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RESEARCH ARTICLE

SEED QUALITY AND INITIAL PERFORMANCE OF SEEDLINGS OF SOYBEAN PRODUCED OFF-SEASON IN RIO GRANDE DO SUL, BRAZIL

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ABSTRACT

Low temperatures and precipitation in off-season soybean may benefit seed production. This work aimed to evaluate seed quality and initial performance of off-season soybean produced in Rio Grande do Sul, Brazil. The experiment was performed under completely randomized design and treatments consisted of ten soybean genotypes produced off-season. We evaluated 1000 seeds weight, first count of germination, speed of germination index, seedling emergence, speed of emergence index, leaf area and shoot and root dry matter at the 20 and 30 days after sowing. Under off-season cultivation, FPS Iguaçu RR presented the greater value for 1000 seeds weight. BMX Turbo RR performed better for first count of germination, seedling emergence and speed of emergence index, along with FPS Iguaçu RR for seedling emergence. BMX Alvo RR had presented greater speed of germination index. FPS Iguaçu RR presented better performance for leaf area and shoot and root dry matter in both dates. BMX Classe RR presented the lower value for 1000 seeds weight and BMX Tornado RR, BMX Potência RR and FPS Solimões RR for first count of germination. For the speed of germination index, FPS Paranapanema RR and FPS Solimões RR were inferior to the others. BMX Potência RR had the lowest seedling emergence and BMX Tornado RR the lowest values for speed of emergence index, leaf area and shoot dry matter at the 20 and 30 days after sowing, along with BMX Potência RR for shoot dry matter at the 20 days and BMX Classe RR at the 30 days.

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INTRODUCTION

Soybean (*Glycine max* L.) occupies 57% of the area cultivated with grains in Brazil which accounted for a production of almost 96 million tons (CONAB, 2016) with an average yield of 3.01 metric tons per hectare (USDA, 2016). Such production placed Brazil at the second position in production and yield, only behind The United States. The yield of soybean might be impaired by a variety of factors, which include inadequate sowing date. Bastidas *et al*. (2008) observed a decrease up to 43 kg per day of delay. Accordingly, Braccini *et al*. (2004), found a decrease of grain yield varying from 23 to 31 kg per day of delay in sowing date. Delayed sowing leads to early flowering, shortens crop cycle and stature as well as the height of insertion of the lowest pod which hinder harvest (Braccini *et al*., 2004; Bastidas *et al*., 2008; Meotti *et al*., 2012).

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In the states of Rio Grande do Sul and Santa Catarina, the indicated sowing date ranges from the beginning of October and the end of December (Embrapa, 2014). Despite the evident decrease in yield, off-season cultivation has been performed in these states. Among other factors, this fact may be explained by the high risks of environmental hazards and relatively low prices of commercialization in wheat (Meotti *et al*., 2012). In order to obtain high quality soybean seeds, sowing date must allow for mild temperatures during the reproductive stage, preventing the occurrence of poorly formed seeds, and that are appropriate for harvesting in a dry period (Peske *et al*., 2012). Despite the decrease of yield, off-season seed production might represent anviable option in years where environmental hazards or other risk factors during on-season cultivation are contemplated. In the state of Rio Grande do Sul until now, there is paucity of studies evaluating soybean seed quality produced off-season. Thus, the aim of this work was to evaluate seed quality and initial performance of seedlings of

soybean produced off-season in the northwest region of Rio Grande do Sul, Brazil.

MATERIAL AND METHODS

Seed production was performed from January to May 2013, in Tenente Portela – RS, Brazil, which is located at the 27°23'31.04"S and 53°46'50.71"W and at an altitude of 420 meters. The region presents temperate climate with well distributed rains, which is classified as *Cfa* accordingly to Koppen classification (Peel *et al*., 2007) and the soil is classified as an Oxisol. The area used was cultivated under no-till farming and fertilization at sowing employed 300 kg per hectare of 10-20-20 NPK fertilizer formulation. Sowing was performed in January 5th and the management of weeds and pests was performed accordingly with the recommendations for the crop (Embrapa, 2014). Flower initiation occurred from March 8th to 10th and seed harvest was carried out at May 23th. The experiment was performed in a completely randomized design with ten treatments and four repetitions. The treatments consisted of the genotypes BMX Alvo RR, BMX Classe RR, BMX Energia RR, BMX Força RR, BMX Potência RR, BMX Tornado, FPS Iguaçu RR, FPS Paranapanema RR and FPS Solimões RR. Postharvest analyses were performed at the Didactic Laboratory of Seed Analysis at the Federal University of Pelotas.

In order to evaluate seed quality and seedling performance the following analysis were performed:

- 1000 seeds weight**:** eight repetitions of 100 seeds each, accordingly wit Brasil (2009).
- First count of germination**:** performed using four samples with two subsamples of 50 seeds each experimental unit. Seeds were placed to germinate in three sheets of "germitest" paper, humidified with 2.5 times the dry weight of the paper. The paper rolls were then placed to a germination chamber at the temperature of 25ºC and a photoperiod of 24 hours of light. The evaluation was carried out five days after sowing, according to Brasil (2009). Results were expressed in percentage of normal seedlings.
- Speed of germination index**:** realized using four samples with two subsamples of 50 seeds each experimental unit, under the same conditions described for first count of germination. The speed of germination was determined by daily counting the number of germinated seeds. Seeds with a protruding root of at least 3 to 4 mm were considered germinated. The counting was performed always at the same time of day until the obtainment of a constant magnitude of germinated seeds and the results were expressed accordingly to Vieira and Carvalho (1994).
- Seedling emergence**:** was carried out using four repetitions containing 50 seeds each which were disposed to germinate containing the above described soil. The evaluations were performed 20 days after sowing and the results expressed in percentage of emerged seedlings.
- Speed of emergence inde**x:** was determined by daily counting of emerged seeds. The counting was performed until the obtainment of a constant magnitude of emerged seeds and the results expressed accordingly to Vieira e Carvalho (1994).
- Leaf area: measured in four samples of ten seedlings each, using the area meter Licor® LI-300 at the 20 and 30 days after sowing. Results were expressed in square centimeters.
- Shoot and root dry matter: measured in four samples of ten seedlings at the 20 and 30 days after sowing. Seedlings were placed in kraft paper envelopes and dried till constant weight using a kiln equipped with forced ventilation at the temperature of 70ºC. Results were expressed in grams (g).

Data for each variable were subjected to analysis of variance and, when significant at the 5% probability level, means were compared by Tukey test.

RESULTS AND DISCUSSION

Meteorological data from Tenente Portela – RS regarding the period of seed production, which comprised January to May, are presented in Table 1.

Table 1. Average minimum temperature, (T min) and average maximum temperature (T max), in Celsius degrees; Relative humidity (RH), in percentage; Accumulated precipitation (P), in millimeters; Accumulated solar radiation (Sr), in Kj m^{-2} regarding the period of January to May 2013 in Tenente Portela – RS

Month	T min (°C)	T max (°C)	RH (%)	P (mm)	Sr (Kj m^{-2})
January	22.3	23.9	68.7	105.6	34107.4
February	22.0	23.5	76.9	173.6	25564.5
March	19.5	20.7	79.5	218.8	21204.3
April	18.1	19.7	73.7	165.6	28602.0
May	15.3	16.6	80.0	110.0	14161.1

Source: EMBRAPA (2013).

Table 2a. Summary of the analysis of variance for the variables 1000 seeds weight (W1000), first count of germination (FCG), speed of germination index (SGI), seedling emergence (SE) speed of emergence index (SEI) evaluated in seeds of ten soybean genotype produced off-season

F.V.	D. F.	Mean Square				
		W1000[1]	FCG	SGI	SE	SEI
Genotype	9	4070.06*	358.41*	236.49*	307.38*	6.57*
CV (%)		4.89	6.00	6.48	6.36	6.85

F.V. – Factor of variation; D. F. – Degrees of freedom;
*Significant at the 5% probability level;

The analysis of variance (Tables 2a and 2b) revealed significant differences for the variables 1000 seeds weight, first count of germination, speed of germination index, seedling emergence, speed of emergence index, leaf area at the 20 and 30 days, shoot and rot dry matter at the 20 and 30 days. For 1000 seeds weight the genotype FPS Iguaçu RR performed better than the other genotype, being more efficient in the accumulation of reserves in seeds during off-season seed production (Table 3). The remaining genotype BMX Energia RR, BMX Turbo RR, BMX Alvo RR, FPS Paranapanema RR, FPS Solimões RR, BMX Potência RR, BMX Força RR, BMX Tornado RR presented an intermediary performance for this variable. The variety BMX Classe RR presented the lower seed weight, which indicates that its cultivation off-season leads to unsatisfactory conditions of development.

In Brazil, in order to obtain intellectual property protection of genotype, some botanical characteristics under normal conditions of cultivation are used in their description, these characteristics comprise seed weight. The results of this experiment unveiled significant decreases in relation to the described seed weight of 45% for BMX Classe RR and BMX Turbo RR, 44% for BMX Tornado RR and FPS Solimões RR, 41% for BMX Força RR, 40% for FPS Paranapanema RR, 39% for BMX Potência RR, 32% for BMX Energia RR and 29% for BMX Alvo RR, on the other hand, for FPS Iguaçu RR the decrease in seed weight was of only 8%. The lower performance of some genotypes for 1000 seeds weight may be related with unfavorable environmental conditions for growth and development in off-season cultivation. This, may be attributed to the lower solar radiation in march, which may have reduced photosynthetic assimilation and consequently the

Table 2b. Summary of the analysis of variance for the variables leaf area at the 20 (L_{A20}) and 30 days (L_A30), shoot dry matter at 20 (W_{S20})and 30 days (W_{S30}) and rot dry matter at 20 (W_{R20}) and 30 days (W_{R30}) evaluated in seeds often genotype produced off-season

F.V.	D. F.	Mean Square					
		A_{F20}	A_{F30}	W_{PA20}	W_{R20}	W_{PA30}	W_{R30}
Genotype	9	8846.58*	18436.93*	0.158*	0.100*	0.550*	0.072*
CV (%)		11.18	10.65	12.60	16.23	7.30	12.94

F.V. – Factor of variation; D. F. – Degrees of freedom, *Significant at the 5% probability level

Table 2b. Summary of the analysis of variance for the variables leaf area at the 20 (L_{A20}) and 30 days (L_A30), shoot dry matter at 20 (W_{S20})and 30 days (W_{S30}) and rot dry matter at 20 (W_{R20}) and 30 days (W_{R30}) evaluated in seeds often genotype produced off-season

F.V.	D. F.	Mean Square					
		A_{F20}	A_{F30}	W_{PA20}	W_{R20}	W_{PA30}	W_{R30}
Genotype	9	8846.58*	18436.93*	0.158*	0.100*	0.550*	0.072*
CV (%)		11.18	10.65	12.60	16.23	7.30	12.94

F.V. – Factor of variation; D. F. – Degrees of freedom; *Significant at the 5% probability level

Table 3. Means to 1000 seeds weight described for each variety (DES) and average for the observed variables: 1000 seeds weight (W1000), first count of germination (FCG), speed of germination index (SGI), seedling emergence (SE) and speed of emergence index (SEI) measured in seeds of ten varieties produced off-season

Genotypes	DES (g)	W1000 (g)	FCG (%)	SGI	SE (%)	SEI
BMX Alvo RR	164	117.0c*	83bcd	52.2a	89abc	14.5ab
BMX Classe RR	165	90.1e	82bcd	35.8de	92ab	14.0ab
BMX Energia RR	176	120.0bc	91ab	46.8abc	90abc	13.6abc
BMX Força RR	174	103.2d	79cde	40.7cd	79cde	12.9abcd
BMX Potência RR	168	102.6d	70e	35.8de	71e	11.6cd
BMX Tornado RR	175	98.1de	68e	45.2bc	74de	11.0d
BMX Turbo RR	232	126.7bc	95a	50.1ab	96a	15.0a
FPS Iguaçu RR	184	168.4a	88abc	49.8ab	95a	13.9ab
FPS Paranapanema RR	168	100.3d	73de	30.9e	84abcd	12.5bcd
FPS Solimões RR	176	99.3d	70e	33.7e	80bcde	12.3bcd

*Means followed by the same letter in the column are not significantly different by Tukey test at the 5% probability level.

Table 4. Means to leaf area at 20 days (A_{L20}) and 30 days (A_{L30}), shoot dry matter at 20 days (W_{S20}), root dry matter at 20 days (W_{R20}), shoot dry matter at 30 days (W_{S30}) and root dry matter at 30 days (W_{R30}), measured in seeds of ten genotype of soybean produced off-season

Genotypes	A_{L20} (cm²)	A_{L30} (cm²)	W_{S20} (g)	W_{R20} (g)	W_{S30} (g)	W_{R30} (g)
BMX Alvo RR	278.8b*	569.7ab	1.35abc	0.68b	2.70bc	1.16ab
BMX Classe RR	223.8bc	489.1b	1.20bc	0.65b	2.10d	0.89b
BMX Energia RR	214.3bc	467.3b	1.20bc	0.77b	2.28cd	1.11ab
BMX Força RR	266.9b	573.6ab	1.34abc	0.66b	2.52bcd	1.16ab
BMX Potência RR	240.6bc	510.0b	1.16c	0.74b	2.29cd	1.06ab
BMX Tornado RR	183.9c	473.9b	1.00c	0.63b	2.12d	0.91b
BMX Turbo RR	276.7b	574.6ab	1.57ab	0.83b	2.84bc	1.07ab
FPS Iguaçu RR	358.8a	692.9a	1.69a	1.16a	3.35a	1.33a
FPS Paranapanema RR	248.0bc	506.9b	1.36abc	0.68b	2.42bcd	0.95b
FPS Solimões RR	254.0b	513.0b	1.38abc	0.66b	2.48bcd	0.99b

*Means followed by the same letter in the column are not significantly different by Tukey test at the 5% probability level.

accumulation of reserves. A lower solar radiation reduces carbon fixation as well as the remobilization of carbon and nutrients from leaves and stems which results in the decrease of 1000 seeds weight (Oya *et al*., 2004). Furthermore, low temperatures, which occurred during March and April, reduce the carriage of assimilates to seed storage tissues and, as a result, decrease seed quality and vigor (Braccini *et al*., 2003). First count of germination presented significant differences in seed vigor, BMX Turbo RR performed better for this variable while BMX Tornado RR, BMX Potência RR, FPS Solimões RR and FPS Paranapanema RR presented the lower values (Table 3).

Results obtained by Albrecht *et al*. (2009) indicate that off-season seed production may lead to seeds with low physiological quality. Seeds with low vigor reduce, delay and impair the uniformity of seedling emergence (SCHUCH *et al*., 1999) and thus, reduce yield (Kolchinski *et al*, 2005). The speed of germination index was higher for the genotype BMX Alvo RR (Table 3). The genotype which had the lower performances for this variable were FPS Paranapanema RR e FPS Solimões RR. The evaluation of speed of germination index is performed through the daily counting of germinated seeds dividing the result of each count by the number of days necessary for its germination (Vieira and Carvalho, 1994). For this reason, greater values for this variable indicate a higher number of germinated seeds per day, leading to more homogeneous plant stands and, possibly, more uniform maturity. The majority of the genotypes tested presented values higher than 80% for seedling emergence, except BMX Força RR, BMX Potência RR and BMX Tornado RR (Table 3). The best performances for this variable were observed in BMX Turbo RR and FPS Iguaçu RR. The seedling emergence is an indicative of vigor, thus, it is evident that the cultivation of soybean off-season leads to differential responses for each genotype and, thus, some genotype are inadequate for the obtainment of high quality seeds off-season. Regarding speed of emergence index, the genotype FPS Iguaçu RR presented the greater value while BMX Tornado RR the lower. Greater indexes indicate a rapid exposure of shoot tissues above the soil and a higher interspecific competitiveness to weeds.

The best performance for all evaluations regarding the initial growth, which include leaf area and shoot and root dry matter at the 20 and 30 days after sowing, was observed for FPS Iguaçu RR while for most of the remainder genotypes there were no significant differences between them. Furthermore, BMX Tornado RR presented the lower performance for leaf area at 20 DAS, shoot dry matter at 20 and 30 DAS along with BMX Potência RR for shoot dry matter at 20 DAS and BMX Classe at 30 DAS. These results indicate that FPS Iguaçu RR maintains a satisfactory performance when its seeds are produced off-season ensuring a rapid expansion of leaf primordial and, consequently, a higher intra and interspecific competitiveness of its seedlings. Different leaf area for soybean seedlings may be attributed to the intrinsic features of each genotype, environment and the specially, due to the effects of off-season seed production (Meotti *et al*., 2012). The outstanding performance of FPS Iguaçu RR regarding seedling leaf area and shoot and root dry matter in off-season cultivation may be explained by the differences observed in 1000 seeds weight. Accordingly, the genotype BMX Tornado RR, BMX Potência RR and BMX Classe RR which presented, in general, the lower values regarding seedling performance were also the ones with the lower values for 1000 seeds weight. Overall, our results demonstrate that the seed quality and initial performance of soybean seeds when produced off-season is variable as to genotype employed and highly related to a superior ability to accumulate reserves which leads to greater seed weights. However, other factors may be involved once seed weight does not entirely explain the differences observed in the vigor tests performed.

Conclusions

In the conditions under which the experiment was conducted theFPS Iguaçu RR presented the greater value for 1000 seeds weight and the BMX Turbo RR showed seedling emergence and speed of emergence index, along with FPS Iguaçu RR for seedling emergence. The FPS Iguaçu RR presented the greatest performance for leaf area and shoot and root dry matter in all dates of evaluation and BMX Classe RR presented the lower value for 1000 seeds weight.

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