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**Row spacing in the growth and yield of the soybean's cultivar**

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Abstract - Row spacing at sowing is a determining factor in the arrangement of plants in the environment, influencing growth and soybean productivity. This study aimed to verify the behavior of three soybean cultivars in three different spacing. The experiment was conducted in a commercial farm in the country of Rondonópolis of Mato Grosso (MT) State. The experimental design was performed in randomized block design, with five replicates in factorial 3x3, three row spacing, 0.35m; 0.45m and 0.50m, keeping a population of 350,000 plants/ha⁻¹, and three cultivars, BMX Desafio RR, BMX and BMX Ultra IPRO IPRO Bonus of Brasmax® company. We evaluated the number of pods per plant (NPP), number of grains per plant (NGP), plant height (PH), number of reproductive nodes (RN), height of insertion of the first reproductive node (HIR), lodging (L), 1000 grain weight (TGW) and productivity (PROD). In all spacing, cultivar BMX Bonus was higher in PH, NR and TGW. Cultivar BMX Desafio was higher in NPP and TGW. The cultivars responded differently in the spacing, but it did not suffer significant fluctuations in final yield. Plant tipping lodging was observed with reduced spacing.

Keywords: Glycine Max; Soybean Crop; Sowed spacing; Management practices

Introduction

Soybean is one of the most cultivated plants in the world due to its versatility of use (Gesteira et al. 2015). In the crop of 2015/2016, the country produced 98 million of tons of soybean, in which the middle-west region was responsible for 50% of this production (Conab, 2016).

Modifications in the spatial arrangements of the culture can be performed through the variation of number of plants in the lines and in the row spacing lines. Therefore, it is possible to identify the ideal spacing, in order to induce the genotype to achieve its maximal productive potential; and posteriorly, develop a recommendation for soybean cultivation (Peixoto et al. 2000; Madalosso et al. 2010).

The necessity of new studies on soybean plant spacings occurs due to a change in morpho-physiological characteristics of the soybean cultures; management practices and opening of new areas. These studies foster innumerable advantages such as: use efficiency of water in function of quicker shading of the ground; distribution of roots; more uniform exploration of soil fertility; and higher plant solar energy interception, which minimizes the costs of application of defensives and increases productivity expectations (Procópio et al. 2013).

Diverse arrangements of plants are evaluated in crops, such as cross sowing (Procópio et al. 2013), double row sowing (Procópio et al. 2014) and reduction of row spacing without increase of plant population per area. Plant arrangements, that promote high light and agrochemicals penetration in the sunshade, improving the photosynthetic rate, leaf sanity and longevity on ground may maximize gain productivity (Bruns, 2011). In this way, this study intends to collaborate in the reduction of inadequate use of arrangements and imbalance between vegetative and reproductive growth; moreover to reduce risks of plant lodging (Mauad et al. 2010; Balbinot Jr. 2012). Based on the above considerations, this study aimed to verify growth and productivity of three soybean cultivars (BMX Desafio RR, BMX Ultra IPRO e BMX Bônus IPRO) in three different row spacings (0,35; 0,45 and 0,50 m).

Methods

This study was conducted since October of 2015 in a commercial farm of the city of Rondonópolis, of the state of Mato Grosso (MT); at 16°58'67" south latitude, 54°86'25" west longitude and 566m altitude. Based on Köppen's climate classification, the region is characterized by humid

tropical climate (type Aw) with a wet season in the summer and a dry season in the winter. The annual temperature and precipitation averages are 26,8 °C

and 1127 mm, respectively. The pluvial precipitation and average temperatures can be found in Figure 1.

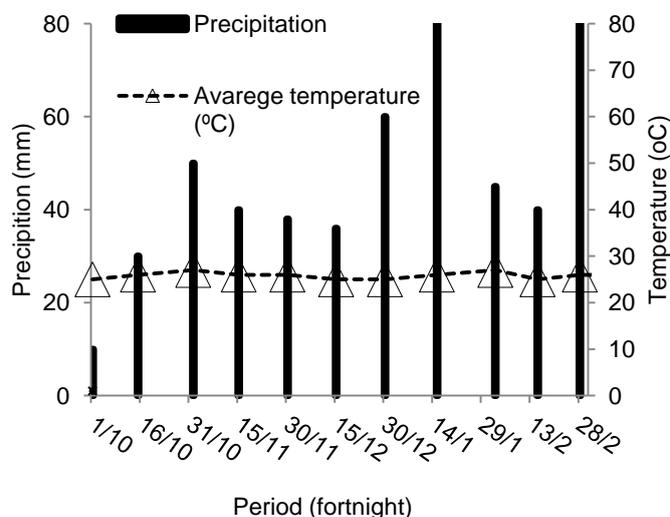


Figure 1 – Pluvial precipitation (mm) and average temperature (°C) referred to the period between October of 2015 and March of 2016. Rondonópolis (2016), crop of 2015/2016.

The experimental delineation was arranged in randomized block design (DBC), with five repetitions in 3x3 factorial scheme and in three row spacings (0,35m; 0,45m and 0,50m). A population of 350 thousand plants/ha⁻¹ and three cultivars, BMX Desafio RR, BMX Ultra IPRO and BMX Bônus IPRO, of the Brasmax[®] company, totalizing nine treatments, were maintained in the experiment. The total plots were constituted in 12 lines of 70 meters of length. The useful plots were composed by 60m of 10 central lines of the total plot. Lateral lines and 5m in end, considered row borders, were not considered. The principal characteristics of the cultivars are described in Table 1.

The soil of the experimental area is known as Latossolo Vermelho, which has a clayey texture. Cultivation was performed under established no-tillage system. Sowing was performed at October 20th of 2015. A plot seeder was regulated to distribute seeds in the wished row spacings (0,35; 0,45 and 0,50m) corresponding to a final population of 350 thousand plants/ha⁻¹. Fertilization on the sowing furrow was at a dose of 500kg/ha⁻¹, using the formulation 00-18-18.

The seeds were treated with the fungicides and insecticides Carbendazim+Tiram at a dose of 200 mL/100 kg⁻¹ seeds. The insecticide Fipronil was used at a dose p.c. of 200 mL/100 kg⁻¹ seeds and a liquid inoculant at a dose of 200 mL/100 kg⁻¹ seeds. The insecticide clorantraniliprole, and fungicide traizóle and estrobirulin were used. The herbicide used was the glyphosate, at a dose of 960 g ia/ha⁻¹, which is efficient in control of weeds in the soybean RR (Pereira et al, 2016).

On February 4th of 2016, approximately 105 days after emergency, harvesting was performed in the useful plot using a plot harvester, on February 4th of 2016, approximately 105 days after emergency. After grain harvesting, threshing and separation, grain humidity was 180g of water/kg grain. The grains were dried in a greenhouse of forced air circulation, at 60 °C, until achieving 130g of water per kg⁻¹ of grains. Posteriorly, the grains were weighted and the plot productivity was extrapolated for obtainment of the productivity (PROD) in kg ha⁻¹. The variable, 1000 grain weight (TGW) was evaluated after harvesting of each plot. The grain masses were homogenized and using a board with 1000 holes, a quantity of 1000 grains was separated for weighting.

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Data was submitted to analyses of variance at 5% of probability through the F-test, using SISVAR software (Ferreira 2011).

Table 1 – Principal agronomic characteristics of three cultivars used in the experiment. Rondonópolis (2016). Crop of 2015/2016.

Cultivar	Desafio	Ultra	Bônus
Maturation Group	7.4	7.5	7.9
Growth habit:	Indeterminate	Indeterminate	Indeterminate
Stature:	Medium	Medium	High
Ramification index:	Low	Low	Medium
Resistant to lodging	Yes	Yes	MR

Results and discussion

Plant height (PH) and height of insertion of the first reproductive node (HIR) were influenced by the interaction between cultivars and row spacings. The cultivar BMX Bônus achieved the highest heights, independently of the row spacing length. BMX Ultra, had an intermediate behavior and the BMX Desafio had the lowest heights. The increase of the row spacing reduced linearly the cultivar heights (Figure 2a). For HIR, the BMX Bônus cultivar reached the lowest insertion and BMX Desafio the highest HIR (Figure 2b).

In a study with double densified rows, Solano & Yamashita (2012) verified that plants grow more in densified row spacings than in less densified row spacings. Procópio et al. (2014) also found that soybean plants in higher sowing densities grew more; therefore, they proposed that in smaller row spacings, it's necessary to reduce the number of plants per meter in the lines. This results in more equidistant distribution of plants, in respect to plant arrangements with larger row spacings. This equidistant condition results in less competition for light at the beginning of the cycle, reducing shadowing among soybean plants. Under a determined fixed population of plants, e.g 350 million of plants, an increase in plant height was observed. These results agree with the results found by these authors, in which the formation of branches directs photoassimilates to vegetative growth.

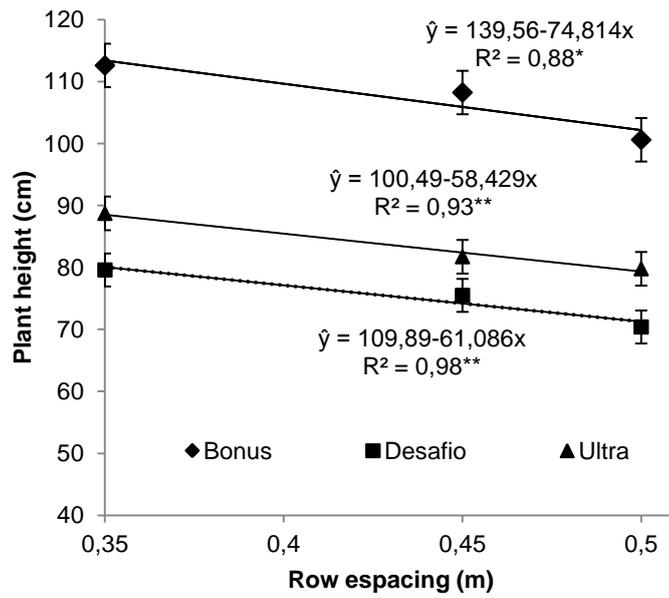
For the variable HIR, the cultivar BMX Desafio e BMX Ultra would probably show fewer losses due to the regulation of the platform of the harvester machine in the row spacing 0,35m. According to Ferreira Júnior et al. (2010), harvesting is efficient when height of the first pod is around 10 cm in soils relatively flat and with use of adequate harvester machines. According to Mauad et al. (2010), plant height and height of insertion of the first reproductive node are correlated variables; and its behavior is related to the increase of intraspecific competition for water, nutrients and principally light, whose behavior results in blanching of the plants.

The number of the grains per plant was influenced by the interaction among the cultivars and the row spacings. The cultivar BMX Desafio achieved the highest number of grains per plant, with 91 grains in the row spacing 0,5m. BMX Ultra achieved 82,4 grains per plant and was not influenced by row spacing. BMX Bônus achieved 65 grains, the lowest number of grains in the row spacing 0,5m (Figure 3).

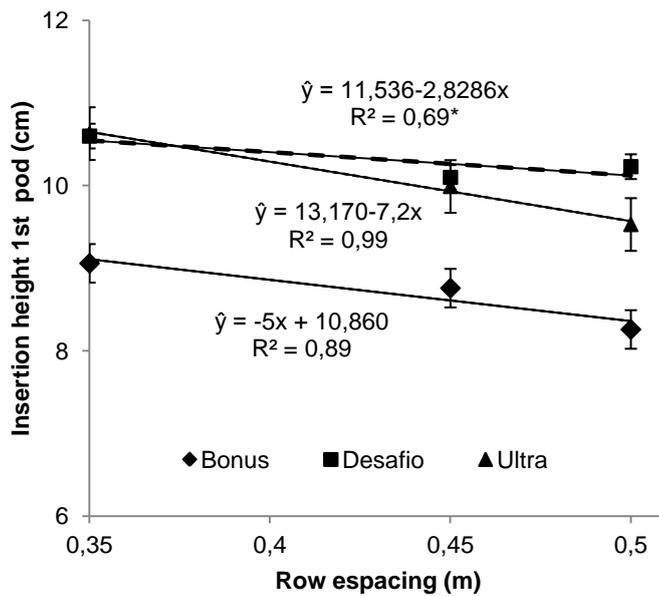
The variables number of reproductive nodes (RN) and number of pods per plant (NPP) showed significant difference among the row spacings. The lowest values were obtained of the row spacing 0,5m. Row spacing 0,35 and 0,45m showed very close values, probably due to higher plant heights. The row spacings presented interferences on the number of reproductive nodes (RN) and on the number of pods per plant (NPP) (Figures 4a and 4b). The optimal spacing for these two variables was around 0,45m. The cultivars achieved the highest number of nodes (16,74) and highest number of pods (36,13 pod/plant⁻¹), being this spacing responsible for the maximal expression of the cultivar productive potential. According to Peixoto et al. (2000), this fact also interrelates to the increase in plant height. Parcianello et al. (2004) verified increments in the number of reproductive nodes, number of pods per plant and grain yield with row spacing enlargement. According to the authors, better interception efficiency of solar radiation by the plants is related to these variables.

The cultivars influenced the number of reproductive nodes (NR), number of pods per plant (NPP), 1000 grain weight (TGW) and lodging percentage (LP) (table 2).

Among the cultivars, NR was superior for BMX Bônus (17,69), with 2,24 more nodes than BMX Ultra and with 3,39 more nodes than BMX Desafio. These are considered expressive values and are justified by the character of each cultivar. Procópio et al. (2013) found 13,9 nodes, but using soybean cultivars with determined habit. On the other side, the number of pods per plant was higher in the cultivars BMX Desafio and BMX Ultra, with 38,94 and 37,94 pods per plant, respectively. The cultivar BMX Bônus achieved 30,67 nodes, a difference of 21,23% in relation to BMX Desafio. For TGW, the cultivar BMX Bônus achieved 220,22g/1000 seeds⁻¹, 22,8% higher than BMX Desafio (170g 1000 seeds⁻¹). BMX Ultra has an intermediate behavior in this variable, with 179,44g/1000 seeds⁻¹. Procópio et al. (2013) also did not verified alterations in TGW of the undetermined cultivar BRS 359 RR, in which populations were kept between 375 and 562 thousand seeds/ha⁻¹. Reduced lodging (L) values were observed in the cultivars. BMX Bônus showed the highest L, followed by BMX Ultra. BMX Desafio did not present lodging.



a)



b)

Figure 2 – a) Plant height b) Height of insertion of the first pod of three soybean cultivars (BMX Desafio IPRO, BMX Bonus IPRO and BMX Ultra IPRO) in three sowing spacings (0,35; 0,45 and 0,5 m). Rondonópolis, crop of 2015/2016.

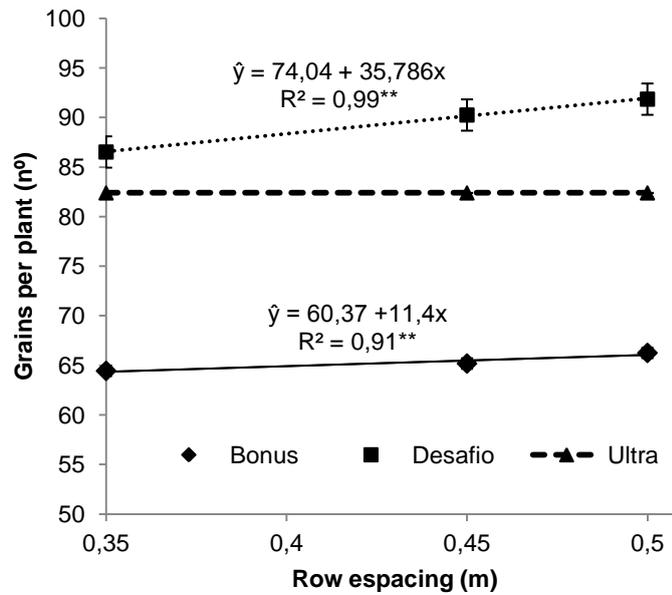
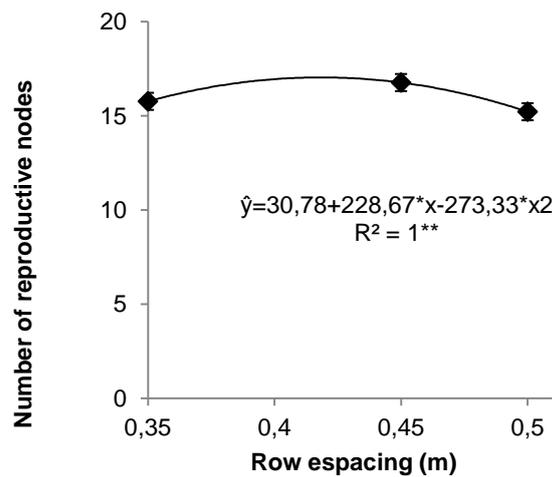
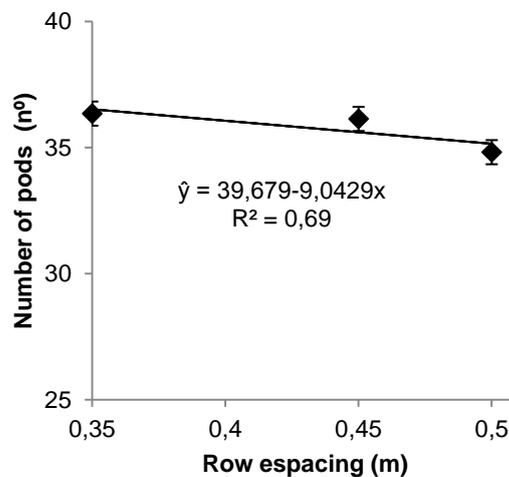


Figure 3 – Number of grains of three soybean cultivars (BMX Desafio, BMX Bonus, IPRO e BMX Ultra IPRO) in three sowing spacings (0,35; 0,45 and 0,5m). Rondonópolis, crop of 2015/2016.



a)



b)

Figure 4 – a) Number of reproductive nodes (NR) and b) Number of pods per plant (NPP) of three soybean cultivars (BMX Desafio IPRO, BMX Bônus IPRO and BMX Ultra IPRO) in three sowing spacings (0,35; 0,45 and 0,5m). Rondonópolis, crop of 2015/2016.

Lodging (L) increased with the reduction of row spacing (Figure 5). Row spacing 0,35m presented the highest number of lodged plants; however the value found was little expressive, less than 1%. According to Balbino Júnior (2012), attention to the risks of lodging is an important factor to be considered. Ideal adjustments of plants are important to not exceed the number of plants per area.

In this study, the different row spacings and cultivars did not alter grain productivity. Nevertheless, BMX Desafio was the most productive cultivar, with an average yield of 5280 kg/ha⁻¹ (88 sacs/ha⁻¹). This value was 6% superior to BMX Bônus and 4% to BMX Ultra. The average productivity of this study was 4920 kg/ha⁻¹ (82 sac/ha⁻¹); much further than the national productivity average, which is around 3000 kg/ha⁻¹ (50 sacs/ha⁻¹) (Conab, 2016).

The highest soybean productivities found by Procópio et al (2014) were obtained through row

spacings and populations values close to the values used in this study. In the region of Lavras, Minas Gerais (MG) State, Tourino et al. (2002) verified an increase in soybean productivity using 45cm of row spacing and a reduction of density to 10 plants m⁻¹. In this experiment, it was possible to conclude that the increase in the spacing uniformity among plants in row spacings contributes to a reduction in lodging and to an increase in soybean productivity. This result is connected to two factors: number of pods per plant and 1000 grain weight. With the reduction of row spacings and increase of distance among plants in the lines, it was expected to increase balance of space among the plants and consequently increase the final productivity. In spite of the occurrence of higher number of pods per plant, the same was compensated by a higher number of grains per plant in the treatment using a larger row spacing.

Table 2 – Averages of number of reproductive nodes (RN); number of pods per plant (NPP); 1000 grain weight (TGW) and lodging (L) of three soybean cultivars (BMX Bônus IPRO, Desafio IPRO, e BMX Ultra IPRO) in three sowing spacings (0,35; 0,45 and 0,5m) Rondonópolis, crop of 2015/2016.

Cultivar	Variables analyzed			
	RN	NPP	TGW	L
BMX Bônus IPRO	17,69 a	30,67 c	220,22 a	0,77 b
BMX Desafio IPRO	14,30 c	38,94 a	170,00 c	0,00 a
BMX Ultra IPRO	15,75 b	37,49 b	179,44 b	0,22 a
CV(%)	2,16	1,03	1,50	17,75

The averages followed by the same letter in the column do not differ among each other in the Turkey's test (P<0,05).

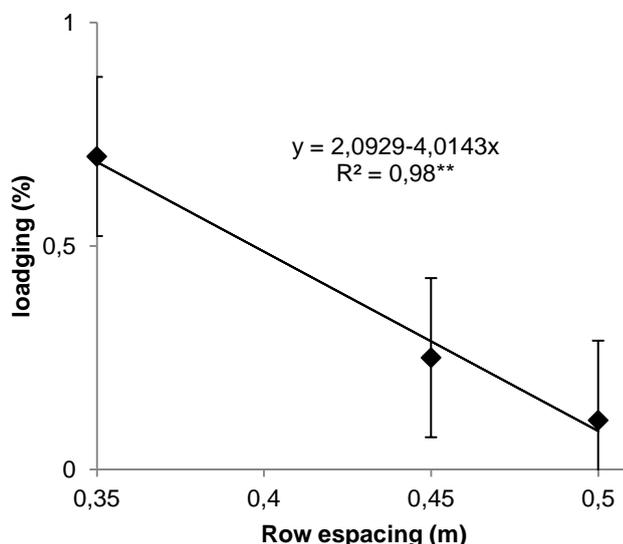


Figure 5 – Average lodging percentage of three soybean cultivars (BMX Desafio IPRO, BMX Bônus IPRO and BMX Ultra IPRO) in three sowing spacings (0,35; 0,45 and 0,5m). Rondonópolis, crop of 2015/2016.

Conclusion

With reduced row spacing and the same plant population per hectare, there were increases in the values and height of insertion of the first pod and plant height.

With a population of 350 thousand plants, independently of the spacing, the cultivar BMX Desafio achieved the highest number of pods and grains per plant; and the cultivar BMX Bônus the highest 1000 grain weight.

With the reduction of row spacings among plants, an increase in the levels of lodging occurred in the cultivars BMX Bônus and BMX Ultra.

Despite the fact that cultivar BMX Bônus achieved the same productivity as the cultivars BMX Desafio and BMX Ultra, BMX Bônus may present more losses. This may be due to the height of insertion of the first reproductive node, which was much lower than height insertion in the other cultivars.

The cultivars BMX Bônus BMX Desafio and BMX Ultra achieved with 350 thousand plants, the same productivity, independently of the row spacing length.

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