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RESEARCH ARTICLE

PLASTOCHRON IN SOYBEAN CULTIVARS UNDER THE SPACE ARRANGEMENTS

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ABSTRACT

The plastochron is an important parameter in the use of agricultural modeling for annual crops. The objective of this study was to determine the plastochron soybean cultivars in different spatial arrangements. Two experiments were conducted in the field, one in the crop year 2012/2013 and other 2013/2014. The cultivars used were BMX Ativa RR, BMX Turbo RR e BMX Potência RR and spatial arrangements 45, crossed, 20, 20x40, 20x60, 20x80 cm, with three replications. The center row of each plot after emergence marked up five plants, and in these counted the number of visible nodes on the main stem twice a week, emergency until the issuance of the last node, determining also, its phenological stage. The plastochron ranged from 57.27 to 77.19 °C day node-1 among cultivars in two years. The first crop year 2012/2013 showed meaningful differences for all cultivars. In the second crop year (2013/2014), only 20x40 and 20x60 cm there are no meaningful difference between cultivars. In this cultivation, there was the inverse of the previous year, compared to the cultivars, beyond the differences are not as meaningful as in the previous year. In conclusion, the plastochron varies with cultivars, spatial arrangements and crop years. It is suggested to further study with new soybean cultivars in different arrangements, so that you can use this data in agricultural modeling.

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INTRODUCTION

The soybean cultivation *(Glycine max (L.)* Merrill) is influenced by climatic factors of temperature, photoperiod and water availability. Most cultivars adapted to regions where the temperatures range between 20 and 30 °C, the optimum temperature for development of about 30 °C (Setiyono *et al.,* 2007). To characterize the development of plant species, the most suitable time unit is the thermal time (°C day) (Streck *et al.,* 2005). This time unit is the one that best describes the development of the plants, because for each plant species reaches a certain stage of development, requires a certain thermal time above the base temperature below which the plant does not develop, or is so slow it can be neglected (Kantolic, 2008). Thus, by the thermal time and the total number of nodes on the main stem of the plant, it is possible to calculate an important indicator of the cultures, the plastochron, defined by the time between the appearance of two successive nodes in the plant (Martins *et al.,* 2011; Streck *et al.,* 2008).

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The cultivar and the time of soybean planting, and water and thermal conditions of the crop year, alter plastochron (Martins *et al.,* 2011; Streck *et al.,* 2008). Conditions of development of culture, including changes in management, modify the response of plants to various environmental factors. Among these, the plant arrangement, by changing the spacing between rows and culture density (Rambo *et al.,* 2003). The plastochron is important for the agricultural modeling of cultures, but there are few studies that characterize it, therefore, of great importance their study associated the new soybean cultivars and different managements currently employed in the culture. This study aimed to determine the plastochron soybean cultivars in different spatial arrangements.

MATERIALS AND METHODS

Study local

Two field experiments were conducted in Frederico Westphalen/RS (27° 23' 48" S, 53° 25' 45" O, 490m altitude), one in the crop year 2012/2013 and another in 2013/2014. The soil of the area belongs to the mapping unit Passo Fundo,

classified as dystrophic Red Latosol typical, clayey texture, deep and well drained (EMBRAPA, 2006), and the climate is Cfa by the Köppen climate classification.

Growing conditions

The experimental design was a randomized block in factorial 3x6, being three soybean cultivars (BMX Ativa RR, BMX Turbo RR and BMX Potência RR) and six spatial arrangements (45, crossed, 20, and paired rows of 20x40, 20x60 and 20x80 cm), with three replications. Seeding was carried out manually in the days 28/11/2012 and 12/02/2013, with based fertilizer according to the recommendation of the Commission of chemistry and soil fertility (CQFS, 2004), of 28 kg ha^{-1} N, 168 kg ha^{-1} of P2O5 and 126 kg ha^{-1} K2O. It is considered as an emergency when 50% of the seedlings had emerged, an average of eight days after seeding, and thinning in the two years was performed seven days after the emergency to a density of 250,000 plants ha^{-1}, for all treatments. The management to control pests, diseases and weeds was carried out according to the recommendations for soybean (RPSRS, 2012). The plots consisted of three meters in length and width varied according to the arrangement, five rows in the arrangements 45 and crossed, ten rows in spaced 20, five rows paired in 20x40, 20x60, 20x80 cm totaling width of 2.25; 2.25; two; 2.6; 3.4 and 4.2 m respectively.

Determination of plastochron

The center row of each plot after emergence, marked up five plants and in these counted the number of visible nodes on the main stem twice a week, emergency until the issuance of the last node, determining also its phenological stage according to scale of Fehr e Caviness (1977). A node was considered visible when leaf associated to it was with edges of at least one leaf blade unrolled and not touching (Johnson, 1997).

Meteorological data

Throughout the period of f culture development, in two years, we collected data from meteorological elements, air temperature and rainfall obtained in Automatic station belonging to the INMET (National Meteorological Institute). The daily thermal time (STd, °C day) were calculated from the emergency, second to Gilmore and Rogers (1958) according to Eq. 1.

$$STd=(Tmed-Tb).1dia \quad \ldots\ldots (1)$$

being:

Tmed - is the average air temperature calculated by the average between the maximum and minimum temperatures of the air of each day

Tb - is the base temperature and to soybean considered 10°C (Piper *et al.,* 1996)

The accumulated thermal time (STa, °C dia) was calculated by Eq. 2.

$$STa=\sum STd \quad \ldots\ldots (2)$$

sendo:

STd = daily thermal time, °C day

Method validation

The relationship between the number of nodes and the accumulated thermal time (Figure 1), indicates the air temperature as an important environmental factor influencing the development of the plant and consequently the emission of nodes, so demonstrating that the estimated plastochron by the method linear regression is appropriate (Sinclar *et al.,* 2005; Streck *et al.,* 2005).

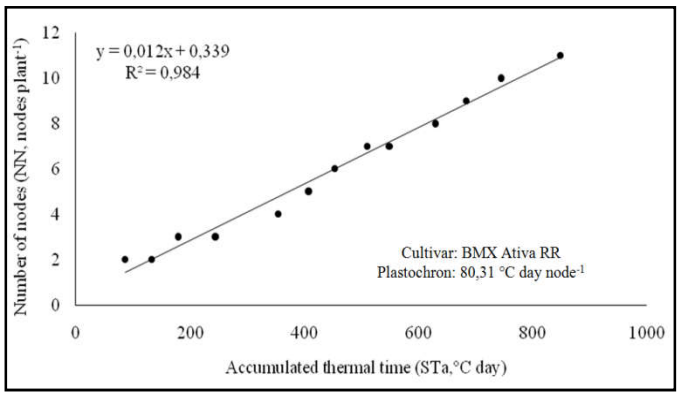

Figure 1. Number of nodes accumulated in the main stem of soybean (NN) and accumulated thermal time (STa°C day), used for calculating the plastochron in a plant within a repetition (five plants) cultivar BMX Ativa RR, the space arrangement of 45 cm in the year 2013/2014. Frederico Westphalen, RS. 2016

Annual meteorological conditions

The average air temperature was similar in the two years with mean values near 25 °C (Figure 2). These were within the great range for the development of soybean ranging from 20 to 33 °C (Setiyono *et al.,* 2007) according to the phenological stage. The month of February both in 2012/2013 as in 2013/2014 had the highest maximum temperature of 35.9 and 36.7 °C, respectively, exceeding the great range. However, not reaching the maximum cardinal temperature ranging 38-45 ° C, according to the stage (Setiyono *et al.,* 2007), where growth and development are considerably smaller. The precipitations were higher in the cultivation period in the year 2013/2014 than 2012/2013, with 1.262 mm and 1002.2, respectively (Figure 2). However, the distribution was better from December in the first year, in the second year, there was little rainfall in February, with total volume of only 16.2 mm, which may have influenced the development of culture, especially in the pod formation and grain filling.

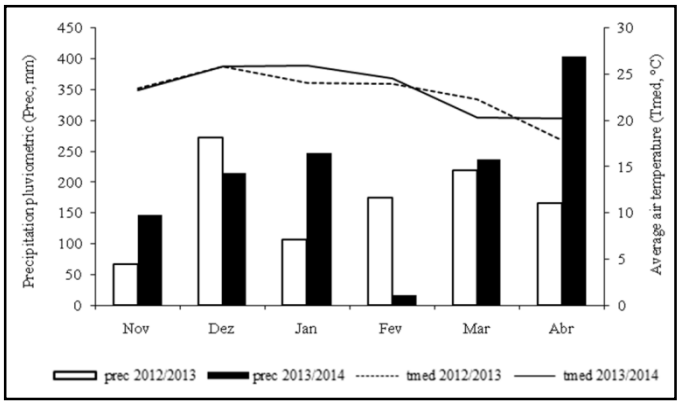

Figure 2. Precipitation pluviometric (Prec) and the average air temperature (Tmed) in crop years 2012/2013 and 2013/2014. Frederico Westphalen, RS. 2016

Statistical analysis

For each selected plant was obtained a linear regression between the number of nodes (NN) on the main stem and the accumulated thermal time (STa), from this, we calculated the plastochron the inverse of the slope of the linear regression. The plastochron values were subjected to Tukey test at 5% probability of error, and to compare space arrangements, was used as arrangement recommended to 45 cm, and this comparison was performed by Dunnett's test 5 % probability.

RESULTS AND DISCUSSION

The plastochron ranged from 57.27 to 77.19 °C day node^{-1} among cultivars in both years (Table 1). The first crop year 2012/2013 showed meaningful differences for all cultivars. In general, BMX Turbo RR was superior in all other space arrangements, only the crossed, which did not differ from BMX Ativa RR. To BMX Potência RR, the plastochron values were lower than the other cultivars in the first year, resulting in accumulation of lower thermal time in relation to others (Table 1). The plastochron of BMX Turbo RR indicates slower growth, because it requires greater accumulation of degree days to issue the next node. To BMX Ativa RR, the plastochron has performed intermediary in relation to the other cultivars in the first year, its time interval between the emission of two nodes did not show up so fast.

Variations of plastochron among cultivars are not related to the cultivar cycle (Streck *et al.,* 2008), which can be observed in this work, as in the first and the second crop year, there were no meaningful differences between the BMX Ativa RR and BMX Potência RR in some space arrangements, which are quite disparate as they have 5.6 maturity groups and 6.7 respectively (BRASMAX, 2014). In the second crop year (2013/2014), only 20x40 and 20x60 cm there was no difference among cultivars. In this cultivation, there was the inverse of the previous year, compared to the cultivars, beyond the differences are not as expressive as in the previous year. BMX Turbo RR presented is less than or equal to the others in all space arrangements, not differing from other cultivars only in 20x40 and 20x60 cm. Already BMX Ativa RR was greater than or equal to BMX Potência RR in arrangements 45, crossed and 20 cm, although they are of different maturity groups, their accumulation degrees day-1 was similar this year. These data corroborate work in the plastochron soybean cultivars also had meaningful differences (Sinclar *et al.,* 2005; Streck *et al.,* 2008; Martins *et al.,* 2011). In space arrangements development different cultivars obtained each year in almost all evaluated arrangements. BMX Ativa RR got the smallest variation between years for all arrangements, with statistical difference only in 20x40 cm. Already BMX Turbo RR was lower in the second year compared to the first. And BMX Potência RR was just the same in crossed arrangements, 20 and 20x80 cm.

Table 1. Plastochron (°C day node^{-1}) of soybean cultivars submitted to different space arrangements (cm) in the crop year 2012/2013 (1st year) and 2013/2014 (2nd year). Frederico Westphalen, RS. 2016

Space arrangements (cm)	Crop Year	Cultivars		
		BMX Ativa RR	BMX Potência RR	BMX Turbo RR
45	1° year	68.48 a B*	63.76 b C	72.57 a A
45	2° year	69.27 a AB	73.10 a A	65.24 b B
Crossed	1° year	73.33 a AB	69.45 a B	73.87 a A
Crossed	2° year	75.82 a A	73.74 a A	68.19 b B
20	1° year	70.44 a B	63.25 a C	77.19 a A
20	2° yaer	70.04 a A	66.60 a AB	64.90 b B
20x40[(1)]	1° year	68.52 a B	65.23 a B	75.18 a A
20x40	2° year	57.27 b A	60.84 b A	60.76 b A
20x60	1° year	63.16 a C	67.32 a B	73.83 a A
20x60	2° year	64.34 a A	62.43 b A	62.44 b A
20x80	1° year	65.79 a B	60.52 a C	73.67 a A
20x80	2° year	67.77 a A	62.06 a B	64.39 b AB

*Lowercase letters compare the column, and uppercase on the line. Means followed by the same letter do not differ by Tukey test at 0.05 error probability.
[1]Paired rows spacing of 20 cm, separated by 40 cm spacing. CV: 8, 77%

Table 2. Plastochron (°C day node^{-1}) of soybean cultivars submitted to different space arrangements compared to recommended space (45 cm) in the crop year 2012/2013 (1st year) and 2013/2014 (2nd year). Frederico Westphalen, RS. 2016

Crop Year	Space arrangements (cm)	Cultivars		
		BMX Ativa RR	BMX Potência RR	BMX Turbo RR
1° Year	45	68.48	63.76	72.57
	crossed	73.33	69.45 +	73.87
	20	70.44	63.25	77.19
	20x40	68.52	65.23	75.18
	20x60	63.16	67.32	73.83
	20x80	65.79	60.52	73.67
	Média	68.23	64.79	74.38
	CV (%)	9.96	6.52	7.03
2° Year	45	69.27	73.11	65.24
	crossed	75.82	73.74	68.19
	20	70.04	66.60 -	64.9
	20x40	57.27 -	60.84 -	60.76
	20x60	64.34	62.43 -	62.44
	20x80	67.77	62.06 -	64.39
	Média	67.42	66.46	64.32
	CV (%)	10.79	8.35	8.59

[+]Higher meaningful difference to the recommended arrangement (45 cm). [-]Meaningful difference lower than the recommended arrangement (45 cm) by Dunnett test 0.05 error probability.

In the crop year 2013/2014, there was an irregular distribution of rainfall, especially with a volume of very low rainfall in February, this time that BMX Turbo RR and BMX Potência RR were still in development, flowering and some plants grain filling. This irregular distribution, associated with the higher temperatures compared to the previous year, affected the development of culture, example of BMX Turbo RR accelerated its development by reducing the thermal time required to issue the next node. When comparing the space arrangements relative to the recommended arrangement, most used (45 cm) (Table 2), there is differentiated response of cultivars each year. BMX Ativa RR did not differ in relation to the arrangements in the first year, already in the second year the arrangement of 20x40 cm made up less than 45 cm. BMX Potência RR was higher in the first year only in the cross arrangement, in the second year the arrangements 20, 20x40, 20x60 and 20x80 cm showed inferiority to plastochron arrangement of 45 cm, showing that the average temperature higher this year associated with irregular rainfall, raised the plastochron values at 45 cm and crossed, but the arrangement of plants in the arrangements of 20, 20x40, 20x60 and 20x80 cm caused the plastochron was smaller. BMX Turbo RR did not differ with respect to the arrangement of 45 cm in any year, although it obtained a large difference in average plastochron, in the first year 74.38 °C day node^{-1} and in the second year 64.32 °C day node^{-1}.

The study of different space arrangements must take into account the changes in the growth and development of cultivations. One of the main benefits of reducing spacing on soybean in the same population, is the best distribution of plants in the area, resulting in a faster siol shading, making occurs a better use of water and also greater and faster interception of solar radiation (Rambo *et al.,* 2004; Heiffig *et al.,* 2006), as well as studies showing a higher grain yield due to the increased number of pods per m^2 (Parcianello *et al.,* 2004). However, the advancement of *Phakopsora pachyhizi* disease, made the studies to turn to the influence of the space arrangements on the progress of the disease. According Madalosso *et al.,* (2010) the reducing the spacing between rows allowed better conditions for the establishment and progress epidemic beyond the less effective control, however, the greater spacing of 60 cm in lower values for cumulative disease higher yield.

Currently there was a change in soybean cultivars used in Brazil, passing of determinate habit growth genotypes, medium to late cycle and seeding from mid-November and during December, to genotypes of indeterminate growth, relative maturity group of 5.0 to 6.5, with a concentration of seeding from mid-October and November, and thus allow in some places the second summer crop (Strieder *et al.,* 2013). These changes are worth the importance of studies on the growth and development of new soybean cultivars. Knowledge the required range for the appearance nodes in soybean, is of paramount importance for use in agricultural modeling and adhesion management practices of culture, among which the best spatial arrangement that will promote better development and consequently high productivity. Currently, the recommendation of the components of the spatial arrangement, spacing and density, are already defined by research committees and companies owning cultivars, however, different arrangements, such as those used in the United States should be studied in Brazil, it can be an alternatively to increase the productivity of Brazilian grains. In conclusion, the plastochron varies with cultivars, space arrangements and crop years. It is suggested to further study with new soybean cultivars in different arrangements, so that you can use this data in agricultural modeling.

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