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The productive performance of soybean genotypes depends on the distribution of plants in the field

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Abstract

This study aims to evaluate the effect of the distribution of plants in the field on the productive performance of soybean genotypes. The test was developed in the field, in two agricultural crops, on a farm located in the District of Monte Bonito - Pelotas (RS, Brazil), in eutrophic haplic planosol soil, with geographic coordinates 31° 40' 27"S and 52°23' 28 "W. The experiment consisted of twelve treatments involving two factors: factor A - 3 soybean genotypes (NA 5909 RR (super early, growth indeterminate and maturation group A), NS 6006 IPRO (high grain weight, growth indeterminate and maturation group B 5.9), and NS 5959 IPRO (precocity, indeterminate growth and maturation group C) and factor B - 4 line spacing (0.17; 0.30; 0.45 and 0.60 meters). The experimental design used was randomized blocks in a factorial scheme (3x4) with four blocks. The plant population used was 330.000 plants ha^{-1}. Five random plants plot, except for grain yield, were evaluated per plot. To evaluate the productive performance the main stem diameter, final plant height, number of branches per plant, number of pods per plant, number of seeds per pod, the weight of a thousand seeds, and yield were measured. Soybean plants better distributed in the cultivation area, in the spacing of 0,17 and 0,30 meters, have higher plant height, stem diameter, and productive performance. The genotypes of soybean performance are influenced by the distribution of plants, and this response depends on the genotype and the production environment.

Keywords: Glycine max; main components; productivity.

Introduction

The expectation of total grain production in Brazil is nearly 250 million tons becomes soybeans responsible for 48% of this production, with national average productivity of 3.269 kg per hectare (Conab, 2020). In the actual conjuncture, soybean is expanding new frontiers and developing new regions, promoting jobs and income. However, in addition to promoting the growth of the cultivated area, it is necessary to develop technologies seeking the best use of resources, raising average productivity, and increasing the farmer's income.

Soybean is a species that presents phenotypic plasticity. Modern cultivars have shown different characteristics of leaf morphology, leaf angle, trifoliate size, plant height, ramifications, and further studies are needed to promote adaptations to different managements (Zanon et al., 2016). Soybean cultivation carried out in the southern region of Rio Grande do Sul is brand new and has been a challenge for technicians and producers in this region because due to the environmental and soil conditions, the culture can respond differently to the practices management practices commonly adopted (Zanon et al., 2015; Marchesan et al., 2017; Gubiani et al., 2018).

In this sense, changes in the way plants are distributed require a management strategy that has shown different results in grain yield according to the year, location, plant genotype, sowing time, and growth habit. and plant population (Balbinot Junior et al., 2015a, 2015b; Jardim Rosa et al., 2016; Carmo et al., 2018). Plants better distributed in the area, cultivated under reduced row spacing, present faster crop canopy closure, better response to fertilization, greater leaf area index, and the best interception of photosynthetically active radiation (Heiffig et al., 2006; Silva et al., 2013; Jardim Rosa et al., 2016). These facts result in increased photosynthetic activity in plant tissues, good vegetative growth, and thus the formation of a more efficient photosynthetic input to be used in the reproductive period to obtain higher grain yields (Matsuo et al., 2017).

The higher photosynthetic input at the beginning of the reproductive period (R1-R2) results in lower floral abortion, promoting a higher number of pods and seeds per plant (Glier et al., 2015). The same authors report that the thousand-seed weight (TSW) is directly related to leaf area and net photosynthesis at the same time as the beginning of grain filling (R5). The number of pods and seeds per plant and the thousand-seed weight (TSW) are the main yield components for the soybean crop and present a direct correlation with grain yield (Dalchiavon and Carvalho, 2012). Therefore, the use of reduced spacing in which there is a better distribution of plants in the area can be a strategy of management practice to be used by farmers to increase their production levels for the soybean crop.

Another aspect to be considered is that due to the rapid closing of the canopy, the leaves of the lower third are shading early, and the influx of CO_2 and the stomatal conductance of the shaded leaves may be lower due to poor light conditions, significantly reducing the photo assimilation rate and, possibly, crop productivity (Fioreze et al., 2013). However, Matsuo et al. (2017) reducing the spacing from 0.70 m to 0.35 m between rows under the same plant population in the area and obtained a gain of 420 kg ha^{-1} of soybean grains. Therefore, this study aims to evaluate the effect of plant distribution in the field on the productive performance of soybean genotypes in the southern region of Rio Grande do Sul.

Results and discussion

Exploratory analysis for the effect of row spacing

According to the data collected on plant growth (Table 1, Figure 2), a significant effect of row spacing is verified for plant height, stem diameter, and the number of branches in at least one of the three genotypes used in the present study, in the two agricultural seasons. The number of the branches (crop 2016/17) did not show a significant effect on the spacing between lines. In this sense, in the 2015/16 crop, the plants originated by NS 5959 IPRO genotype stood out with plant height and stem diameter, on average, 8% greater, and, in general, 40% less branching in the different spacings studied (Table 1). The genotype NA 5909 RR showed an intermediate plant height, stem diameter 6% smaller than the average of the other genotypes, and the number of branches per plant like the cultivar NS 6006 IPRO. The NS 6006 IPRO genotype presented plant height like the NA 5909 RR and, approximately 8% smaller than the NS 5959 IPRO, and intermediate stem diameter.

Compared to similar models given in the 2016/17 harvest (Table 1), in general, all the models presented plants and stem diameter, except for the NS 6006 IPRO, which, within 0.17 m, performed worse than the other genotypes for the two variables.

Relative contribution of the variables and genotype

Regarding the number of branches, it is possible to observe that the genotype NA 5909 RR, regardless of the spacing between the lines, presents superior branching capacity and better use of what is available for its growth, thus repeating the results obtained in the 2015/16 harvest. On other hand, we verified that in variable values such as plant height and stem diameter variables, the absolute genotype IPRO showed an average, harvesting the results obtained, 2015/16. Possibly, in the crop of the study, significant differences were not observed soon after the sowing of the crop in the field or there was a long period without significantly expressive, causing a delay in the emergence of the plants, changing the period of the vegetative stage, a period in which the plants show higher growth rates. Therefore, different gen plants cannot express their differentiation potential due to late emergence (Zan et al., 2015; Carmo et al.).

Under conditions of reduced spacing, plants present faster closing between the sowing row, higher interception of early solar radiation, greater leaf area index, and, consequently, a higher rate of vegetative growth (Heiffeg et al., 2006; Matsuo et al., 2017). It is also worth noting that it is not only aerial development that is superior plant roots also have higher growth rates (Matsuo et al., 2017). However, depending on the genotype and cultivation environment different responses can be observed (Jardim Rosa et al., 2016). In the 2016/17 crop, only the effect of spacing on plant height was observed for the NA 5909 RR genotype and stem diameter for the NS 6006 IPRO genotype due to the short period of the vegetative growth stage, which limits the expression of the potential maximum, like what happened with the differences between the genotypes already explained above for the variable tables (Table 1).

For the number of branches per plant, considering the two seasons studied, only the effect of the spacing between lines in the 2015/16 season was observed for the genotype NA 5909 RR, which has a greater capacity for branching as an intrinsic characteristic, as can be seen in Table 1. The number of branches per plant is influenced by row spacing. However, other factors can affect this plant's response to spacing, such as sowing time, plant population, and genotype (Balbinot Junior et al., 2015a; Jardim Rosa et al., 2016).

In conditions of greater spacing between rows, there is a better interception of sunlight with superior quality by the side of the plant that stimulates the ramification in the direction perpendicular to the cultivation row. However, depending on environmental conditions, for example, lower radiation in sunlight, luminosity can be a limiting factor for lateral branching, thus presenting plants grown in different arrays with the same number of branches (Luca & Hungria, 2014; Balbinot Junior et al., 2015a). Other factor that can limit the branching of plants is their genotype. Some genotypes may have a genetic control for non-branching.

The high plant population used in this study which can be a limiting factor for plants not responding to changes in-row spacing (Procópio et al., 2014; Modolo et al., 2016). Regarding the spacing between the sowing lines, in the 2015/16 season, we verified that the spacing between the sowing lines increased, and the plants of all genotypes showed a linear tendency to reduce their height (Figure 2A). Analyzing the stem diameter (Figure 2C), we have seen a quadratic trend, where the plants reached the biggest stem diameter in the spacing of 0.30 m.

In the 2016/17 season, the height of plants (Figure 2B for 51) showed a linear trend of reduction of the space between the sowing lines only for the RR, an increase, and a quadratic trend for the diameter (Figure 2D) of the genotype NS 6006 IPRO, reaching maximum performance at 0.45 m spacing. Therefore, they are reduced-growing plants like tall-growing growing plants and more growing plants, tall-growing, and growing, larger plants, tall-growing, and growing plants. These results corroborate those found by Matsuo et al. (2017). However, due to the greater intraspecific competition of plants in the row at greater spacing, the greater height of plants in the spacing may occur (Jardim Rosa et al., 2016). These results show that environmental and management conditions can change the response of genotypes to distribution among plants in the field.

The productive performance of soybean genotypes in the 2015/16 harvest is a result of data on plant height and stem diameter in the same harvest (Tables 1 and 2). The NS 5959

IPRO genotype presented, in general, a few pods per plant 17.6% higher than the NS 6006 IPRO and similar to the NA 5909 RG, seeds per pod 5% higher than the NA 5909 RG and similar to the NS 6006 IPRO, and thousand-seed weight 7.3 and 26% higher than the NS 6006 IPRO and NA 5909 RG genotypes, respectively. These results promoted superior productivity of the NS 5959 IPRO genotype in 24.0% and 46.9% in relation to the NS 6006 IPRO and NA 5909 RG genotypes, respectively. The NS 6006 IPRO genotype showed a productive advantage of 18.5% in relation to the NA 5909 RG genotype (Table 2).

In the 2016/17 season, there are no differences between the genotypes studied, considering the number of pods per plant and the number of seeds per pod. Just the NS 6006 IPRO genotype had the lowest number of pods in the 0.17 m spacing (Table 2). These yield components are directly related to the photosynthetic apparatus and to momentary photosynthesis in the stages from the beginning of flowering (R1) to pod formation (R4) (Glier et al., 2015). These results demonstrate that a short period of vegetative growth, due to late emergence, does not allow the formation of the photosynthetic apparatus suitable for the expression of all the productive potential of the genotypes studied. This effect is responsible by promote the differences between genotypes to be minimized. The number of seeds per pod, in isolation, is a yield component that does not present a significant correlation with soybean grain yield (Dalchiavon and Carvalho, 2012).

Regarding the thousand-seeds weight (Table 2), it is possible to observe that, in general, the NS 5959 IPRO genotype was 11.0% higher than the NA 5909 RG genotype and 1.9% compared to the NS 6006 IPRO genotype, which in turn had a thousand-seeds weight 8.9% higher than the NA 5909 RG. Regarding the difference, in percentage, of the thousand-seeds weight between the genotypes, in the two seasons studied, it was possible to observe that the effects were attenuated, reinforcing the theory of the environmental effects, due to late emergence, on the responses of cultivars to production factors under study.

The grain yield of the different genotypes (Table 2) is related to the growth and formation of yield components during the production cycle. In the 2016/17 season, due to environmental conditions and other biotic factors such as abiotic and considering that the performance of the crop in the field is dependent on the genotype X environment interaction, the genotypes that showed the highest productivity were the NS 5959 IPRO and the NA 5909 RR genotype, surpassing the productivity of the NS 6006 IPRO genotype. The productivity of soybean genotype results of the interaction of several biotic and abiotic factors that occur throughout the crop cycle, which can influence the formation of yield components and, consequently, grain yield (Dalchiavon and Carvalho, 2012).

When the spacing between the sowing lines increased, there was a reduction in the crop yield components affecting the grain yield, and it happens in both seasons, except for the number of seeds per pod (Figure 3). The number of seeds per pod (Figure 3C and 3D) is a yield component that suffers minor influence from the management practices adopted with the distribution of plants in the area, changes in grain yield are often mainly due to the variations that occur in the number of pods per plant (Balbinot Junior et al., 2015a).

The number of pods per plant showed, in the 2015/16 season (Figure 3A) for all genotypes, a quadratic trend of response to the increase in the spacing between rows, presenting a maximum performance in the spacing of 0.30 m with a significant reduction in the subsequent spacing. The spacing of 0.30 m showed a 33.7% higher number of pods than the biggest spacing studied.

The 2016/17 harvest (Figure 3B) shows the genotypes with different behaviors. The genotype NA 5909 RR showed a linear trend of reduction as the spacing between sowing lines increased the value of the smallest spacing studied (0 .17 m), with the number of pods 26.5% higher than the biggest spacing studied (0.60 m). The genotype NS 6006 IPRO showed a trend of quadratic response with a maximum point in the spacing of 0.45 m, presenting the number of pods as 2.1% higher than the biggest spacing studied.

The NS 5959 IPRO genotype did not show the effect on the different spacings studied. In this sense, it is worth noting that all genotypes in both seasons of the study, except for only NS 5959 IPRO in the second season, showed a tendency to reduce the number of pods per plant as the spacing increased. These results as the number of pods per plant defined in the period between flowering and the complete formation of pods, in which plants with high photosynthetic input and consequently high absorption of carbon dioxide present a g setting and conception of pods (Glier et al., 2015). In this sense, soybean plants grown under reduced row spacing have a higher leaf area index in the full flowering (R2) and beginning of grain filling (R5) stages, resulting in the setting of a higher number of pods, which can cause reflections on the grain yield (Matsuo et al., 2017).

For the thousand-seed weight, we checked that in the Season 2015/16 (Figure 3E), only the NS 6006 IPRO genotype showed a significant effect in the different spacings, with a linear reduction of the seed mass as the spacing between rows increased. In the spacing of 0.17 m, the mentioned genotype presented the thousand-seeds weight 1.4% higher than the spacing of 0.60 m. The other genotypes showed no influence of row spacing on the accumulation of photo assimilates in grains.

In the 2016/17 season (Figure 3F), for the thousand-seeds weight, the effect of the different spacings between rows studied was more evident, where all genotypes responded in a quadratic way as the spacing between the sowing rows increased. For genotypes NS 5959 IPRO and NA 5909 RG, the threshold reached the spacing of 0.45 m. The genotype NS 6006 IPRO has a higher point reached in the spacing of 0.30 m. The average difference of the three genotypes between the maximum thousand-seed weight and the dots of lowest thousand- seeds weight (0.17 m) corresponds to 5.4%.

Thus, adding the effects on crop components yield, the spacing between crop lines shows an effect on soybean grain yield in the two seasons studied for all cultivars (Figures 3G and 3H). In the 2015/16 crop (Figure 3G), it can verify that as the spacing between rows increased, within the studied interval, there was a quadratic reduction in the crop yield of the three genotypes under study, with a maximum spacing of 0.17 m. In 2015/16, the spacing of 0.17 m showed productivity of 4.6% higher than the spacing of 0.60 m, which corresponds to an increase of, on average, 3.2 bags per hectare under the conditions of the present study.

For the 2016/17 crop (Figure 3H), a quadratic response behavior to the increase in row spacing we verify, reaching a maximum at 0.30 meters spacing for the three genotypes under study. In the 0.30 m spacing, the average yield of the three genotypes was 23.4% higher than the 0.60 m spacing. In the 2016/17 crop (Figure 3H), a high distinction between the productivity averages of each spacing compared to the

Table 1. Plant height, stem diameter and number of branches per plant of three soybean genotypes cultivated under different row spacing in two agricultural seasons, Pelotas-RS, 2020.

E. L. (m)	Genotypes					
	A	B	C	A	B	C
Plant height (cm)						
	Season 2015/16			Season 2016/17		
0,17	106.8	100.2	100.3	84.4 a	74.5 b	85.7 a
0,30	101.0	94.2	93.6	81.5 a	87.7 a	88.6 a
0,45	97.7	85.0	93.4	82.2 a	77.0 a	81.2 a
0,60	95.8	88.4	88.2	82.5 a	76.3 a	78.3 a
Média	100.3 a	91.9 b	93.9 ab	82.6	78.9	83.4
C.V. (%)	8.0			5.7		
Stem diameter (mm)						
	Season 2015/16			Season 2016/17		
0,17	8.2	7.7	7.5	6.1 a	4.5 b	6,.1 a
0,30	8.1	8.3	7.5	5.6 a	5.6 a	5.5 a
0,45	8.3	7.6	7.6	6.0 a	5.7 a	5.5 a
0,60	7.6	6.9	7.0	5.5 a	5.5 a	5.6 a
Média	8.1 a	7.6 ab	7.4 b	5.8	5.3	5.7
C.V. (%)	7.3			9.2		
Number of branches						
	Season 2015/16			Season 2016/17		
0,17	2.9 a	3.8 a	4.2 a	2.9	3.2	5.5
0,30	1.8 b	5.2 a	5.3 a	2.4	4.0	5.0
0,45	3.3 b	4.2 ab	5.6 a	1.7	3.1	5.0
0,60	2.6 b	3.6 b	5.4 a	3.3	3.8	6.0
Means	2.6	4.2	5.1	2.6 c	3.5 b	5.3 a
C.V. (%)	21.1			25.0		

*Means followed by the same lowercase letter on the line, within each crop studied, do not differ by Tukey's test at 5% error probability. (A - NS 5959 IPRO; B - NS 6006 IPRO; C - NA 5909 RR; E.L. - line spacing; C.V. - coefficient of variation).

Table 2. Number of pods and seeds per plant, mass of a thousand seeds and productivity of three soybean genotypes cultivated under different spacing between rows in two agricultural crops, Pelotas-RS, 2020.

E. L. (m)	Genotypes					
	A	B	C	A	B	C
Number of pods per Plant						
	Season 2015/16			Season 2016/17		
0.17	48.3	41.9	47.0	43.5 a	29.6 b	45.8 a
0.30	54.0	49.2	45.5	40.4 a	36.6 a	39.3 a
0.45	50.7	39.6	48.1	38.1 a	38.5 a	39.5 a
0.60	39.9	33.4	37.9	37.1 a	37.7 a	36.2 a
Means	48.2 a	41.0 b	44.6 ab	39,8	35,6	40,2
C.V. (%)	13.8			10.2		
Number of seeds per pod						
	Season 2015/16			Season 2016/17		
0.17	2.08	2.05	1.93	2.55^{ns}	2.57	2.38
0.30	1.99	2.16	2.04	2.49	2.61	2.33
0.45	2.09	2.17	2.09	2.51	2.48	2.38
0.60	2.27	2.09	1.97	2.53	2.52	2.60
Means	2.11 ab	2.12 a	2.01 b	2.42	2.52	2.54
C.V. (%)	5.9			5.9		
Thousand-seeds weight (g)						
	Season 2015/16			Season 2016/17		
0,17	160.268 a	154.238 a	129.597 b	165,313 a	163,945 a	150,553 b
0,30	162.682 a	153.277 b	134.680 c	171,542 a	171,394 a	153,699 b
0,45	169.303 a	152.102 b	129.625 c	175,650 a	170,569 b	158,869 c
0,60	164.010 a	152.133 b	126.954 c	174,954 a	168,584 b	156,125 c
Means	164.066	152.937	130.214	171,865	168,623	154,811
C.V. (%)	2.7			1.1		
Productivity (kg ha^{-1})						
	Season 2015/17			Season 2016/17		
0.17	5347	4395	3430	4660	4202	4996
0.30	5022	4610	3539	5541	5186	4954
0.45	4828	4077	3812	4764	4252	4951
0.60	5571	3666	3357	4182	4134	4386
Means	5192 a	4187 b	3534 c	4787 ab	4444 b	4822 a
C.V. (%)	14.9			9.1		

*Averages followed by the same lowercase letter on the line, within each crop studied, do not differ by Tukey's test at 5% error probability. (A - NS 5959 IPRO; B - NS 6006 IPRO; C - NA 5909 RR; E.L. - line spacing; C.V. - coefficient of variation).

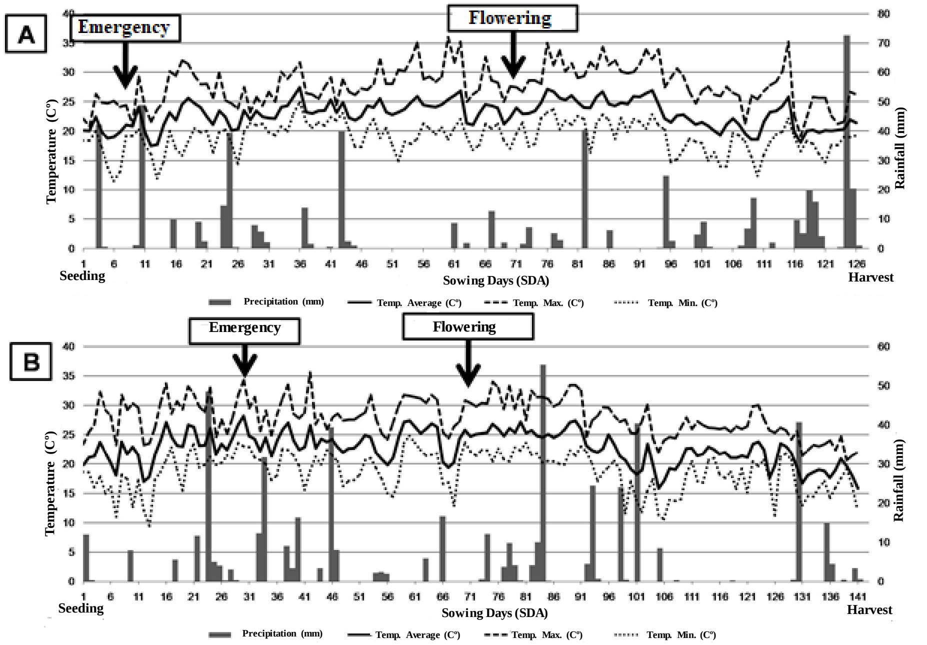

Fig 1. Maximum temperature (Max Temp), minimum temperature (Min Temp), average temperature (Average Temp of the years) and Average temperature during the B. 2016/2017 harvest period, Pelotas – RS. Source: Pelotas Agroclimatological Station (EMBRAPA/UFPel).

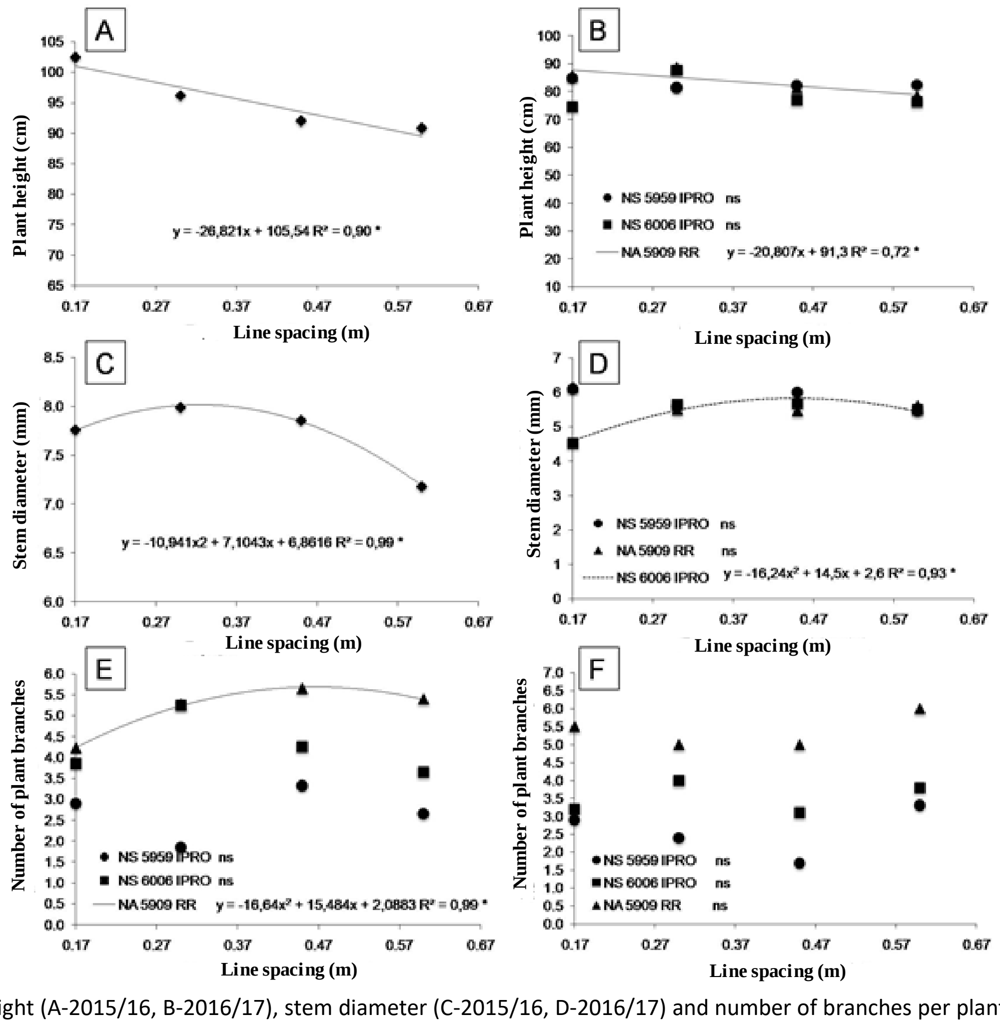

Fig 2. Plant height (A-2015/16, B-2016/17), stem diameter (C-2015/16, D-2016/17) and number of branches per plant (E-2015/16, F -2016/17) of three soybean genotypes cultivated under different spacing between rows in two agricultural seasons, Pelotas-RS, 2020. ns – not significant * significant at 5% probability.

2015/16 crop (Figure 3G). This result is the opposite of expected, due to the short time of vegetative development in the 2016/17 crop. However, it is worth mentioning the frequent occurrence of rain this time before the harvest in the crop 2015/16, as can be seen in Figure 1A, which may have caused the loss of seed mass, comparing the thousand-seeds weight of different harvests (Table 2).

When reduced row spacing is used, there is a better distribution of plants in the cultivation area, which can promote better use of the environmental resources available for plant development, resulting in greater crop productivity (Balbinot Junior et al., 2015a; Jardim Rosa et al., 2016; Matsuo et al., 2017; Vitorino et al., 2017). The plants cultivated in the reduced spacings presented a better performance in the yield components, and the number of pods per plant, as well as the mass of a thousand seeds and, finally, the grain yield, are strongly influenced by net photosynthesis in the period between from flowering to the end of grain filling (Glier et. al, 2015). Soybean plants grown in reduced spacing have higher interception of photosynthetically active solar radiation during their production cycle, resulting in high pod set, accumulation of photo assimilates in the grains, and productivity (Silva et al., 2013).

The superior performance of plants in reduced spacing is built throughout the soybean crop cycle, resulting in plants with higher productivity. However, it is worth noting that the environmental conditions are crucial for the plants to express their full productive potential and effectively present the response to the changes performed in their management. The use of reduced spacing in the soybean crop, providing a better arrangement between the plants in the field, is a promising management practice. However, the development of new technologies aimed at this management condition is essential, i.e., finding genotypes more adapted to each situation. (Matsuo et al., 2017).

Materials and methods

Plant material and experimental setup and conditions

This study was performed with the Graduate Program in Science and Technology of Seeds of the Faculty of Agronomy Eliseu Maciel (FAEM) belonging to the Federal University of Pelotas (UFPel). The experiment was carried out in the field, in two agricultural seasons (2015/16 harvest and 2016/17 harvest), on a farm located in the District of Monte Bonito - Pelotas (RS-Brazil), in eutrophic haplic planosol soil, with geographic coordinates 31° 40' 27" S and 52°23' 28"W.

Climatic data monitoring

The daily climatic data of precipitation and maximum, average and minimum daily temperature, referring to the duration of the tests, were collected at the EMBRAPA/UFPEL meteorological station, located close to the experiment site with the geographic coordinates 31º 52' 00'' S and 52°23'28"W, and are illustrated in Figure 1.

Experimental design and treatments

The experiment consisted of twelve treatments involving two factors: factor A - 3 soybean genotypes (NA 5909 RR (super early, growth indeterminate and maturation group A), NS 6006 IPRO (high grain weight, growth indeterminate and maturation group B 5.9), and NS 5959 IPRO (precocity, indeterminate growth and maturation group C) and factor B - 4 spacing between lines (0.17; 0.30; 0.45 and 0.60 meters).

The experimental design adopted was randomized blocks in a 3x4 factorial scheme with four blocks. Each plot has a dimension of 2.4 meters wide and 4 meters long. for the evaluations, 0.6 meters were discarded on each side of the plot and 0.5 meters on each end to serve as a border.

The soil was prepared with one plowing and two harrowings, to reduce the presence of clods and impediments to the emergence of seedlings. Before sowing, soil sampling was carried out in the test area to be sent to a soil analysis laboratory. With the data from the soil analysis, fertilization was carried out according to the recommendations of the CFQS RS/SC (Commission of Fertility and Soil Chemistry – RS/SC, 2016) for the soybean crop, incorporating the nutrients into the soil at the time of sowing.

Practices to control pests and cultural management were made according to the soybean recommendations. The plant population used for the experiment was 330 thousand plants per hectare, thus seeking to meet the list of recommendations for the plant population of all genotypes under study. Sowing was performed manually and in furrows on December 4, 2015, and December 9, 2016, at a sowing density of 50 seeds per meter. Subsequently, plants are thinning, adjusting the spacing between plants in the row according to the spacing between the rows of each plot, maintaining the same plant population per area.

Measurements of plant characteristics

For the experimental determinations, five random plants from the area of each plot were evaluated, except for grain yield, which was evaluated as the total area of each portion, when plants reached the R8 stage on the scale of Fehr & Cavinees (1977). The experimental determinations were the diameter of the main stem, final plant height, number of branches per plant, number of pods per plant, number of seeds per pod, the thousand-seeds weight, and productivity.

The number of pods per plant was determined through the direct count of pods in the five plants evaluated. The results expressed the number of pods per plant (average of the five plants). The average number of seeds per pod was obtained by directly counting the seeds in the five plants evaluated and divided by the total number of pods. The results were expressed as seeds per pod (average of the five plants). The thousand-seed weight was determined by weighing eight subsamples of one hundred seeds collected in the area per plot, with the average value expressed in grams.

Statistical analysis

After data collection, the assumptions of analysis of variance were performed. Once these were met, the data were submitted for analysis of variance, and when the significance level by the F test at 5% probability, the qualitative factor (genotype) was submitted to Tukey's average comparison test at 5% probability. For the quantitative factor (spacing) polynomial regression analysis was performed at 5% probability. Statistical analyzes were performed using the R software (R Core Team, 2014).

Conclusions

The use of reduced spacings of 0.17 and 0.30 meters for soybean cultivation provides plants with high height and stem diameter without promoting changes in the number of branches, and these results are dependent on the environmental conditions of cultivation and genotype.

Soybean plants grown under reduced spacing of 0.17 and 0.30 meters present superior productive performance, and their response is dependent on the production environment.

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