academicJournals

Vol. 13(1), pp. 7-13, 4 January, 2018
DOI: 10.5897/AJAR2017.12717
Article Number: CEA43BE55265
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Sowing seasons × maturity groups on quantitative traits in soybean

Carla Michelle da Silva[1*], Fábio Mielezrski[2], Daniela Vieira Chaves[3], Edivania de Araújo Lima[3], José Hamilton da Costa Filho[4] and Antônio Veimar da Silva[5]

[1]Universidade Federal de Viçosa – UFV, Campus Universitário, Viçosa – MG, Brazil.
[2]Universidade Federal da Paraíba - UFPB, Campus Areia, Areia – PB, Brazil.
[3]Universidade Federal do Piauí – UFPI, Campus Profª Cinobelina Elvas, Bom Jesus – PI, Brazil.
[4]Universidade Federal do Rio Grande do Norte – UFRN, Campus Universitário Lagoa Nova, Natal – RN, Brazil.
[5]Universidade Estadual do Piauí – UESPI, Picos – PI, Brazil.

Received 7 September, 2017; Accepted 11 October, 2017

The world economic importance of soybean (*Glycine max* (L).) crop is consolidated, and tests to verify the best sowing season for yield gain of cultivars are demanded. The aim of this study is to analyze the effect of sowing season on soybean cultivars of different maturity groups, since the determination of the optimum time for planting soybeans and the cultivar most suited to the region under study can increase yield components and consequently productivity. The experiment was conducted in Currais, State of Piauí, Brazil, and involved evaluation of 12 treatments resulting from the interaction between: 1) sowing seasons: 11/22/2014; 11/29/2014; 12/6/2014; 12/13/2014; 12/20/2014 and 12/27/2014 and 2) two cultivars of maturity groups 8.2 and 8.6. The experiment was a randomized complete block design with four replications, in subdivided plots, and the nested effect in the plot was sowing dates. Data were analyzed using ANOVA and Tukey's test ($p \leq 0.05$). Interaction was significant for number of pods, pod length, dry mass of stem, dry mass of pods and number of grains per plant, but not for productivity and one thousand seed mass. In the agricultural year 2015/2016, the climatic factors worked directly on the components of soybean production, and it is possible to adopt any period of November and December for its planting.

Key words: *Glycine max*, climatic elements, yield components, photoperiod.

INTRODUCTION

Soybean (*Glycine max* (L.)) is one of the most cultivated crops in the world. In Brazil, the cultivated area is 32,092.9 ha, with a productivity of 2,998 kg ha^{-1} and 96,228 tons produced in 2014-2015 (CONAB, 2015).

*Corresponding author. E-mail: veimar26@hotmail.com.

Among the Brazilian states, Piauí stands out for the growing expansion of soybean in the Cerrado area (Alcântara et al., 2012). The planted area, productivity and production are 673,700 ha, 2,722 kg ha^{-1} and 1,833.8 tons, respectively (CONAB, 2015). The Cerrado in the State of Piauí presents Central Brazil Tropical climate which is hot with average above 18°C every month, semi humid with 4 to 5 dry months (EMBRAPA, 2015). It is located in the MATOPIBA region (encompassing the States of Maranhão, Tocantins, Piauí and Bahia) and it stands out in the Brazilian scenario due to its flat topography, deep soils and favorable weather for the cultivation of major crops of grain and fiber (Borghi et al., 2014), which allowed agricultural expansion in this region.

Soybean yield depends on the sowing season, since plant development and production are related to the climatic elements and the different soybean maturity groups (Chen and Wiatrak, 2010; Kapoor et al., 2010). In this sense, it is necessary to determine the best time for planting, so that climatic conditions are favorable for the development of soybean and for a higher production of grains (Alcântara et al., 2012). In the Piauí Cerrado, sowing is traditionally between November 15 and December 15 (Cruz et al., 2010a). Therefore, the objective of this study was to evaluate the effect of sowing time on the yield components of soybean cultivars of different maturity groups produced in Serra do Pirajá, Cerrado microclimate. Since soybean is a crop that depends intrinsically on climatic conditions, sowing time plays a key role in its development and final productivity.

MATERIALS AND METHODS

Location of the experiment and soil analysis

The experiment was conducted in the crop year 2014-2015 at São João Farm, in Currais, State of Piauí (9° 1' 59'' S, 44° 41' 18'' W, and 590 m). Climatic data regarding air temperature, relative humidity (%) and rainfall (mm) were collected daily at the farm's Portable Automatic Weather Station during the study period. The estimated average values that each cultivar received of these elements in different sowing dates, both in the vegetative and reproductive stage, were calculated with Excel® 2010. The chemical properties of the soil were analyzed and fertilization was done according to soil analysis. The concentrations obtained were OM = 12.6 g dm^{-3}; pH $CaCl_2$ = 4.3, P = 8.4 ppm, S = 9.4 ppm, K = 1.2 mmolc dm^{-3}, Ca = 9.7 mmolc dm^{-3}, Mg = 2.3 mmolc dm^{-3}, Al = 3.0 mmolc dm^{-3}, H + Al = 35.4 mmolc dm^{-3}, SB = 13.2, CEC = 48.6 mmolc dm^{-3}, V = 27.1%, m = 6.2%, Cu = 1.6 ppm, Fe = 210.1 ppm, Mn = 2.5 ppm, Zn = 0.4 ppm, total sand = 630 g kg^{-1}, silt = 60 g kg^{-1} and clay= 310 g kg^{-1}.\

Adopted statistic

The experiment was a split plot randomized complete block with four replications. Each plot consisted of 25 m rows 0.5 m apart, and the subplots were 10 rows per cultivar. Seeds were inoculated and treated as follows: 4 doses of inoculant 5×10^9 CFU mL ha^{-1} + 140 mL ha^{-1} Standak Top®.

Sowing season and soybean cultivars

Sowing was done weekly from the onset of rainfall and there were six seasons (S): 11/22, 11/29, 12/06, 12/13, 12/20 and 12/27/2014. The soybean cultivars studied were C1, with a cycle of 110 to 115 days and maturity group 8.6; and C2 with a 100 days cycle and maturity group 8.2. The sowing was manual, 25 seeds m^{-1} and excess seedlings which were later thinned to 14 plants m^{-1} for C1 and 16 plants m^{-1} for C2, with a resultant final population of 300,000 and 330,000 plants ha^{-1}, respectively. The harvest was done manually when the plants reached the phenological stage R9. Pods were collected, stored in plastic bags and taken to the Laboratory of Plant Science of the Piauí Federal University (UFPI), where threshing was done.

Rated characters

Yield components were the following variables: pod length (PL); number of grains per pod (NGPO); number of grains per plant (NGPL); number of pods per plant (NPP); stem dry mass (SDM) and pod dry mass (PDM); mass of one thousand grains (MTG) and productivity (PROD) (Brasil, 2009; Alcântara et al., 2012; Souza et al., 2013). After obtaining data, the Shapiro Wilk test was performed, and next, the analysis of variance was run using the R statistical software. Data corresponding to pod numbers were transformed using the 1/x formula. Next, the significant interaction between season and cultivars was checked at $p \leq 0.05$, afterward, a statistical breakdown of treatments was performed and whenever significant, the comparison between mean values was made by Tukey's test at 5% probability.

RESULTS AND DISCUSSION

The results of the analysis of variance evidenced significant interaction cultivar (C) × sowing season (S) for number of pods per plant, pod length, stem dry mass, pod dry mass and number of grains per plant (Table 1), indicating that climatic elements and maturity group interfered with the development of plants (Chen and Wiatrak, 2010).

The combined effect of C × S was compared to the recommendations of the cultivar with higher average performance of NPP, PL, SDM, PDM and NGPL and the best sowing season, represented by E3 (Table 2).

Unfolding of the interaction C × S

The highest mean number of pods per plant was found in sowing time 1 with C1, while for C2 the highest values were observed in sowing times 3, 4 and 6 (Table 2). This was probably because rainfall was better distributed during the vegetative stage in sowing times 3, 4 and 6

Table 1. Analysis of variance for the number of pods per plant (NPP), pod length (PL), stem dry mass (SDM), pod dry mass (PDM) number of grains per plant (NGPL) number of grains per pod (NGPO), mass of one thousand grains (MTG) and productivity (PROD).

VF	DF	Mean square							
		NPP	PL	SDM	PDM	NGPL	NGP	MTG	PROD
Cult (C)	1	218^{NS}	3.4^{NS}	150**	211*	5874*	0.5^{NS}	1110*	114608^{NS}
Sowing seasons (S)	5	342*	4.1^{NS}	19*	107*	4723*	0.2^{NS}	4478**	36398^{NS}
C × S	5	256*	6.8*	12*	124*	3887*	0.2^{NS}	89^{NS}	138512^{NS}
Error	33	67	2.5	3	41	1184	0.3	79	124526
VC (%)		30.8	3.9	36.39	36	32	21.3	6.59	13.94

^{NS}Non-significant; *p ≤ 0.05, **p ≤ 0.01 (Snedecor's F test). Cultivars (Cult), Sowing seasons (S), Interaction between cultivar and sowing seasons (C x S); Variation coefficient (VC); Degree Freedom (DF). Pod length (PL); number of grains per pod (NGPO); number of grains per plant (NGPL); number of pods per plant (NPP); stem dry mass (SDM) and pod dry mass (PDM); mass of one thousand grains (MTG) and productivity (PROD).

Table 2. Mean values of the interactions for the variables: number of pods per plant (NPP), pod length (PL), stem dry mass (SDM), pod dry mass (PDM), number of grains per plant (NGPL) of the cultivars C1 and C2 in 6 distinct sowing dates.

S	NPP (u)		PL (mm)		SDM (g)	
	C1	C2	C1	C2	C1	C2
1	33.42^{Aa}	$25A^{Ba}$	40.57^{Aa}	41.29^{Aba}	3.56^{Aa}	4.63^{Ba}
2	24.12^{ABa}	26.25^{ABa}	40.682^{Aa}	40.87^{Aba}	2.98^{Aa}	4.39^{Ba}
3	30.49^{ABa}	31.94^{Aa}	39.84^{Ab}	42.83^{Aa}	2.48^{Ab}	7.14^{Ba}
4	28.50^{ABa}	36.00^{Aa}	40.87^{Aa}	42.62^{Aa}	2.20^{Ab}	6.72^{Ba}
5	15.22^{Ba}	13.42^{Ba}	40.65^{Aa}	38.70^{Ba}	4.35^{Aa}	6.57^{Ba}
6	15.02^{Bb}	39.75^{Aa}	40.89^{Aa}	38.38^{Bb}	4.29^{Ab}	11.65^{Aa}
VC (%)	30.84		3.86		36.39	

S	PDM (g)		NGP (u)	
	C1	C2	C1	C2
1	17.97^{Aa}	16.24^{Ba}	85.08^{Aa}	85.08^{Aa}
2	14.08^{Aa}	14.36^{Ba}	69.42^{Aa}	69.42^{Aa}
3	15.25^{Ab}	34.49^{Aa}	89.16^{Ab}	89.16^{Ab}
4	12.88^{Aa}	19.30^{Ba}	87.83^{Aa}	87.83^{Aa}
5	16.97^{Aa}	17.76^{Ba}	124.66^{Aa}	124.66^{Aa}
6	17.19^{Aa}	17.38^{Ba}	125.37^{Aa}	125.37^{Aa}
VC (%)	35.87		31.87	

Uppercase letters: comparisons between sowing seasons; lowercase letters: comparisons between cultivars (Tukey's test; p ≤ 0.05). Sowing (S); Variation coefficient (VC).

(Figure 1). Regarding S1 with C1, these discrepant results could be explained with respect to the cultivar's maturity group because even though it was subjected to water stress, it may have been favored by the rainy season at the defining moments of this variable. Thus, rainfall may have promoted the high number of pods for plants at this date, since the high availability of water increase yield components. Likewise, stress conditions will cause a negative influence on the biological yield of soybeans, by damaging the final production of the plants (Siahbidi et al., 2013). The other climatic elements did not affect the studied variables, since temperatures in the range 20 to 30°C and adequate humidity are critical to the growth and development of soybean (Alcântara et al., 2012; Taiz and Zeiger, 2013; Battisti and Sentelhas, 2014) (Figures 1 and 2).

Sowing season 6 was a conflicting point, which generated good results in C2 (Table 2). It occurred due to

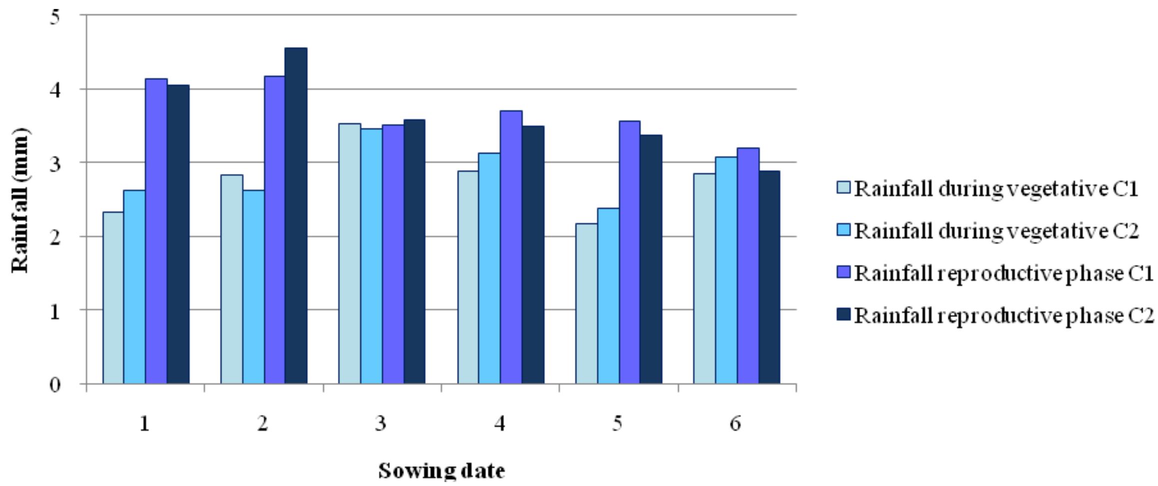

Figure 1. Temporal evolution of average rainfall during the vegetative and reproductive stages of the cultivars C1 and C2 during each sowing season.

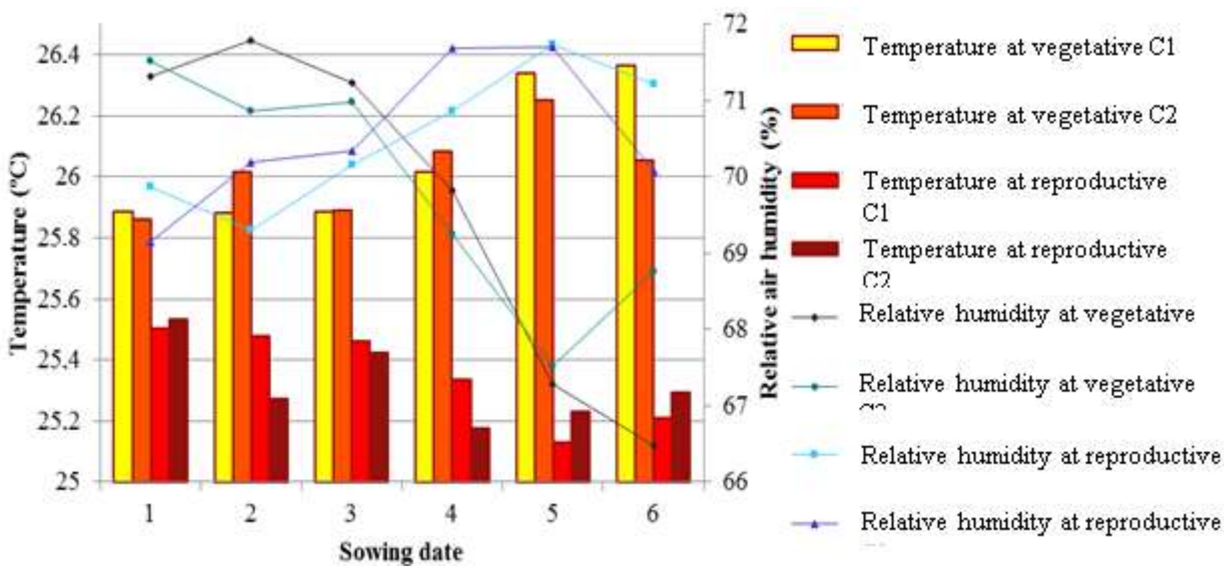

Figure 2. Temporal evolution of average temperature and relative humidity at vegetative and reproductive stages of the cultivars C1 and C2 during each sowing season.

the adequate rainfall during the vegetative stage, causing higher NPP. Although rainfall was less significant than in other dates, there is a possibility that C2 took greater advantages because its maturity group is greater than C1, enabling it to make better use of the water. The difference in duration of the phenological stages between cultivars (maturity group) is a major factor in determining yield components, suffering direct influence on genetic and environmental factors (Chen and Wiatrak, 2010).

In pod length, sowing dates 3 and 4 brought higher averages for C2, matching with NPP, while sowing seasons 5 and 6 had lower PL values. However, sowing season did not have effect on C1 (Table 2). These differences probably occurred due to sowing date to have greater influence on the results than the maturity group (Cruz et al., 2011a). Stem dry matter in S6 had a higher average for C2 (Table 2) than other sowing dates. The plants of that date were larger than the result of well-distributed rainfall during the growth period (Figure 1). This fact is justified because water participates in the physiological processes of the plant, such as cell expansion, favoring stem growth and increasing the dry mass of the plant. Thus, sowing time and maturation cycle affect crop development (Cruz et al., 2010b; Taiz and Zeiger, 2013).

For pod dry mass, S3 had higher values for C2 while other seasons had lower values, the same was observed for C1 (Table 2). This is explained by the balance in water availability, both at vegetative and reproductive stages (Figure 1) since the accumulation of PDM occurs until the beginning of the R6 stage, and thereafter remains unchanged. If the availability of water for the plant is adequate throughout the cycle, the plant will have higher dry mass. Thus, small temporal differences of sowing time and maturity group contributed to this variation on average (Kurihara et al., 2013). For the number of grains per plant, the highest averages were observed in sowing seasons 3, 4 and 6 in C2 (Table 2), similar results for number of pods, because if the plant has a high NPP, it will probably also have a greater NGPL. This can be explained because the yield components (NPP, NGPL) are positive and related with the overall productivity, and reducing these components will cause reduction in grain yield (Kobraei et al., 2011).

Concerning the cultivars, there were significant differences in NPP for S6, where C2 presented higher mean value than C1 (Table 2). Conflicting results were observed in PL, which produced the highest mean for C2 and the lowest for C1 at the same sowing date. However, the results in S3 were the opposite. For SDM, C2 also achieved higher yield than C1, in sowing seasons 3, 4, and 6. C2 also had higher values than C1 in PDM and NGPL at S3. Although both cultivars are early-maturing varieties, the difference of a few days in the sowing date caused different results in yield components. This may have occurred because of different effects of climatic elements on each maturity group (Figures 1 and 2). This difference of days between the two cultivars favored more the maturity group 8.6 than the 8.2, because of rainfall and temperature, since soybean production is largely dependent on these elements (Kirnak et al., 2008; Bellaloui et al., 2011; Khan et al., 2011).

In general, S3 had higher mean values for most variables evaluated for both cultivars studied. As for the cultivars, C2 was statistically superior to C1 in every variable analyzed. However, differences between both seasons and cultivars were found, which supports the hypothesis of the influence of sowing date, due to changes in climatic elements and the length of the crop cycle (Chen and Wiatrak, 2010; Hu and Wiatrak, 2012). Furthermore, climatic elements and the cycle of each cultivar are related to physiological processes of the plants. In this experiment, water was a limiting factor in the production of photosynthates and their translocation in the phloem, restricting better results in yield components (Taiz and Zeiger, 2013).

Source of variation of the mass of one thousand grains (MTG) and productivity (PROD) for the factors cultivars (C) and sowing seasons (S)

The mass of one thousand grains showed no significant interaction between sowing date and cultivars; however, there was statistical difference for the factors separately (Table 1). Hence, ages 1 and 2 had the highest mean value for the mass of a thousand grains, while the lowest MTG values were obtained in sowing seasons 5 and 6 (Figure 3). Regarding cultivars, C2 had a higher mean value in agreement with the other results (NPP, PL, SDM, PDM and NGPL) (Table 2).

The amount of rainfall decreased in the later sowing dates (Figure 1), meaning that the amount of water available in dates 3, 4, 5 and 6 was much lower than that in the first two sowing seasons. The resulting decrease in MTG probably occurred because the plants need greater water accumulation in stages R1 to R7, and yield components are highly affected by periods of water stress, as they are the key elements to raise productivity in the field (Alcântara et al., 2012; Siahbidi et al., 2013).

For productivity, there was no difference between sowing dates and cultivars (Figure 4), meaning that all sowing dates and cultivars produce good results in productivity, that is, sowing may be done from late November to late December, based on the data of the 2014-2015 crop year for these cultivars.

Although sowing seasons 1 and 2 exhibited significantly different mean values for the mass of one thousand grains, the productivity was not different, that is, the results were similar between sowing dates 3, 4, 5 and 6, even with lower MTG values. The greater productivity of sowing dates 3, 4, 5 and 6 is the result of a greater number of grains per plant, despite the lower MTG value.

Interaction effects were verified for the variables NPP, PL, SDM, PDM and NGPL, but not for MTG and PROD (Table 1). This was probably due to the uneven rainfall during the crop cycle in sowing dates, as seen in Figure 1, with a greater accumulation of rainfall in the first three weeks from R1. However, the later sowing seasons benefited from rainfall in the vegetative stage, favoring an increase in dry matter production and contributing with productivity. If the rainfall events had continued well distributed until the end of March, an interaction between MTG and PROD in seasons 3, 4, 5 and 6 could have occurred, because this is the period where weather conditions are best for soybean plants and their development favors a high grain yield (Meotti et al., 2012). Nonetheless, to verify this, further experiments are

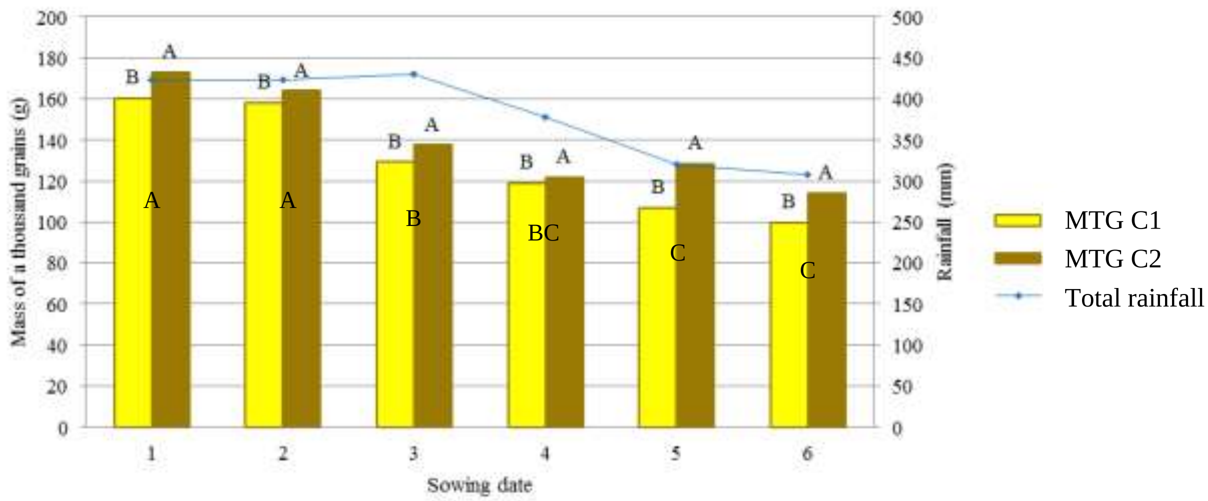

Figure 3. Mass of one thousand grains as a function of sowing season and total rainfall from sowing to harvest. Letters above the columns refer to cultivars, letters in the middle of the column refer to seasons.

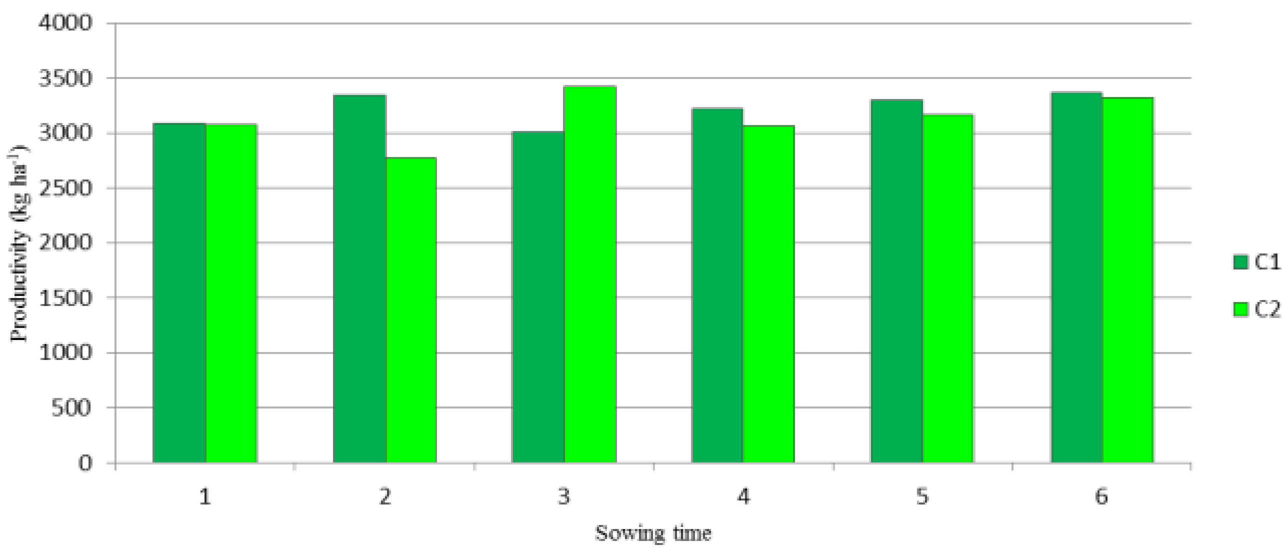

Figure 4. Average productivity for each sowing season for cultivars C1 and C2.

required to evaluate the results with irrigation if the rains ceased before grain filling.

Conclusion

Soybean sowing in the vicinity of Currais, State of Piauí, Cerrado microclimate, can be performed between November 20 and December 27 without changing productivity. Further, climatic elements work directly on yield components and on grain production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Alcântara NF, Petter FA, Pavan BE, Schmitt CR, Almeida FA, Pacheco LP, Piauilino AC (2012). Desempenho agronômico de cultivares de soja em duas épocas de semeadura no cerrado piauiense. Comun. Sci. 3:215-219.

Battisti R, Sentelhas PC (2014). New agroclimatic approach for soybean sowing dates recommendation: A case study. Rev. Bras. Eng. Agríc. Amb. 18:1149-1156.

Bellaloui N, Reddy KN, Gillen AM, Fisher DK, Mengistu A (2011). Influence of planting date on seed protein, oil, sugars, minerals, and nitrogen metabolism in soybean under irrigated and non-irrigated environments. Am. J. Plant Sci. 2:702-715.

Borghi E, Bortolon L, Avanzi JC, Bortolon ESO, Ummus ME, Gontijo Neto MM, Da Costa RV (2014). Desafios das novas fronteiras agrícolas de produção de milho e sorgo no Brasil: desafios da região do MATOPIBA. In: Karam, D.,and P. C. Magalhães. Eficiência nas cadeias produtivas e o abastecimento global. Sete Lagoas: Associação Brasileira de Milho e Sorgo. Cap. 25:263-278.

Brasil (2009). Ministério da Agricultura. Departamento Nacional de Produção Vegetal. 2009. Regras para Análise de Sementes. Brasília: MAPA/ACS. 365p.

Chen GH, Wiatrak P (2010). Soybean development and yield are influenced by planting date and environmental conditions in the southeastern coastal plain, United States. Agron. J. 102:1731-1737.

Conab (Companhia Nacional de Abastecimento) (2015). Acompanhamento da safra brasileira: Grãos. Safra 2014/15: Décimo segundo levantamento. 103p.

Cruz TV, Peixoto CP, Martins MC, Brugnera A, da Ledo SCA, Lopes PVL (2010ª). Acúmulo de matéria seca e área foliar de cultivares de soja em duas épocas de semeadura no Oeste da Bahia. Magistra 22:103-111.

Cruz TV, Peixoto CP, Martins MC (2010b). Crescimento e produtividade de soja em diferentes épocas de semeadura no oeste da Bahia. Sci. Agrar. 11:33-42.

Empresa Brasileira de Pesquisa Agropecuária (Embrapa). (2015). Matopiba: caracterização, agenda e agências. Coordenador: Evaristo Miranda. Grupo de inteligência territorial estratégica (gite). https://www.embrapa.br/gite/projetos/Matopiba/150317_MATOPIBA W EBSITE.pdf. (Acceso: Agosto 2015).

Hu M, Wiatrak P (2012). Effect of planting date on soybean growth, yield, and grain quality: Review. Agron. J. 104:785-790.

Kapoor N, Arya A, Siddiqui MA, Amir A, Kumar H (2010). Seed deterioration in chickpea (*Cicer arietinum* L.) under accelerated aging. Asian J. Plant Sci. 9:158-162.

Khan AZ, Shah P, Khan H, Nigar S, Perveen S, Shah MK, Amanullah S, Khalil K, Munir S, Zubair M (2011). Seed quality and vigor of soybean cultivars as influenced by canopy temperature. Pak. J. Bot. 43:643-648.

Kirnak H, Dogan E, Alpaslan M, Celik S, Boydak E, Copur O (2008). Drought stress imposed at different reproductive stages influences growth, yield and seed composition of soybean. Philipp. Agric. Sci. 91:261-268.

Kobraei S, Etminan A, Mohammadi R, Kobraei S (2011). Effects of drought stress on yield and yield components of soybean. Ann. Biol. Res. 2:504-509.

Kurihara CH, Venegas VHA, Neves JCL, Novais RF (2013). Acúmulo de matéria seca e nutrientes em soja, como variável do potencial produtivo. Rev. Ceres 60:690-698.

Meotti GV, Benin G, Silva RR, Beche E, Mumaro LB (2012). Épocas de semeadura e desempenho agronômico de cultivares de soja. Pesqui. Agropecu. Bras. 47:14-21.

Siahbidi MMP, Aboughadareh AP, Bazdar A, Naghavi MR (2013). Investigation of water deficit stress effects on yield and yield components of four soybean cultivars at different growth stages. Int. J. Biosci. 3:104-109.

Souza CA, Figueiredo BP, Coelho CMM, Casa RT, Sangoi L (2013). Arquitetura de plantas e produtividade da soja decorrente do uso de redutores de crescimento. Biosci. J. 29:634-643.

Taiz L, Zeiger E (2013). E. Fisiologia Vegetal. Porto Alegre: Artmed. 918p.