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Sowing periods, agronomic performance and seed quality of soybean cultivars in the Planosol soil

Geison Rodrigo Aisenberg[1], Felipe Koch[1], Gustavo Zimmer[1], Gustavo Henrique Demari[1], Vinícius Jardel Szareski[1], Ivan Ricardo Carvalho*[1], Manoela Andrade Monteiro, João Roberto Pimentel[1], Velci Queiróz de Souza[2], Francisco Amaral Villela[1], Tiago Pedó[1], Tiago Zanatta Aumonde[1]

[1]Universidade Federal de Pelotas, CEP 96010-610, Capão do Leão, RS, Brazil
[2]Universidade Federal do Pampa, Dom Pedrito, RS, Brazil

***Corresponding authors: carvalho.irc@gmail.com**

Abstract

Understanding of sowing in an ideal season for each region and cultivar is essential for the crop to reach each of its stages in more favorable climatic conditions. The objective of this study was to evaluate the influence of different sowing times on agronomic attributes of two soybean cultivars and the physiological quality of soybean seeds in soil type Eutrophic Haplic Planosol. The experimental design was completely randomized, in a factorial scheme 4 x 2, with four sowing times and two soybean cultivars, with eight replications. The sowing was executed at the beginning and end of November (1^{st} and 2^{nd} epochs) and beginning and end of January (3^{rd} and 4^{th} epochs), using the cultivars: Fundacep 64 RR and BMX Potência RR. The experiment was carried out in polyethylene vessels with volumetric capacity of 10 liters. The morphological attributes of the plants were evaluated, such as: height, stem diameter, number of pods and seeds per plant, 1000 seed weight, as well as seed germination and vigor. Seeding after January 1^{st} negatively affected the agronomic behavior of soybean plants, with reduction of plant height, stem diameter, number of pods and seeds per plant. The sowing on November 1st favored the obtaining of seeds with lower physical quality in terms of 1000 seed weight; however, seeds with superior physiological performance. Late sowing showed an alternative for the production of soybean seeds in the South region of Rio Grande do Sul, mainly due to the higher quality of the seeds produced in this period.

Keywords: Germination, *Glycine max* L., Dry matter, Planosol.
Abbreviation: Hp_plant height; D_stem diameter; P_{PL}_number of pods per plant; S_{PL}_number of seeds per plant; W1000_thousand seed weight; G_germination; FGC_first germination count; Wt_total dry matter of soybean seedlings.

Introduction

Soybean is a commodity used as a basic raw material for the production of bran and oil, and is also consumed in natura (Castro et al., 2006). Brazil is the second largest producer of soybeans, producing 96.2 million tons of grain in the 2014/15 crop, with an average productivity above 3.0t ha-1 (CONAB, 2015). Plants of this species are sensitive to the duration of daylight hours, whose flowering occurs if the length of days is less than the critical photoperiod.

In Rio Grande do Sul, 5.2 million hectares of soybean were cultivated in the 2014/15 harvest, contributing with 15% of the grain national production of this species (CONAB, 2015). In recent years, there has been a considerable increase in the area under cultivation in the south region of the state of Rio Grande do Sul, from 30,000 hectares in the 2000/01 crop to over 125,000 in the 2012/2013 crop.

The coastal plain region is characterized by the predominance of Planosol type soils, which have low to moderate fertility and B textural horizon. These floodplain soils differ from those in highlands because they are subject to temporary flooding conditions (Rosa et al., 2008).

During cultivation of a plant species, including soybeans, biotic and abiotic factors may affect growth and development, which may compromise crop productivity (Silva et al., 2012; Szareski et al., 2016a). The development of soybean plants during their cycle is influenced by sowing time (Albrecht et al., 2008), which can decrease the number of days for flowering, plant height and yield (Amorin et al., 2011).

Adverse environmental conditions such as photoperiod and temperature negatively influence morphological attributes (Meotti et al., 2012; Szareski et al., 2015), growth, seed filling, nutrient absorption, and photosynthetic rate (Ferreira et al., 2007). In addition, they cause problems in the remobilization of carbon and nutrients from the leaves and stems to the seeds (Oya et al., 2004). Thus, the sowing season negatively affects the physiological quality of soybean seeds, being, studies on the subject, incipient in the south region of the state of Rio Grande do Sul.

The temperature, as well as the photoperiod is the main environmental factors that influence the development of the flowering process of soybean plants (Ting-Ting et al., 2015). The occurrence of high temperatures during the flowering stage of the plants, or only for a short period of time in this stage, can affect the reproductive process of the plants, due to the negative effect on dispersion and germination of the pollen (Salem et al., 2007).Temperatures equal to or above 30ºC during the development cycle cause reduction in seed size and, consequently, affect the production (Tacarindua et al., 2012). Moreover, adverse environmental conditions in the field during the seed development process may reduce the germination and vigor of the seeds (Egli et al., 2005; Szareski et al., 2016b).

The production and use of seeds with high genetic potential and high quality, combined with the use of appropriate cultivation techniques are essential tools to obtain higher crop yields (Albrecht et al, 2009). Soybean plants from high quality physiological seeds present higher height, stem diameter and grain yield than those obtained from seeds with low quality (Schuch et al., 2009).

In view of the above, this study aimed to evaluate the influence of different sowing times on agronomic attributes of two soybean cultivars and the physiological quality of soybean seeds.

Results and Discussion

With the exception of stem diameter, there was a significant interaction among the factors studied for evaluated variables. The diameter of the stem was only affected by sowing epochs (Table 1).

For both cultivars, the highest and lowest height of the plants was verified for sowing in the first and last seasons, respectively (Table 2). It was verified that as the sowing was delayed, the plants reached lower height. For the cultivar Fundacep 64 RR, the last sowing season resulted in plants with 58% lower height compared to those produced from the first season. For the cultivar BMX Potência RR, the sowing performance in the last season caused a reduction of 50% in plant height, compared to that of the first season.

There was a significant difference in plant height between the cultivars when sowing in both the first and the last season, and the cultivar BMX Potência RR showed higher height in relation to the Fundacep 64 RR, on both occasions (Table 2). There was no significant difference in plant height of the cultivars as a function of sowing performance in the second and third seasons.

The difference in plant height between the two cultivars for the first and last sowing season is possibly due to the difference in growth habit, because the cultivar Fundacep 64 RR presents a determined growth habit, while BMX Potência RR has an indeterminate habit. In the present study, soybean plants with a specific growth habit have a terminal and axillary racemic inflorescence. These plants, when reaching the flowering stage, have already incorporated about 90% of the dry matter of their plants (Nogueira et al., 2009). In contrast, cultivars with an indeterminate growth habit have an axillary inflorescence, which has an apical bud, which maintains vegetative growth even after flowering has started (Nogueira et al., 2009; Mundstock and Thomas, 2005).

Considering that both soybean cultivars used belong to similar maturity groups, they may have reached the reproductive stage in a similar period. The delay of sowing in soybeans, within the recommended period, can lead to reduced plant height (Amorin et al., 2011; Cruz et al., 2010). These results may be due to changes in the phenological stages of the crop and, consequently, to the shortening of the development cycle. In this context, Fietze Rangel (2008) reports that even sowing being carried out at the time recommended for soybean cultivation. Its delay may lead to a reduction in the number of days between the passage of the plants from one phenological stage to another.

For both cultivars, the largest diameter of the stem was observed in plants from the first sowing season (Table 2). Sowing in the third and fourth seasons resulted in a reduction in stem diameter of the plants compared to those produced in the first sowing season, with 46% and 58% for Fundacep 64 RR and 40% and 51% for cultivar BMX Potência RR. No significant differences were observed for stem diameter between the two cultivars. The delayed sowing of soybean negatively affects the vegetative and productive performance of this species, leading to a reduction in the number of leaves, dry matter and leaf area (Cruz et al., 2010). The negative effect is mainly due to shortening of the cultivars cycle (Cruz et al., 2010).

The highest number of pods per plant in both cultivars was observed for the first sowing season (Table 2), so the delay of sowing caused a reduction in the number of pods per plant. For the two cultivars, sowing in the last season caused a reduction in the number of pods per plant^{-1}, in relation to the first sowing season, with a reduction of 56 and 53% for the cultivars Fundacep 64 RR and BMX Potência RR, respectively.

Seeding in November was provided higher number of seeds per plant in both cultivars, (Table 2). The sowing in January affected negatively the number of seeds per plant in both cultivars, but in the last sowing the reduction reached 51% and 53% for the cultivars Fundacep 64 RR and BMX Potência RR, respectively.

There was a significant difference in the number of seeds per plant between the two soybean cultivars, for the first two sowing times (Table 2). In the first and second seasons, the number of seeds per plant in the cultivar BMX Potência RR was higher, represented by 14% and 15% in relation to that produced by the cultivar Fundacep 64 RR.

In both soybean cultivars, there was a reduction in the thousand seed weight (Table 3). The sowing of the cultivars Fundacep 64 RR and BMX Potência RR, in the last season caused a decrease of 32 and 31% in the thousand seed weight, respectively, in comparison to the sowing executed in the first season.

The reduction of the one thousand seed weight with the delay of the sowing season may be related to the reduction of the available solar radiation (Figure 1b). In addition, temperature and photoperiod influence the formation and number of floral primordia (Jiang et al., 2011), in the flowering and photosynthesis of plants (Ferreira et al., 2007), together with reductions in the vegetative period, due to the cultivars reach the critical photoperiod in less time (Cruz et al., 2010), inducing flowering by short days (Rocha et al., 2012).

In all sowing epochs, there was a significant difference in the W_{1000} between the two cultivars, and the BMX Potência RR obtained higher values (18%) in relation to the Fundacep 64 RR (Table 3). The variation of the W_{1000} observed between the two cultivars may be related to their genotypic characteristics, according to cultivar descriptors. In both cultivars, the W_{1000} reached the highest values for the first sowing season and the lowest results for the last season, with a reduction of approximately 32 and 31% for the cultivar Fundacep 64 RR and BMX Potência RR, respectively.

Table 1. Summary of the analysis of variance for the variables plant height (H_P), stem diameter (D), number of pods per plant (P_{PL}), number of seeds per plant (S_{PL}), thousand seed weight (W_{1000}), germination (G), first germination count (FGC) and total dry matter of soybean seedlings (W_t). Capão do Leão – Rio Grande do Sul, 2013/2014.

Source Of variation	D.F.	Meansquare							
		H_P	D	P_{PL}	S_{PL}	W_{1000}	G	FGC	W_T
Cult (C)[1]	1	465.8*	2.5^{ns}	68.1^{ns}	3510.6*	2569.1*	300.1*	1058.0*	2613.6*
Epo (E)[2]	3	6727.5*	256.7*	8573.8*	39526.4*	8297.4*	2043.0*	1995.3*	160.0*
C X E	3	322.4*	3.2^{ns}	277.2*	2258.7*	478.8*	1182.1*	1406.0*	546.1*
Residue	49	23.1	1.6	62.8	439.8	14.7	26.5	19.3	30.3
CV (%)		7.49	11.59	11.26	12.95	2.64	6.11	5.57	9.00

*[1]Cultivar; [2]Epoch; *significant by the F test (p≤0,05); ^{ns}not significant by the F test (p≤0,05).*

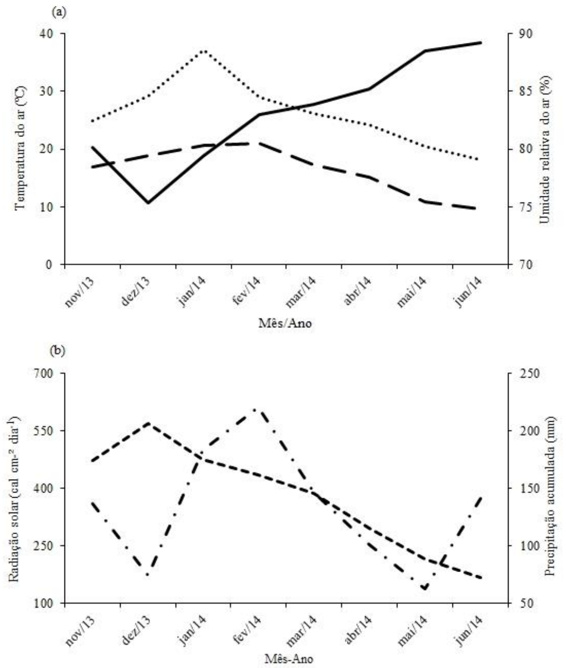

Fig 1. Maximum (⋯⋯) and minimum temperatures (— — —), relative air humidity (———) (a), solar radiation (- - - - -) and accumulated rainfall (- · - · -) (b) during the period of conduction of the experiment in Capão do Leão - Rio Grande do Sul, 2013/2014.

Table 2. Plant height (H_P),stem diameter (D), number of pods (P_{PL}) and seeds per plant (S_{PL}) of soybean cultivars Fundacep 64 RR (Fun) and BMX Potência RR (Pot), at sowing on different dates in Capão do Leão – Rio Grande do Sul, 2013/2014.

Time	H_P		D		P_{PL}		P_{PL}	
	Fun	Pot	Fun	Pot	Fun	Pot	Fun	Pot
Nov_1	83 aB	88 aA	15 aA	14 aA	95 aA	97 aA	196 aB	228 aA
Nov_2	72 bA	81 bA	14 aA	13 aA	81 bA	82 bA	174 abB	204 aA
Jan_1	56 cA	54 cA	8bA	8bA	61 cA	52 cB	155 bA	136 bA
Jan_2	34 dB	44 dA	6cA	7bA	42 dA	45 dA	96 cA	107 cA
MSD_{line}	4.83		1.28		7.96		21.07	
MSD_{column}	6.40		1.69		10.54		27.90	

[1]Averages followed by the same lowercase letter, in the column, and upper case, in the line, are not differentiated by the Tukey test (p≤0.05).

Table 3. Thousand seed weight (W_{1000}), germination (G), first germination count (FGC) and total dry matter of soybean seedling (W_T), cultivar Fundacep 64 RR (Fun) and BMX Potência RR (Pot), in function of sowing on different dates in Capão do Leão – Rio Grande do Sul, 2013/2014.

Epoch	W_{1000} (g)		G (%)		FGC (%)		W_T (mg)	
	Fun	Pot	Fun	Pot	Fun	Pot	Fun	Pot
Nov_1	167.2 aB	173.1aA	45 cB	81 bA	40 dB	80 bA	41.4 bB	64.4 abA
Nov_2	149.7 bB	159.7bA	93 abA	71 cB	86 bA	67 cB	58.6 aB	72.3 aA
Jan_1	125.0 cB	153.9 cA	87 bB	98 aA	67 cB	93 aA	44.4 bB	79.1 aA
Jan_2	113.8 dB	119.7dA	100 aA	100 aA	99 aA	98 aA	64.0 aA	61.0 bA
MSD_{line}	3.8581		7.5767		6.4578		8.1004	
MSD_{column}	5.1074		10.159		8.6584		10.861	

[1]Averages followed by the same lowercase letter, in the column, and upper case, in the line, are not differentiated by the Tukey test (p≤0.05).

In both cultivars, the highest values of seed germination were obtained for the last sowing season, reaching superiority of 55 and 19% for the germination values of the first season, for the cultivar Fundacep 64 RR and BMX Potência RR, respectively. In the first and third sowing season the cultivar BMX Potência RR reached superiority in the germination values, however, in the second season, the cultivar Fundacep 64 RR reached higher values, in the last sowing season no significant differences were observed between the two cultivars.

The highest value of the first germination count of both cultivars was observed in the last sowing season (Table 3). For the cultivar Fundacep 64 RR, sowing in the first season resulted in a reduction of 59% in the number of normal seedlings, compared to those sown in the last season. For the cultivar BMX Potência RR, sowing in the second season determined a reduction of 31% in the first germination count of this cultivar, compared to the sowing performed in the last season. There was a significant difference in the values of the first germination count of the two soybean cultivars for the first three sowing epochs, and for the seeds of the first and third epochs, the highest values were observed in the cultivar BMX Potência RR, in relation to Fundacep 64 RR.

Unfavorable environmental conditions of rainfall, temperature and relative humidity in the field during the growth and development stages of the seeds may lead to a reduction in the germination and vigor of the soybean seeds produced (Egli et al., 2005; Szareski et al., 2016). High temperatures, as well as the occurrence of water deficit during the period of seed filling, may affect germination (Minuzzi et al., 2010). Thus, the reduction in germination and first germination count, due to the delay of sowing, may be related to the occurrence of unfavorable climatic conditions, such as high temperatures at the time of seed formation and filling.

The maximum temperature in December 2013 was 37°C and in February 2014, 38°C. In addition, in January 2014, the maximum temperature reached values close to 40ºC. The cultivars Fundacep 64 RR and BMX Potência RR belong to maturation groups 6.9 and 6.7, respectively, and in this way, at the sowing in November in the State of Rio Grande do Sul, they will reach the phenological stage R5, that is, they begin the process of seed filling 80 to 90 days after sowing in the field (Trentin et al., 2013). Thus, it is evident that the sowing in the first two epochs provided the beginning of the seed filling process between the end of December and the beginning of January. During these months, high air temperatures and solar radiation occurred.

The highest dry matter of the seedlings of the Fundacep 64 RR cultivar was obtained for sowing during the last season, however, there was no difference from those coming from the second sowing season (Table 3). The dry matter of the seedlings of the cultivar Fundacep 64 RR from sowing in the last season was 56% higher in comparison to those produced from the first sowing season. For the cultivar BMX Potência RR, the highest value of seedlings dry matter was obtained at sowing in the third season, but this did not differ from that of the first and second seasons. The sowing of the cultivar BMX Potência RR in the third season resulted in the superiority of 29% regarding the dry matter production of seedlings, in relation to the sowing performed in the last season. The cultivar BMX Potência RR presented higher production of total dry matter of seedlings in the first three sowing times compared to the cultivar Fundacep 64 RR.

The highest values of total dry matter of seedlings obtained for both cultivars sown in January may be related to the most favorable conditions for the production of soybean seeds of high quality and vigor (Minuzzi et al., 2010). This response can be attributed to the occurrence of mild temperatures, which favor the adequate formation of soybean seeds (Braccini et al., 2003).

The delay in sowing can cause a reduction in plant height, drastically affect crop development cycle and yield (Garcia et al., 2007). The reduction of the number of pods and seeds per plant, due to the delay of sowing, may be due to the shortening of the stage, as well as to the total cycle of the same (Barbosa et al., 2013).

Materials and Methods

Location and experimental design

The experiment was carried out at the EliseuMaciel Agronomy College, Federal University of Pelotas, in the municipality of Capão do Leão-RS, located at latitude 31° 52 'S, longitude 52° 21' W. The climate of the region is temperate with well distributed rainfall and hot summer, being of the type Cfa by the classification of Köppen.

The experimental design was completely randomized, in a 2 x 4 factorial scheme, two soybean cultivars and four sowing seasons, using eight replications. The soybean cultivars used were Fundacep 64 RR and BMX Potência RR, belonging to maturity groups 6.9 and 6.7, respectively. The sowing was done on November 1^{st} and 28^{th}, 2013 (Nov1 and Nov2) and, on January 1^{st} and 28^{th}, 2014 (Jan1 and Jan2), corresponding to the four seasons. Ten seeds were sown in each vase, and after the emergence there was executed the thinning, to maintain four plants per pot.

The plot consisted of a black polyethylene vessel, with a volume of 10 liters, containing as soil substrate of the A1 horizon from the Solodic Eutrophic HaplicPlanosol, characteristic of the region, having chemical and physical characteristics of pH (H_2O): 5.4; P: 15.5 mg dm^{-3}; K: 54 mg dm^{-3}; Ca: 2.8 cmol dm^{-3}; Mg: 0.5 cmolc dm^{-3}; Al: 0.4 cmol dm^{-3}; Fe: 1400 mg dm^{-3}; Cu: 0.3 mg dm^{-3}; Zn: 0.9 mg dm^{-3}; Mn: 27.0 mg dm^{-3}; CTC: 6.0 cmolc dm^{-3}; Base saturation: 54%; Organic matter: 1.4%; Clay: 15%. Previously the soil was corrected according to soil analysis and based on the Manual of Fertilization (CQFS RS / SC, 2004). The basic fertilization consisted of 0.71 kg m3 of phosphorus and 0.84 kg m3 of potassium, using triple superphosphate and potassium chloride, respectively. The irrigation of the plants was daily and manually, in order to meet the water requirement of the crop, the pots were maintained in the field capacity, being determined previously by the tension table methodology. The monthly averages of temperature and solar radiation were obtained from the bulletin of the Agroclimatic Station of Pelotas, located one hundred meters from the place of cultivation (Figure 1).

Measurement of traits

The seeds were harvested manually and when they reached a water content of 16%, varying according to the cycle of each cultivar. The water content of the seeds was determined by the greenhouse method (Brasil, 2009). Seed threshing and processing were performed manually. For the processing of the seeds there were used sieves with circular holes of different diameters (5.0 to 7.5 mm).

For the evaluation of the agronomic attributes of the plants at the end of the experiment, the height of the plants was determined, measured from the soil level to the upper end of the longer stem, using a tape measure, and the results were expressed in centimeters. The diameter of the main stem was determined following the standard for the crop (two centimeters above ground level), using a digital caliper, the results being expressed in millimeters. The number of pods and seeds per plant were determined by direct counting and the results were expressed in total number of pods and seeds per plant.

For the determination of the physical and physiological quality of the seeds, the 1000 seed weight was evaluated (Brasil, 2009). The germination test was carried out in eight samples with four subsamples of 50 seeds, on Germitest germination paper, and the conduction of the test and evaluation were performed according to Brazil (2009). The first germination count was conducted under the same conditions of the germination test, being evaluated at five days after sowing. The counting was done by computing the number of normal seedlings (proportional and well developed shoot and root parts), the results being expressed as a percentage (Brasil, 2009). For the determination of the total dry weight, four samples of 10 seedlings were used at the end of the germination test. They were packed in brown paper envelopes and dried in a forced ventilation oven at 70°C for 72 h. For this, the seedlings were conditioned in brown paper envelopes and submitted to drying in forced ventilation oven, under a temperature of 70°C, until constant weight.

Statistical analysis

The data were submitted to analysis of variance and to the F test ($p \leq 0.05$), and if significant, the averages of the factors were compared by the Tukey test at a probability level of 5%. Values relating to climatic data were interpreted on the basis of trends throughout the growing cycle.

Conclusions

Sowing after January 1st negatively affects the agronomic behavior of soybean plants, with a reduction in plant height, stem diameter, number of pods and seeds per plant.

Sowing on November 1st favors the obtaining of seeds with inferior physical quality in terms of one thousand seed weight, however, seeds with superior physiological performance.

Late sowing shows an alternative for the production of soybean seeds in the south region of Rio Grande do Sul, mainly due to the higher quality of the seeds produced in this period.

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