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RESEARCH ARTICLE

Physiological quality of conventional soybean cultivars of seeds as a function of pod position in plant canopy

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ABSTRACT

Soybean cultivars have different growth habits, and the cultivation of those of indeterminate habit has increased significantly in Brazil. Thus, the aim of this study was to evaluate the physiological quality of soybean seeds produced in two harvests, from cultivars with different growth habits and ripening cycles, harvested in different canopy thirds of the plant in the canopy. The seeds were produced in Ipameri, Goiás –Brazil, in two crop harvests, 2014/15 and 2015/16. A completely randomized design was used in a 4x3 factorial scheme with four replications. The treatments consisted of four soybean cultivars with different growth habits and ripening cycles (BRS 6780, BRS 6980, BRS 7980 and BRS 8381), harvested in three positions of the plant canopy (upper, middle and lower). Germination, first count, accelerated aging and electrical conductivity tests were performed. It was observed that the physiological quality of genetic materials studied was influenced by the variable environmental conditions. Soybean cultivars the early cycles produced seeds of superior physiological quality, regardless of plant growth habit. Seeds of soybean cultivars of indeterminate and determined growth habits and earlier cycle, harvested from the upper and middle thirds of the plant, are of better quality. Finally, cultivars with semi-determined and determined habits and late cycles will produce lower quality batches of seeds, regardless of which third of the plant they were harvested.

Keywords: *Glycine max L.*, Conventional breeding; Seed quality; Viability and Vigor

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) has an increasingly important role in world food security (Chirchir et al., 2016; Fang et al., 2017) and in the economic development of various countries, especially in Brazil, as its utilization and appreciation contribute significantly to the trade balance surplus (Castro et al., 2016), besides being one of the most important agricultural crops in the country, corresponding to more than one-third of total grain produced in the 2013/2014 agricultural year (Bornhofen et al., 2015).

Over the years, the soybean cultivation area has grown, thus providing increased demand for seeds (Xavier et al., 2015; Saryoko et al., 2017). In this context, the use of high-quality seeds for planting crops takes on an essential role in obtaining high yield (Finoto et al., 2017; Paixão et al., 2017).

To be classified as high quality, the seeds must have excellent physiological characteristics, such as high vigor and germination, in addition to ensuring physical and varietal purity (Franca Neto et al., 2016). These factors account for seed performance in the field, culminating in important events to ensure high plant performance affecting the uniformity of development, yield and product quality (Marcos-Filho 2015a). However, during the production process, a range of factors may influence the physiological quality of the seeds; these include relative humidity, temperature, photoperiod and seed moisture content (Chirchir et al., 2016).

Studies on growth habits associated with the position of pods in the plant canopy could contribute decisively to agricultural processes, such as genetic breeding (Vicente et al., 2016), and the improvement of application technologies, for better health pods and seeds, in particular those of the lower part.

With regards to the position of the pods on the different thirds of the stem of the plant, some studies differ as to the physiological quality of the seeds in relation to their position. Adam et al. (1989) worked with two soybean

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cultivars under field conditions for three consecutive harvests, and obtained seeds of better physiological quality in the upper third. Ferreira (1994) evaluating the quality of soybean seeds as a function of the pod position on the plant, found that the pods on the middle third produced better quality seeds, while those of the lower third produced worse quality seeds. Similarly, Flores (2016) evaluated soybean seeds from determined and undetermined growth, observed within the thirds, of both habits, for two harvests, difference in viability and in vigor, with the lower third having the poorest seed quality.

Most modern soybean cultivars currently cultivated in Center-South of Brazil, where more soybean is produced in the country, belong to the type with indeterminate growth and maturity group (GM) ranging from 6 to 9 in different production systems, which allows greater overlap of vegetative growth with reproductive development in relation to the growth cultivars determined (Procópio et al., 2013; Zanon et al., 2016; Vicente et al., 2016), enabling better adaptation to climate adversities and photoperiod during the crop cycle. However, as undetermined cultivars have uneven maturity due to greater variation in flowering and length of the seed-filling periods compared to determined cultivars, this can affect the physiological quality of seeds produced in different thirds of the plant (Sharma et al., 2013; Kato et al., 2018). Although potentially more productive, in relation to cultivars of determined and semi-determined growth, which produce seeds little influenced by their position on the plant.

There are numerous studies on yield as a function of soybean plant growth habits (Rambo et al., 2002; Navarro Junior and Costa, 2002; Perini et al., 2012; Cella et al., 2014), however, information on physiological quality of seeds produced by plants of indeterminate habit in relation to the determined habit is incipient. These gaps bring to light the need for new studies to be created in order to evaluate and assist decision-making, as well as to determine the ideal technique to be adopted in the soybean of seeds production process.

Thus, investigative work involving new conventional genetic materials of soybean with early, medium and late cycles with different growth habits and in use by farmers, as to the physiological quality of seeds produced is necessary, in order to provide lots of seeds of superior quality of a product had when "niche market", and therefore has not attracted interest from large seed companies in the area in its multiplication.

This work aimed to evaluate the physiological quality of seeds from conventional soybean cultivars the different growth habits, harvested from three position in the plant canopy.

MATERIAL AND METHODS

Site description and field experiment

The soybean seeds were produced in the 2014/15 and 2015/16 agricultural seasons, located in Ipameri (17º45'25" S, 48º00'01" W and altitude of 800 m), located in the southeast of the State of Goiás, Brazil. The climate of the region is tropical Semi-humid (Aw), according to Kopper, high temperatures, with annual averages ranging between 19 and 26 °C and rainfall ranging from 1300 to 1700 mm, with rainfall in summer and dry in winter. The climatic regime during the periods of the seed fields for the two harvests (Fig. 1).

The soil where the seeds were produced was classified as dystrophic Red Yellow Latosol (Embrapa, 2013). The soil sample corresponded to the superficial layer, 0-20 cm in depth, in which the chemical analysis data were: pH ($CaCl_2$) = 5.2;H+Al = 2.2 $cmol_c$ dm^{-3}; Organic material = 28.0 g dm^{-3}; CTC = 5.34 $cmol_c$ dm^{-3}; base saturation =58.75 %; Ca = 1.8 $cmol_c$ dm^{-3}; Mg = 1.0 $cmol_c$ dm^{-3}; K = 126.0 mg dm^{-3}; P = 4.0 mg dm^{-3}; S = 3.4 mg dm^{-3}; B = 0.23 mg dm^{-3}; Zn = 2.9 mg dm^{-3}; Cu = 1.3 mg dm^{-3}; Fe = 61.1 mg dm^{-3}; Mn = 19.5 mg dm^{-3}; Mo = 0.5 mg dm^{-3}, and having the following physical characteristics: clay = 330 g kg^{-1}; silt = 90 g kg^{-1}; sand = 580 g kg^{-1}.

Experimental design and treatments

The experiment design was completely randomized in a 4×3 factorial scheme with four replications. The treatments consisted of seed samples from four conventional cultivars, developed by traditional breeding techniques, with different growth habits and ripening cycles (BRS 6780 - indeterminate growth habit, GM 7.9, 95-day cycle; BRS 6980 - growth habit undetermined, GM 6.9, 100-day cycle; BRS 7980 - determined growth habit, GM 7.9, 120-day cycle; BRS 8381 - semi-determined growth habit, GM 8.3, 130-day cycle; harvested at different plant canopy positions (TS - upper third; TM - middle third, TI - lower third) (Fig. 2).

Implementation and conduct of the experiment

The plots consisted of four lines of five meters in length, with 0.50 m between the lines, with the useful area the two central lines of the plot, totaling 5 m².

The base fertilization used was 360 kg ha^{-1} of NPK formulation 02-28-18, granule mixing compound. A mechanical seeder was used in the sowing procedure, aiming at a density of 17 emerged seedlings per linear meter, totaling 380,000 plants per hectare of cultivars BRS 6780 and BRS 6980; and density of 12 emerged seedlings per linear meter, totaling 270,000 plants per hectare of cultivars BRS 7980 and BRS 8381. The seeds

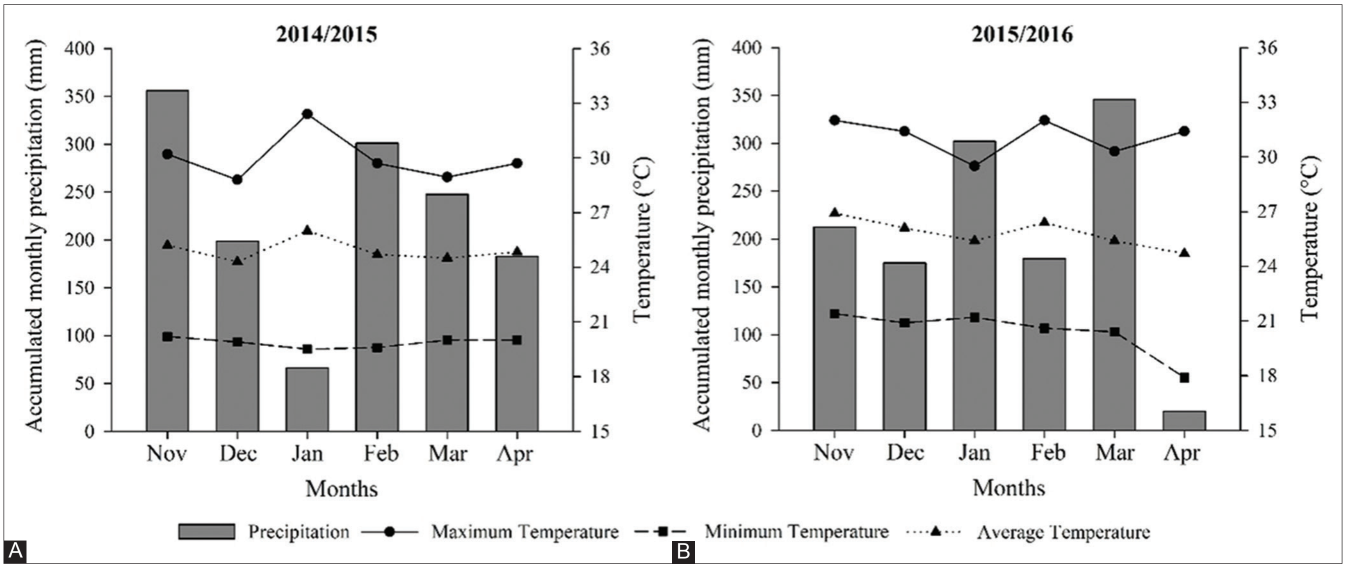

Fig 1. Accumulated monthly precipitation (mm) and maximum, mean and minimum temperature means in the period from November to April in the agricultural harvests: 2014/15 (A) and 2015/16 (B). Source: Ipameri Meteorological Station (INMET), Brazil.

Fig 2. Illustrative diagram of the upper (a), middle (b) and lower (c) thirds.

were previously treated with fipronil insecticide at a dosage of 0.37 kg i.a./100 kg of seeds. At sowing, the inoculant *Bradyrhyzobium japonicum* was added at a dose of 100 mL for each 50 kg of seeds. The seed categories used were C1 (certified first generation) and C2 (certified second generation) in the 2014/15 and 2015/16 harvests, respectively. Both harvests were cultivated in no-tillage area, second-crop corn stover.

Sowing took place in the first half of November 2014 and 2015. During the development of the cultivars, phytosanitary management was carried out according to technical recommendations for soybean cultivation in Brazil. Pest control was carried out in four stages, with the application of the active ingredients: diflubenzuron (50 g ha^{-1}), chlorpyrifos (1 L ha^{-1}), acephate (1 L ha^{-1}) and chlorfluazuron (0.5 l ha^{-1}). Weeds were managed post-emergence with the active ingredients cletodim (0.4 L ha^{-1}), chlorimuron-Ethil (30 g ha^{-1}), imazetapyr (300 mL ha^{-1}) and lactofen. (300 mL ha^{-1}). Three applications were made to control fungal diseases in both harvests, using the following active ingredients: piraclostrobin + epoxiconazole (600 mL ha^{-1}), carbendazim (800 mL ha^{-1}).

Evaluated tests

Harvesting was manual, with the plants being cut at ground level and the threshing performed by a stationary trailer, after the seeds reached the R8 stage, with moisture content recommended for harvesting ranging from 13.0 to 15.0% (w.b). For the harvesting procedure, first, the plants were selected which were in a perfect state without broken branches or pointers. From the threshed seed lots, samples corresponding to 1.0 kg were taken for each third of each cultivar, and later the seeds were packed in paper bags, identified and sent to the laboratory for analysis. Soon after the seed batches arrived at the laboratory, they were dried at a controlled temperature of 35 ºC until reaching a moisture content of ± 12%. After the seeds drying, we submitted them to the physiological quality tests.

- Moisture content - was determined by the standard greenhouse method, with forced ventilation, at 105 ± 3 ºC for 24 hours, with four 25-seed subsamples for each treatment (Brasil, 2009). The results were expressed as percentage, wet basis (w.b.).
- Germination test - the germination pattern test was determined in four replicates of 50 seeds distributed in germitest paper rolls, moistened with an amount of distilled water equivalent to three times the weight of the dry substrate. The rolls were grouped by replicates of each plot, and kept in a germination chamber at

25 ºC. The counting of normal seedlings took place on the 8th day after sowing (Brasil, 2009). The results were expressed as mean germination percentage.

- The first counting test - corresponded to the percentage of normal seedlings observed five days after the beginning of the germination pattern test (Brasil, 2009).
- Accelerated aging - we conducted the accelerated aging with 250 seeds, on canvas inside plastic boxes (gerbox), in a single layer, with no contact with the 40 mL distilled water contained in the bottom. We closed and maintained the boxes at 42 ± 2 °C for 48 hours (Krzyzanowski et al., 1999) in a BOD incubator (Biochemical Oxygen Demand). After this period, we divided 200 seeds into four subsamples of 50 seeds and performed the germination test as previously described. The number of normal seedlings counting occurred after five days of seed stay in the germinator, kept at 25 °C. After seed aging, we determined the moisture content by using the remaining 50 seeds, divided into two subsamples (Brasil, 2009).
- Electrical conductivity - we used in four subsamples of 50 seeds, previously weighed, soaked in plastic cups (300 mL) containing 75 mL deionized water. The cups were placed and kept in BOD chambers with a constant temperature of 25 ± 2 °C for 24 hours. The conductivity reading occurred with portable conductivity meter. The results were in $\mu S\ cm^{-1}\ g^{-1}$ seeds (Krzyzanowski et al., 1999).

Statistical Analysis

The physiological data on the seeds obtained in the two trials were initially subjected to individual variance analysis at 5% and 1% probability, according to the criteria established by Banzatto and Kronka (2006) for two-factor factorial tests. Subsequently, the joint variance of the variables common to both tests was analyzed. The effects of the treatments were studied, when significant, by Tukey test at 5% probability. Statistical calculations were performed using SISVAR 5.3 software (Ferreira, 2010).

RESULTS AND DISCUSSION

The moisture content of the soybean seed batches, determined at the beginning of the experiments, belonging to different genetic materials, harvested from the three positions of the plant canopy at the beginning of the analyses ranged from 10.6 to 12.2%. Therefore, these percentages of water found in the seeds are important for laboratory analysis, aiming to standardize tests and obtain reliable results.

The interactions between harvest x cultivar and cultivar x third significantly influenced the results of the germination, first counting, accelerated aging and electrical conductivity tests performed on conventional soybean cultivars harvested in different positions in the canopy of the plant. The harvest x third interaction influenced only the electrical conductivity test, and on the other hand, no significant effect of the harvest x cultivar x third on the tests was detected (Table 1).

The BRS 6780, BRS 6980 and BRS 7980 soybean cultivars (Table 2) showed germination in excess of 80% in the 2014/2015 harvest, and this value is within the minimum soybean seed sales standard in Brazil (> 80-85%) (Brasil, 2009). On the other hand, for the cultivar BRS 8381 the average germination value was 69.8%, below the minimum standard required, probably due to the longer cycle of this genetic material, together with the excess precipitation near the harvest time (late February and March) in this first harvest (Fig 1). Nevertheless, it is generally noted that in the 2014/15 harvest batches were obtained from higher quality conventional soybean genetic materials compared to the 2015/16 harvest.

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability.

In the 2015/16 harvest (Table 2) the germination percentages were generally below the value within the

Table 1: Summary of variance analysis (Mean Squares) for germination (GER), first counting (FC), accelerated aging (AA) and electrical conductivity (EC) tests performed on conventional soybean seeds

Source of variation	DF	Mean Squares			
		GER	FC	AA	EC
Harvest (S)	1	5280.6666 **	1093.5000 **	6176.0416 **	45736.4704**
Cultivar (C)	3	1944.2222 **	2260.1111 **	4115.1527 **	5129.4620**
Third (T)	2	1238.0416 **	1877.5416 **	3025.0416 **	209.3357^{NS}
S x C	3	322.4444 **	658.0555 **	2942.0416 **	5074.8377**
S x T	2	76.0416 ^{NS}	91.6250 ^{NS}	130.7916 ^{NS}	677.2211**
C x T	6	310.2638 **	379.6527 **	919.4861 **	236.6787**
S x C x T	6	127.1527^{NS}	88.5138^{NS}	82.1250^{NS}	60.8385^{NS}
Residue	72	42.9166	53.8333	34.3472	26.6673
CV (%)	-	8.2	10.4	8.3	7.13

**Significant according to the F test at 1% probability, ^{NS}Not Significant. DF - Degrees of freedom minimum soybean seed sales standard in Brazil (> 80-85%). It is probable that the reduction in rainfall during the seed filling phase (late January and February), coupled with high temperatures (Fig 1) in the 2015/16 harvest, may have affected the accumulation of seed reserves of the genetic materials tested, in addition to the excess precipitation occurring near the time of harvest (March) (Fig 1), directly affecting the germination power of the seeds produced, especially the cultivar BRS 8381, thus confirming the results obtained in the previous harvest (2014/15).

When harvested seeds were evaluated separately according to plant strata, i.e., upper, middle and lower, a significant difference was also observed between cultivar vs. third in terms of the physiological quality of seeds produced in the two harvests (Table 3). In general, it was found that the best quality soybean seeds were obtained in the upper and middle thirds of the plant and, on the other hand, for the lower third of the plant, poorer quality seeds were produced. These data are similar to those obtained by Flores (2016), who obtained better physiological seed quality in percentage values from the upper and middle strata of the plant, while for the lower stratum the values were the lowest.

Other research results also corroborate those of this study, such as Ferreira (1994), when evaluating the quality of soybean seeds as a function of the position on the plant, and finding that the pods from the middle third of the plant produced better seed quality, while the lower third produced the poorest quality seeds, as well as those of Adam et al. (1989), who found higher weight and better quality seeds in the upper third of the plant.

Table 2: Mean values for soybean seed germination as a function of harvest x cultivar interaction

Harvests	Soybean cultivar				
	BRS 6780	BRS 6980	BRS 7980	BRS 8381	Mean
	Normal seedlings (%)				
2014/2015	96.3^{aA}	87.7^{bA}	92.2^{aA}	69.8c^{A}	86.5
2015/2016	79.0^{aB}	65.7^{bB}	76.8^{aB}	65.2^{bA}	71.7
Mean	87.7	76.7	84.5	67.5	79.1

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability

Table 3: Mean values of soybean seed germination as a function of cultivar x third interaction

Soybean cultivar	Plant thirds			
	Upper	Middle	Lower	Mean
	Normal seedlings (%)			
BRS 6780	87.00^{aA}	85.00^{aA}	91.00^{aA}	87.67
BRS 6980	84.50^{aA}	77.25^{bB}	68.25^{cC}	76.67
BRS 7980	90.00^{aA}	86.50^{aA}	77.00^{bB}	84.50
BRS 8381	80.00^{aA}	67.00^{bC}	55.50^{c}D	67.50
Mean	85.37	78.93	72.93	79.09

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability

The fact that the upper stratum of the soybean plant produces seed batches of better physiological quality may be due to the greater photosynthetic activity of the leaves located in the apical region of the plant. On the other hand, the lower physiological quality of seeds produced on the lower part of the plant could be attributed to the intensity of shrubbing in this part, leading to decreased photosynthetic activity in the plant, as well as the creation of a favorable microclimate for proliferation of pathogens, mainly due to high humidity rates at the site.

In addition, Rambo et al. (2002) point out that soybean plants have an upper layer of dense leaves which hinders light penetrating to the lower strata, revealing that the upper and middle canopy strata make a major contribution to plant grain yield. Coupled with this, it is likely that the leaves of the lower stratum, being more shaded, perform less photosynthesis, providing a lower amount of assimilated to the seeds, which may affect physiological quality.

This type of response is relevant to understanding plant physiology regarding directing accumulated reserves for soybean (grains) product of economic interest, and to direct the work of plant breeding programs in selecting materials with superior behavior, in addition to improving pesticide application technologies throughout the canopy of the plant, especially the lower part (Vicente et al., 2016).

Soybean seed vigor, evaluated by the first counting test, was influenced by harvest vs. cultivar. The highest percentage of vigorous seedlings was obtained in the 2014/15 harvest from the BRS 6780 and BRS 7980 cultivars, which did not differ from each other (Table 4). In contrast, the lowest seedling vigor found was in BRS 8381, regardless of the harvest. In general, it can be noted that in the 2015/16 harvest, soybean seeds were obtained with lower vigor compared to the 2014/15 harvest, but the cultivars BRS 6780, BRS 7980 and BRS 7980 showed higher behavior than cultivar BRS 8381. regarding the quality of the seeds produced. The significant difference regarding seed vigor between the cultivars BRS 8381 compared to the other materials investigated can be attributed to the difference in cycles, as the long cycle of cv. BRS 8381 caused its harvest to coincide with high rainfall, especially in the second harvest, as highlighted, and not exactly due to the habit of growing soy plants.

Thus, the results obtained for vigor according to the first counting test are consistent with the viability results, in which cultivar BRS 8381 produced lower quality seed batches in both harvests evaluated (Table 4). For Botelho (2012), when seeds deteriorate, there is a progressive loss of vigor, presenting reduction in speed and uniformity of emergence, lower resistance to adverse conditions, a

Table 4: Mean values of first soybean seed count as a function of harvest x cultivar interaction

Harvests	Soybean cultivar				
	BRS 6780	BRS 6980	BRS 7980	BRS 8381	Mean
	Normal seedlings (%)				
2014/2015	82.50^{aA}	75.33^{bA}	82.50^{aA}	53.50^{cB}	73.45
2015/2016	74.16^{aB}	59.16^{bB}	71.83^{aB}	61.66^{bA}	66.70
Mean	78.33	67.25	77.16	57.58	70.07

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability

Table 5: Mean values of first soybean seed count as a function of cultivar x third interaction

Soybean cultivar	Plant third			
	Upper	Middle	Lower	Mean
	Normal seedlings (%)			
BRS 6780	76.25^{aB}	78.00^{aA}	80.75^{aA}	78.33
BRS 6980	78.50^{aB}	66.75^{bB}	56.50^{cC}	67.25
BRS 7980	85.50^{aA}	77.75^{aA}	68.25^{bB}	77.17
BRS 8381	71.25^{aB}	56.75^{bC}	44.75^{cD}	57.58
Mean	77.87	69.81	65.56	71.08

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability

decrease in the proportion of normal seedlings and, finally, loss of viability.

Among the factors that can affect seed quality, both vigor and viability, special emphasis is given to frequent rainfall at harvest, exposing the seeds to alternating cycles of low and high relative humidity, causing damage by moisture (Marcos Filho, 2015), as occurred principally in the second harvest. However, this problem has occurred quite frequently in recent years in the traditional planting regions of Goiás, Brazil, such as the center, southeast and southwest of the State. This has been mainly due to irregularities in rainfall at the beginning and middle of the harvest, which ends up prolonging the rainy season until April and May, often with above-average rainfall in those months. In this situation, the quality of late-cycle soybean seeds, whether conventional or transgenic materials are the most affected by harvest coinciding with the rainy season.

In addition to the seed harvest not coinciding with the rainy season, there are specific climatic requirements, especially regarding precipitation, for each stage of crop development, aiming to produce quality seeds. The germination-emergence and flowering-seed filling phases are more demanding in terms of water and there must not be water deficit. Studies by Costa et al. (2003; 2005), searching for the best regions of State Paraná. Brazil, for soybean seed production, found that moisture deterioration is one of the main factors contributing to reduced seed quality.

When the first germination counts were conducted with seeds from the upper, middle and lower strata of soybean plants, the interaction between cultivar vs. third of the plant was detected (Table 5). The seeds produced in the lower stratum had less vigorous seedlings, especially cultivar BRS 8381 which differed statistically from the other cultivars used in the test.

As reported above, this result is due to the longer cycle of this cultivar of the four cultivars evaluated, in which the seeds were more exposed to adverse conditions such as high humidity, with negative effects on vigor and viability, especially seeds produced in the lower stratum of the plant.

These results coincide with those of Flores (2016), who evaluated the quality of soybean seeds harvested according to strata of the plant, and found that the lower stratum had the lowest seed quality in two harvests. Here, as above, poorer quality seed batches were produced in the lower canopy of the plant.

On the other hand, cultivar BRS 6780 did not show statistical differences between strata, perhaps because it is the cultivar with the shortest cycle of the evaluated materials, causing its harvest not to coincide with the rainy season, thus explaining the better quality of its seeds, along with the cultivars BRS 6980 and BRS 7980, compared to the quality of the seeds produced by cultivar BRS 6780.

For the accelerated aging test, we analyzed the vigor data for normal seedlings of the harvest vs. cultivar interaction (Table 6). Results are consistent with normal seedling vigor determined in the first counting test, as well as viability in the germination test. In this situation, the late-cycle cultivar, BRS 8381, produced seeds of lower physiological quality compared to the other cultivars evaluated, BRS 6780, BRS 6980 and BRS 7980, with early to medium cycles in both harvests, certainly due to their stay in the field for a longer period of time, meaning the seeds were subject to the conditions of the environment, including rain at harvest.

The cycle difference between the materials studied was apparently of greater relevance to the physiological quality of the seeds produced, when compared to the different growth habits, regarding viability and vigor results. Thus, it is evident that variable environmental conditions (temperature, rainfall, relative humidity) during the seed filling period between the four cultivars, prior to harvesting, were preponderant in decreasing seed quality, especially of the later cycle cultivar BRS 8381.

As has been shown in previous research (Egli et al., 2005; Zorilla et al., 1994), high temperature, high relative humidity, and excessive rainfall during seed filling [R5 (start of seed filling) to R7 (end of seed filling, also called physiological

Table 6: Mean values of normal seedlings obtained in the accelerated aging test applied to soybean seeds as a function of harvest x cultivar interaction

Harvests	Soybean cultivar				
	BRS 6780	BRS 6980	BRS 7980	BRS 8381	Harvests
	Normal seedlings (%)				
2014/2015	95.16[aA]	86.16[bA]	83.00[bA]	49.66[cB]	78.50
2015/2016	70.16[aB]	44.50[cB]	76.00[aB]	59.16[bA]	62.45
Mean	82.66	65.33	79.50	54.41	70.47

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability

Table 7: Mean values of normal seedlings obtained in the accelerated aging test applied to soybean seeds as a function of cultivar x third interaction

Soybean cultivars	Plant third			
	Upper	Middle	Lower	Mean
	Normal seedlings (%)			
BRS 6780	83.50[bA]	73.00[cB]	91.50[aA]	82.67
BRS 6980	79.25[aB]	63.25[bC]	53.50[cC]	65.33
BRS 7980	87.75[aA]	83.75[aA]	67.00[bB]	79.50
BRS 8381	75.00[aB]	49.50[bD]	38.75[cD]	54.42
Mean	81.37	67.37	62.68	70.47

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability

Table 8: Mean values of electrical conductivity reading applied to soybean seeds as a function of harvest x cultivar interaction

Harvests	Soybean cultivar				
	BRS 6780	BRS 6980	BRS 7980	BRS 8381	Mean
	Electric conductivity (μS $cm^{-1}g^{-1}$)				
2014/2015	33.11[cB]	48.77[bB]	47.90[bB]	72.45[aB]	50.55
2015/2016	84.53[bA]	129.67[aA]	75.24[cA]	87.40[bA]	94.21
Mean	58.82	89.22	61.57	79.92	72.38

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability

maturity), stages according to Fehr and Caviness, 1977]; as well as the dry down period from R7 to R8 (harvest maturity) contribute to poor seed quality. Sometimes this poor seed quality is caused by disease infection of the seed enhanced by damp conditions; however, high temperatures can reduce seed quality without increased disease incidence.

The maturity group for the four cultivars from different based on the lengths of the growing cycles mentioned on methodology. So it can be said that timing for the significant periods described above would have been different, and the environmental factors affecting seed quality would have differed along with these changes in seed filling period and the dry down period after R7. A study conducted by Flores (2016), investigating the quality of soybean seeds produced in two consecutive harvests, between cultivars with determined and undetermined growth habit, obtained seedling vigor averages between 72 and 73% for accelerated aging, attributed to the climatic conditions of the seeds in the field. These vigor values are close to those found in this study.

When harvested seeds were evaluated separately according to plant strata, i.e., upper, middle and lower, significant differences were also observed between cultivars (Table 7). In general, the lower third belonging to cultivar BRS 8381 had the worst seed quality compared to the other cultivars and thirds evaluated. Similar results were obtained by Flores (2016), who found lower quality soybean seeds from the lower stratum of late-cycle cultivars.

The results of the electrical conductivity test were affected by the different responses between harvest vs. cultivar (Table 8). In general, it was found that BRS 6780 (95-day cycle) was the cultivar with the highest seed vigor in the 2014/15 harvest, with higher physiological seed quality than the longer-cycle cultivars, due to reducing seed exposure to field conditions.

In the second harvest (2015/16), in general, the worst quality seed batches were obtained, even for cultivar BRS 6980, the previous results of which confirmed their superiority in terms of seed quality. For cultivar BRS 8381, previous results on inferior seed quality were ratified. It is worth mentioning here that the abovementioned problems of rain in the harvest, especially in the month of March 2015/16, when it rained 350 mm (Fig 1), corroborated the decrease in soybean seed quality, especially in later materials.

When harvested seeds were evaluated separately according to plant strata, a significant difference was observed for the electrical conductivity readings in the harvest versus third interaction (Table 9). Of the strata, for the two harvests, a difference in vigor was observed. In general, it can be observed that the lower third was that with the highest seed vigor when it was divided into strata in the two harvests, results that partially contradict the information so far on this subject. In contrast to this result, Ferreira (1994) found that the pods of the middle third of the plant produced better seed quality, while those of the lower third produced lower quality seeds.

The data on the interaction between cultivar vs. third was significant, indicating that there was a differential response between cultivars when evaluated in the lower, middle and upper strata (Table 10). The lower third showed the best vigor (47.59) of seeds belonging to cultivar BRS 6780. These results are in contrast to those obtained by Flores (2016), evaluating soybean cultivars of determined and undetermined growth habit in two harvests, who found that the lower stratum presented the worst seed quality in terms of vigor.

Table 9: Mean values of electrical conductivity reading applied to soybean seeds as a function of harvest x third interaction

Harvests	Plant third			
	Upper	Middle	Lower	Mean
	Electrical conductivity (μS $cm^{-1}g^{-1}$)			
2014/2015	57.47^{aB}	47.97^{bB}	46.22^{bB}	50.55
2015/2016	90.85^{bA}	99.10^{aA}	92.68^{bA}	94.21
Mean	74.16	73.53	69.45	72.38

Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability

Table 10: Mean values of electrical conductivity reading applied to soybean seeds as a function of cultivar x third interaction

Soybean cultivar	Plant third			
	Upper	Middle	Lower	Mean
BRS 6780	65.25^{aB*}	63.61^{aC}	47.59^{bC}	58.82
BRS 6980	88.91^{aA}	92.57^{aA}	86.17^{aA}	89.22
BRS 7980	61.58^{aB}	58.62^{aC}	64.51^{aB}	61.57
BRS 8381	80.89^{aA}	79.35^{aB}	79.53^{aA}	79.92
Mean	74.15	73.53	69.45	217.13

*Means followed by the same letter, lowercase in the row and uppercase in the column, do not differ statistically according to the Tukey test at 5% probability

When comparing the vigor of seeds from the upper and middle thirds of the soybean plant, parts which, so the consensus goes, produce better quality seeds compared to the lower part of the plant, it is noted that the cultivars BRS 6780 (growth habit undetermined,) and BRS 7980 (determined growth habit) stand out from the others, behavior attributed largely to the precocity of these materials in comparison to the others rather than the growth habits themselves. results in agreement with the study of Kato et al. (2018) when they verify that indeterminate growth habit did not much influence seed weight or its uniformity in relation to cultivars of determined growth habit.

CONCLUSIONS

The physiological quality of seeds from the BRS 6780, BRS 6980, BRS 7980 and BRS 8381 soybean cultivars were influenced by the harvest but were possibly more strongly linked with variable environmental conditions (temperature, rainfall, relative humidity) during the flowering and seed filling periods. Soybean cultivars the earlier cycle produce seed batches of superior physiological quality, regardless of plant growth habit. Seeds of soybean cultivars of indeterminate and determined growth habits and earlier cycle, harvested from the upper and middle thirds of the plant, are of better quality. Cultivars BRS 7980 and BRS 8381, of semi-determined and determined habits and later cycles, produce inferior seeds, regardless of the third of the harvested plant.

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Authors' contributions

All authors contributed to the idea, experimental planning, experiments, data analysis, writing and correction of the manuscript. All authors read and approved the final version of the manuscript.

REFERENCES

Adam, N. M., M. B. Mcdonald and P. R. Henderlong. 1989. The influence of seed position, planting and harvesting dates on soybean seed quality. Seed Sci. Technol. 17: 143-152.

Banzatto, D. A. and S. N. Kronka. 2006. Experimentação Agrícola. 4th ed. Funep, Jaboticabal, p. 237.

Bornhofen, E., G. Benin, D. Galvan and M. F. Flores. 2015. Épocas de semeadura e desempenho qualitativo de sementes de soja. Pesq. Agropec. Trop. 45: 46-55.

Botelho, F. J. E., J. A. Oliveira, E. V. R. Von Pinho, E. R. Carvalho, I. B. D. Figueiredo and A. Andrade. 2016. Qualidade de Sementes de Soja Obtidas de Diferentes Cultivares Submetidas à Dessecação com Diferentes Herbicidas e Épocas de Aplicação. Vol. 10. Agro@mbiente, Brazil, pp. 137-144.

Brasil. 2009. Regras Para Análise de Sementes. Secretaria de Defesa Agropecuária. MAPA/ACS, p. 395.

Castro, E. M., J. A. Oliveira, A. E. Lima, H. O. Santos and J. I. L. Barbosa. 2016. Physiological quality of soybean seeds produced under artificial rain in the pre-harvesting period. J. Seed Sci. 38: 14-21.

Cella, V., J. F. Silva, P. H. Azevedo, V. H. Azevedo and L. L. Hoffman. 2014. Efeito da dessecação em estádios fenológicos antecipados na cultura da soja. Biosci. J. 30:1364-1370.

Chirchir, G. J., M. Mwangi, D. O. Nyamongo and J. P. Gweyi-Onyango. 2016. Soybean farm-saved seed viability and vigor as influenced by agro-ecological conditions of Meru South Sub-County, Kenya. J. Appl. Biosci. 101: 9634-9642.

Costa, N. P., C. M. Mesquita, J. B. França-Neto, A. C. Maurina, F. C. Krzyzanowski, M. C. Oliveira and A. A. Henning. 2005. Validação do zoneamento ecológico do estado do Paraná para produção de sementes de soja. Rev. Bras. Sementes 27: 37-44.

Costa, N. P., C. M. Mesquita, A. Maurina, J. B. F. Neto, F. C. Krzyzanowski and A. A. Henning. 2003. Qualidade fisiológica, física e sanitária de sementes de soja produzidas no brasil. Rev. Bras. Sementes 25: 128-132.

Egli, D. B., D. M. TeKrony, J. J. Heitholt and J. Rupe. 2005. Air temperature during seed filling and soybean seed germination and vigor. Crop Sci. 45: 1329-1335.

Embrapa. 2013. Sistema Brasileiro de Classificação de Solos. 3rd ed. Embrapa Solos, Brasília, p. 353.

Fang, C., Y. Ma, S. Wu, Z. Liu and Z. Wang. 2017. Genome-wide association studies dissect the genetic networks under lying agronomical traits in soybean. Genome Biol. 18: 161.

Fehr, W. R. and C. E. Caviness. 1977. Stages of Soybean Development. Iowa State University, Ames, p. 12.

Ferreira, B. M. 1994. Influência da Posição da Vagem, da Época de Colheita e da Cultivar na Qualidade de Sementes de Soja (*Glycine max* (L.) Merrill). Dissertação (Mestrado em Agronomia/ Fitotecnia)-Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal.

Ferreira, D. 2010. Sisvar. Sisvar for Windows v. 5.3: Computer Program Manual. Stat Soft Inc., Tulsa, OK.

Finoto, E. L., T. Sediyama, J. A. A. Albuquerque, M. B. B. Soares, J. A. Galli, P. S. C. Júnior and P. H. S. Menezes. 2017. Antecipação e retardamento de colheita nos teores de óleo e proteína das sementes de soja, cultivar Valiosa RR. Sci. Agropecu. 8: 99-107.

Flores, M. F. 2016. Qualidade Fisiológica e Rendimento de Sementes de Soja em Função do Hábito de Crescimento da Planta. Tese (Doutorado em Agronomia/Fitotecnia)-Universidade Federal do Paraná.

Franca Neto, J. B., F. C. Krzyzanowski, A. A. Henning, G. P. Pádua, I. Loríni and F. A. Henning. 2016. Tecnologia da produção de semente de soja de alta qualidade: Série sementes. EMBRAPA SOJA, Londrina, p. 12.

Kato, S., T. Sayama, M. Shimoto, S. Yumoto, A. Kikuchi and T. Nishio. 2018. The effect of stem growth habit on single seed weigh tand seed uniformity in soybean (*Glycine max* (L.) Merrill). Breed. Sci. 68: 352-359.

Krzyzanowski, F. C. and R. D. Vieira. 1999. Deterioração controlada. In: Krzyzanowski, F. C., R. D. Vieira and J. B. F. Neto. (Eds.), Vigor de Sementes: Conceitos e Testes. ABRATES, Londrina, pp. 61-68.

Marcos-Filho, J. 2015b. Fisiologia de Sementes de Plantas Cultivadas. 2nd ed. Abrates, Londrina, p. 660.

Marcos-Filho, J. 2015a. Seed vigor testing: An overview of the past, present and future perspective. Sci. Agric. 72: 363-374.

Navarro, H. M. and J. A. Costa. 2002. Contribuição relativa dos componentes do rendimento para produção de grãos em soja. Pesqu. Agropecu. Bras. 37: 269-274.

Paixão, C. S. S., C. P. Chrispin, R. P. Silva, L. A. S. Girio and M. A. Voltarelli. 2017. Physical and physiological quality of soybean seeds at three speeds of the harvester. Rev. Bras. Eng. Agríc. Ambient. 21: 214-218.

Perini, L. J., N. S. F. Júnior, D. Destro and C. E. C. Prete. 2012. Componentes da produção em cultivares de soja com crescimento determinado e indeterminado. Semin. Ciênc. Agrár. 33: 2531-2544.

Procópio, S. O., A. A. B. Junior, H. Debiasi, J. C. Franchini and F. Panison. 2013. Plantio cruzado na cultura da soja utilizando uma cultivar de hábito de crescimento indeterminado. Agraria 56: 319-325.

Rambo, L., J. A. Costa, J. L. F. Pires, G. Parcianello and F. G. Ferreira. 2002. Rendimento de grãos da soja e seus componentes por extrato do dossel em função do arranjo de plantas e regime hídrico. Sci. Agrar. 3: 79-85.

Saryoko, A., K. Homma, I. Lubis and T. Shiraiwa. 2017. Plant development and yield components under a tropical environment in soybean cultivars with temperate and tropical origins. J. Plant Prod. Sci. 20: 375-383.

Sharma, S., A. Kaur, A. Bansal and B. S. Gill. 2013. Positional effects on soybean seed composition during storage. J. Food Sci. Tech. 50: 353-359.

Vicente, D., I. Schuster, F. Lazzari, J. P. D. Paranzini, M. A. R. Oliveira and C. E. C. Prete. 2016. Mapping and validation of molecular markers of genes Dt1 and Dt2 to determine the type of stem growth in soybean. Acta Sci. Agron. 38: 61-68.

Xavier, T. S., D. J. Daronch, J. M. Peluzio, F. S. Afférri, E. V. Carvalho and W. F. Santo. 2015. Época de colheita na qualidade de sementes de genótipos de soja. Comunicata Sci. 6: 241-245.

Zanon, A. J., N. A. Streck, T. S. M. Rocha, C. A. Alberto, A. C. Bartz, G. M. Paula, R. Tomiozzo, L. C. Costa, C. A. Fensterseifer, E. L. Tagliapietra, A. P. Cardoso, P. S. Weber and K. P. Bexaira. 2016. Growth habit effect on development of modern soybean cultivars after beginning of bloom in Rio Grande do Sul. Bragantia. 75: 446-458.

Zorilla, G., A. D. Knapp and D. C. McGee. 1994. Severity of phomopsis seed decay, seed quality evaluation, and field performance of soybean. Crop Sci. 34: 172-177.