] states that the first bolls formed, the closer to the main stem, are also the larger in mass and, in cases of abortion due to stress they are eliminated by the plant (usually at the stage of flower buds and/or bolls), which also explains the smaller distance having the lowest productivity.

Assessing the development and cotton productivity in relation to row spacing (0.45, 0.70 and 0.90 m) in Ilha Solteira SP, Ferrari (2008) [16] also found superior results in greater spacing.

Regarding plant density (Figure 3), it has influenced only the number of flower buds per plant, and the use of 10 plants per meter was responsible for the largest flower buds production. It was verified by the quadratic equation generated by the functions (number of flower buds per plant *x* density), the trend line is expressed with little variation, with a slight superiority for the population of 10 plants per meter.

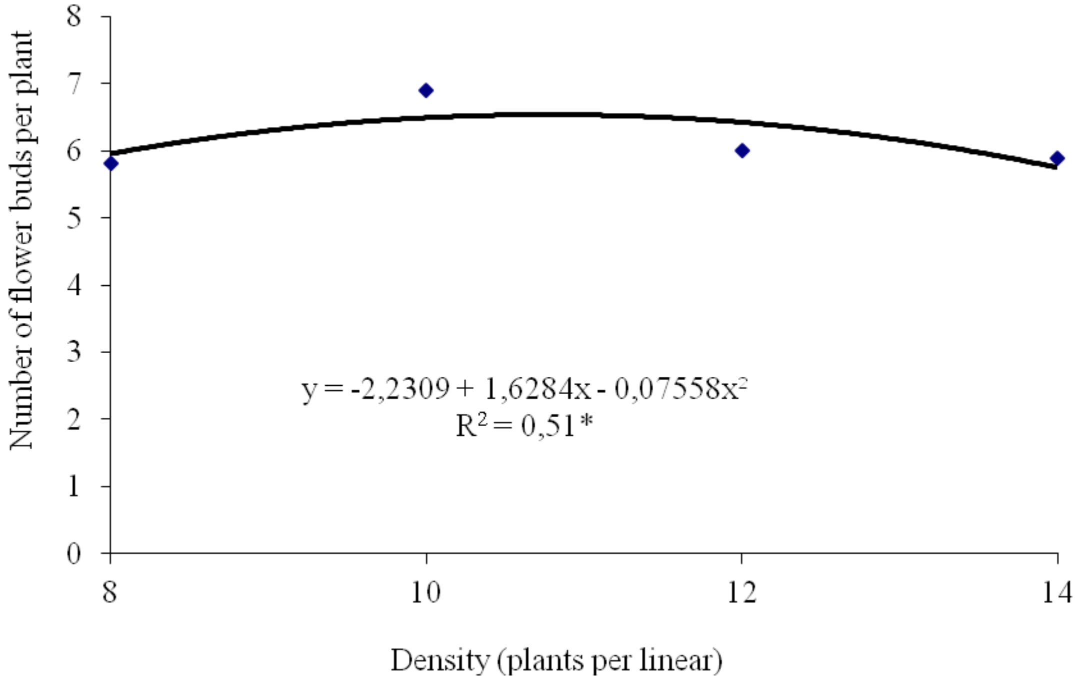

Figure 3: Number of flower buds on different densities.
(Figura 3 - Número de botões florais em relação a diferentes densidades populacionais).

Opposite effect was observed by Kittock et al. (1986) [17] in a similar work, where the increase in plant population coincided with the decrease in productivity. Hillocks (1992) [18] reported that as the plant population increase, there is increasing on drop of flower buds and young fruits, reducing the productivity per plant, also hindering phytosanitary treatments.

The fact that the plant density has not influenced on cotton productivity may be due to the treatments have not extrapolated the limit capacity (maximum and minimum) of plants. Lamas (2006) [19] indicates that this variable varies according to cultivar and environmental factors. \Hearn & Constable. (1984) [20] even claim that cotton is a plant with great plasticity in productivity behavior regarding to plant population with a high capacity to adapt to the situation which it is submitted.

According to the results obtained, spacing exerted a greater influence on cotton crop than the plant density. It was noted that the reduction of spacing subjected the plants to a stress condition, which can be seen in the physiological maturity of the crop.

This fact has forced the harvest schedule to be changed according to the treatments, so that the smaller spacing (0.36 and 0.45 m) were harvested at 149 DAE, 29 days before the other treatments (0.75 and 0.90 m) which completed its cycle in 178 DAE. This effect was also observed by Yamaoka et al. (2009) [21] in a work using the same cultivar, where the reduction was from 15 to 20 days with spacing of 0.40 m and density ranging from 12 to 15 plants per meter. The authors concluded that the 701 FMT cultivar was not adapted to high density.

This reduction in the crop cycle was because the stress the plant was submitted, that make had stimulated it to reproduce to ensure the specie perpetuation. Martin (2006) [13] describes in details this phenomenon in a review and points out advantages and disadvantages to this fact.

Based on the obtained data in this work and the confronting of them with the existing works, it is clear the need of further studies on variables like cultivar, sowing date, among others, and it is also necessary, the regionalization of the data to provide more confidence in adopting a technique.

4. CONCLUSIONS

The smaller spacings provided smaller number of flower buds and lower productivity.

The spacings of 0.75 and 0.90 m between rows had presented higher yields.

Have not checked the effect of the interaction of row spacing x plant density on the crop.

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