Australian Journal of Crop Science AJCS

AJCS 13(07):1155-1161 (2019) ISSN:1835-2707
doi: 10.21475/ajcs.19.13.07.p1674

Productive potential and seed quality of soybean genotypes with different maturity groups

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Abstract

Soybean has economically stood out worldwide. In MATOPIBA region of Brazil (Maranhão, Tocantins, Paiuí e Bahia) it is the most economically important crop with participation in the country's GDP growth. Due to this great growth economic and the incentive to the production of this oilseed, this study aimed to understand the behavior and physiological quality of soybean genotypes and to determine the productive potential of soybean seeds of different cultivars in the Cerrado of the State of Piauí. To this end, an experiment was carried out at Celeiro Farm, located in Serra do Quilombo, municipality of Monte Alegre do Piauí. Sowing followed the usual standards and was carried out on January 10, 2016. The experiment was set up in a randomized complete block design with four replicates. The treatments consisted of five cultivars of INTACTA RR2 PRO soybean, with different maturity groups: C1: MG 8.6, C2: MG 8.3, C3: MG 8.6.1, C4: MG 7.9 and C5: MG 8.5. The analyzed variables were: plant height, number of nodes, internode length, pod length, number of grains per pod, number of grains per plant, one thousand seed weight, productivity, first germination count, germination, seedling length, germination speed index and seedling dry mass. The results indicated that the best cultivars were: C5:TMG 2185 IPRO for plant height, internode length and pod length, and C4: BÔNUS IPRO for number of grains per pod, number of grains per plant, one thousand seed weight, and productivity. Considering the first count, germination, and germination speed index, the best cultivar was C5.

Keywords: yield components; *Glycine max* (L.) Merrill; maturity groups.
Abbreviations: PH_Plant height, NN_Number of nodes, IL_Internode length, PL_Pod length, NGPO_Number of grains per pod, NGPL_Number of grains per plant, TSW_One thousand seed weight, PROD_Productivity, FGC_First germination count, G_Germination, SL_Seedling length, GSI_Germination speed index, SDM_Seedling dry mass.

Introduction

Soybean (*Glycine max* L. Merrill), a commodity of the current market, has been causing intense interest in the majority of rural producers both in Brazil and in the world (Latorraca et al., 2011). Brazil is the world's second largest producer of soybeans, losing only to the USA (Oliveira et al., 2018) also occupying this position as an exporter of soybean grain, meal, and oil (Barbosa et al., 2013).
The cultivated area in Brazil is over 35.000 hectares, with a productivity of 3.394 kg ha^{-1}, with a production of over 119.000 tons produced in 2014/15 (Conab, 2018).
The Cerrado in the State of Piauí presents a tropical climate of Central Brazil, hot with average above 18°C every month, semi-humid with 4-5 dry months (Embrapa, 2015). It is located in the MATOPIBA region (encompassing the states of Maranhão, Tocantins, Piauí and Bahia), and has stood out in the Brazilian scenario due to its flat topography, deep soils and favorable climate for the development of agriculture (Alcântara Neto et al., 2010), allowing agricultural expansion in this region. In the crop year 2017/2018, the planted area, productivity, and production corresponded to 1.534,2 hectares, 2.779 kg ha^{-1} and 4.263,5 tons, respectively (Conab, 2018).
Based on the growing search for soybeans, research has been optimized in the breeding area, investigating the performance of new cultivars with high productivity and adaptation to the most distinct soil and climatic conditions, besides presenting resistance or tolerance to certain conditions (Barbosa et al., 2013).
Periodically, innumerable soybean cultivars have been launched in the national market. However, there is still a predominance of cultivars with a reduced genetic base (Latorraca et al., 2011; IITA, 2009). In this context, the use of cultivars with greater productive potential for the soil and

climate conditions of the region is highly sought after (Barbosa et al., 2013).

In addition to the edaphoclimatic conditions of each region, it is necessary to take into account the pests and diseases existing in each locality, since they significantly limit productivity and production, with losses varying from 60 to 80% of soybean (Bonde et al., 2006; Twizeyimana et al., 2008). Thus, using resistant or tolerant soybean cultivars to local disease pests can be an economically viable practice of controlling soybean diseases and pests (Herbek and Bitzer, 2009), increasing yields and reducing the use of agrochemicals as they tolerate the attacks of pests and diseases in the crop (Staton and Thelen, 2009).

The maturation group of soybean genotype is also relevant because it is related with planting date and must be respected by each locality (Staton and Thelen, 2009). Therefore it is of great importance to study different soybean cultivars with different groups of maturations by locality (Herbek and Bitzer, 2009). So, cultivars with more adaptation to each region can be taken into account to combat the pests and diseases of each area (Helsel and Minor, 2003).

There are several known cultivars adapted to different regions and resistant or tolerant to various diseases and pests of such as INTACTA RR2 PROe cultivars. However, they differ in maturation groups and have their particularities as improved cultivars, which stands out to each. Staton and Thelen (2009) and Rouse (2007) pointed out that the use of genetically improved cultivars has the main objective of solving this problem, leaving the cultivar resistant or tolerant to pests and diseases, increasing yield and productivity of cultures.

Therefore, development of research is essential to define potential of germplasms that may contribute to desirable aspects. In addition, the soil fertility and the rainfall regime of the region must be taken into account along with the potential of cultivars to be sown (Fiorese, 2013). This is because the climate directly affects soybean growth and yield since its development and production are directly related to climatic elements and to the maturity group (Chen and Wiatrak, 2010). For this reason, this study aimed to determine the productive potential and physiological quality of soybean seeds cultivars in the Cerrado, State of Piauí, indicating the most suitable genotypes for the region.

Results and Discussion

The analysis of variance evidenced significant differences at 1% probability among genotypes which can be observed for the traits: plant height (PH), internode length (IL), pod length (PL), number of grains per pod (NGPO), one thousand seed weight (TSW) and 5% probability for the number of grains per plant (NGPL) (Table 3).

The classification of coefficients of variation depended on the evaluated attributes and their positions, since there is a variation according to the degree of maturation of each cultivars. Another relevant point is the rapid flowering of the genotypes when subjected to low latitudes, as they reach the critical photoperiod (Setyiono et al., 2010).

After checking the significance of treatments, the mean values of PH, IL, PL, NGPO, NGPL, TSW, and PROD were broken down aiming to find the most suited to the study region (Table 4).

Regarding the agronomic performance of the genotypes, cultivar 5 was more prominent for average plant height, internode length and pod length. It is considered a medium-cycle cultivar at this latitude, with a degree of maturity of 8.6. This is because cultivars with a longer maturity group stay longer in the field, causing a greater vegetative growth of the plant, a larger accumulation of reserve coming from the long juvenile period (Amorim et al., 2011).

Another important factor is the increase in the average temperature higher than 24°C, which accelerates the vegetative growth of the plant (Sediyama et al., 2015). Thus, temperatures around 30°C, which observed during the conduction of this experiment, collaborated for the adequate development of the cultivars studied, especially cultivar TMG 2185 IPRO.

With respect to the IL of the main stem, cultivar C5 was superior to the others, and the other four did not differ statistically among others. This probably occurs due to the atypical climatic conditions observed in this period. This result is consistent with those reported by Barbosa et al. (2013) when evaluated a soybean plant with high productive potential.

In soybean cultivation, late maturity and high plant height are attributes that usually confer greater competitive fitness to the crop (Fiorese, 2013). In general, these variables are usually associated with grain production, which in turn, is related to the phytomass fraction. This agrees with Amorim et al. (2011), Herbek and Bitzer (2009), who observed that later cycle plants tend to grow more due to the longer vegetative period, caused by the long juvenile period, thus requiring more time to reach the reproductive stage. In another study accomplished by Zanon et al. (2015) and Staton and Thelen (2009), the authors found that cultivars with different maturation groups sown at the same time had a reduction in the cultivar cycle in all sowings at two cultivation sites. This was also verified by Trentin et al. (2013) and by Herbek and Bitzer (2009). Therefore, the late cycle/maturity cultivars can present a higher productivity response under conditions of water stress. Cultivars within longer maturation group have better potentials, since early-mature cultivars may have early flowering, influenced by sowing time, thus reducing plant height and grain yield (Embrapa, 2004; Herbek and Bitzer, 2009).

In general, most of the gains in production are results of the increase in the total number of pods per plant, especially when higher yields are obtained (Barbosa et al., 2013). Reinforcing the results observed in this research, the cultivars with higher degree of maturation also presented higher pod length, and cultivar 2 and 5 were superior to cultivar 3, with significant differences. This may have occurred because of the good distribution of the climatic elements (Figure 1) because the climatic conditions are directly related to the vegetative development and yield of grains (Kapoor et al., 2010).

The production of dry mass reflects the potential accumulation of the plant for use in the formation of reproductive structures and grain filling (Barbosa et al., 2013; Fiorese, 2013). As the rainfall is essential for this development because both excess

Table 1. Soil chemical properties of the experimental area of the Celeiro Farm in the municipality of Monte Alegre do Piauí, State of Piauí, 2016.

Depth	pH	P (mel)	K	CTC	Ca	Mg	Al	OM
cm	$CaCl_2$	---Mg.dm^{-3}---		-----------Cmolc.dm^{-3}---------				g.dm^{-3}
00-20	5.4	79.6	40	8.0	3.10	1.50	0.14	20.5
20-40	4.8	23.8	51	6.9	1.60	0.90	0.18	16.9

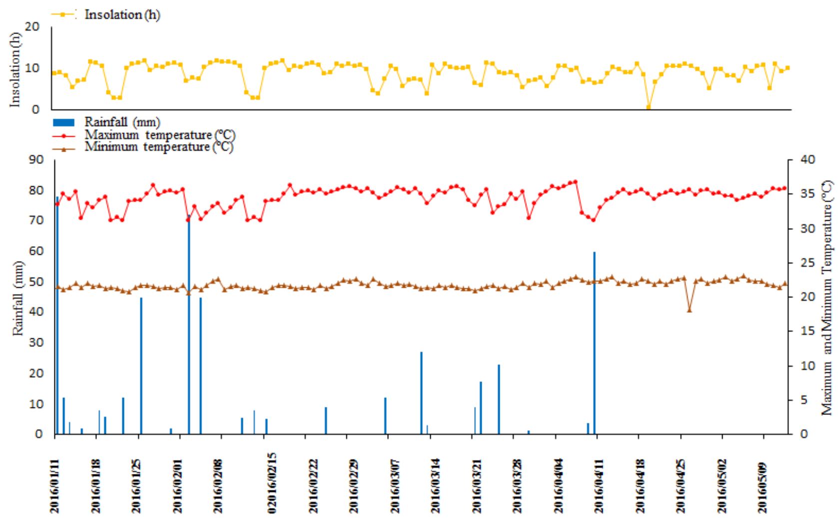

Fig 1. Daily temporal variation of rainfall (mm), maximum and minimum temperature of air (ºC) and insolation (h) from 2016/01/11 to 2016/05/12.

Table 2. Soybean cultivars of different cycles and maturation groups used in the experiment.

	Cultivars				
Characteristics	OPUS IPRO C1: MG 8.6	M8349IPRO C2: MG 8.3	M8644IPRO C3: MG 8.6.1	BÔNUS IPRO C4: MG 7.9	TMG2185IPRO C5: MG 8.5
Maturation group	8.6	8.3	8.6	7.9	8.5
Growth habit	Determinate	Determinate	Determinate	Determinate	Determinate
Pubescence Color	brown	gray	gray	gray	gray
Flower color	purple	purple	purple	purple	purple
Bedding	resistant	resistant	moderately resistant	moderately resistant	moderately resistant

Table 3. Summary of analysis of variance for plant height (PH), number of nodes (NN), internode length (IL), pod length (PL), number of grains per pod (NGPO), number of grains per plant (NGPL), one thousand seed weight (TSW) and productivity (PROD).

SV	DF	Mean squares							
		PH	NN	IL	PL	NGPO	NGPL	TSW	PROD
Treatment	4	70.7**	0.5^{ns}	0.7**	0.16**	0.1**	1351.9*	3171.5**	58712.6**
Error	12	5.2	0.6	0.04	0.02	0.02	414.3	20.89	14638.2
C.V. (%)		6.87	7.15	7.04	3.42	6.11	30.41	2.94	16.65

**Significant at 1% probability; *significant at 5% probability and NS non-significant by Tukey's test.

Table 4. Mean values of plant height (PH), internode length (IL), pod length (PL), number of grains per pod (NGPO), number of grains per plant (NGPL) and one thousand seed weight (TSW).

Treatment	PH	IL	PL	NGPO	NGPL	TSW	PROD
1	32.98 b	3.01 b	3.94 ab	1.89 b	42.50 b	143.14 b	1890.25 b
2	30.22 b	2.66 b	4.11 a	2.10 ab	71.25 ab	151.06 b	1982.50 b
3	30.87 b	2.73 b	3.69 b	1.91 b	59.15 ab	148.06 b	1902.50 b
4	31.75 b	2.89 b	3.97 ab	2.38 a	92.85 a	203.58 a	2348.30 a
5	40.57 a	3.72 a	4.23 a	2.09 ab	68.95 ab	130.35 c	1684.30 c
CV (%)	6.87	7.04	3.42	6.11	30.41	2.94	16.25

Table 5. Analysis of variance for the first germination count ($1^{st}C$), germination, seedling length (SL), germination speed index (GSI), seedling dry mass (SDM).

SV	DF	Mean Squares				
		$1^{st}C$	G	SL	GSI	SDM
Treatment	4	0.079**	0.042**	8.325**	72.895**	0.025^{ns}
Error	15	0.006	0.004	0.763	4.305	0.026
CV (%)		11.56	8.39	9.14	9.26	34.43

** significant at 1% probability ($p \leq .01$). ^{ns} non-significant; Source of variation (SV), Coefficient of variation (CV), Degrees of freedom (DF).

Table 6. Breakdown of the means of treatments for the parameters: First Count ($1^{st}C$), Germination (G), Seedling Length (SL) and Germination Speed Index (GSI).

Cultivar	$1^{st}C$ (%)	G (%)	SL (mm)	GSI
1	59.5 b	73.0 b	112.37 a	20.821 b
2	59.0 b	73.0 b	105.90 a	20.821 b
3	61.0 b	75.0 b	92.54 b	22.226 b
4	57.0 b	69.5 b	76.67 c	20.738 b
5	90.5 a	95.0 a	86.32 bc	29.693 a
C.V. (%)	11.56	8.39	9.14	9.26

and deficit impair the uniformity and performance of the plant (Shrivastava and Kumar, 2015); thus, reducing crop yields and raising economic damage to the farmer.

The upper limits for the number of seeds per pod and seed size are determined genetically. However, these two components can still undergo significant changes, thus raising the yield of the genotype (Sayama et al., 2017). These changes in yield can be caused by several factors, such as changes in the environmental elements (relative humidity and air temperature, radiation, precipitation), amount of weeds and pathogens in the crop, agricultural practices, sowing season, maturation group, fertilization (Allen et al., 2017, Cafaro La Menza et al., 2017), among others.

Cultivar 4 obtained significant prominence in the agronomic traits such as grains per pod and number of grains (Table 4). This difference diverges from the results presented by Custódio (2005), who states that these attributes depend on a set of factors, mainly the size and weight of seeds. These factors, in turn again, depend on the greater vigor of the plant and a longer fruiting period.

The one thousand seed weight and the productivity were also significant, in which cultivar 4 was superior to the others. This can be explained by the good distribution of rainfall during the whole experimental period because the soybean crop needs 450 to 850 mm of well distributed water during its cycle for its good development (Franke, 2000). This is because cultivar 4 was more benefited by the climatic elements because the difference of days between genotypes was the predominant factor in the results found. Chen and Wiatrak (2010) also observed a direct influence of the climatic elements on the maturity groups, causing a discrepancy in the behavior of the plants.

This variability in rainfall is one of the main factors in the oscillations and also in the yields and production of any crop (Dienice and Canever, 2015).

After the field analysis, laboratory analysis was performed. Table 5 lists the results of the analysis of variance for the first count ($1^{st}C$), germination (G), seedling length (SL), germination speed index (GSI) and seedling dry mass (SDM). There was a significant difference for the variables studied, except for the dry mass of seedlings, evidencing that the cultivars have different physiological characteristics.

After checking the significance of difference between treatments, mean values were broken down to determine the best cultivar considering the traits first count ($1^{st}C$), germination (G), seedling length (SL) and germination speed index (GSI) (Table 6).

It can be seen in Table 6 that for the first count ($1^{st}C$), percentage of germinated seeds (G) and germination speed index (GSI), cultivar 5 (maturity group of 8.5) was shown to be significantly superior to the other cultivars. Germination was 95% higher than that recommended for soybean crops, which is above 80%, and the others were lower than those recommended by the seed analysis (Mapa, 2013). The First count was above 90%, which shows that these cultivars of different maturity groups have different behaviors. A similar result was reported by Silva et al. (2010), who studied different soybean varieties and observed different behaviors for the cultivars analyzed.

This was probably because it remained longer in the soil, which resulted in greater vegetative growth and the production of a greater amount of photoassimilates. It also might be due to the even distribution of rainfall, since water is the most important resource that the plant needs for its growth and functioning, thus promoting a better filling of seeds. In the absence or lack of water plants undergo stress which may limit their growth and development (Taiz and Zeiger, 2013). Thus, in addition to the environmental factor, the genetic factor was decisive in the expression of the potential in the plant, since it contributes in several characteristics of soybean development, affecting the morphological, phenological and physiological attributes of the plant (Van Roekel et al., 2015; Carvalho et al., 2017).

Among the genetic characteristics, the maturation group is a criterion of significant relevance, being behind only the yield, since it reflects in all the development of the plant in the field

(Carvalho et al., 2017). In this case, the maturation group 8.5 was neither late nor early, which possibly made it more responsive to the physiological quality of seeds in the characters 1^{st}C, G and GSI. This can be explained because a variety with a smaller maturation group may present a reduced number of leaves with faster development time, compared to a variety in later maturation groups which may progress slower (Carvalho et al., 2017). Thus, the maturation group affects the development of soybean and consequently the formation and quality of the seeds. Nevertheless, for the seedling length trait, there is a divergence with the other variables, with a significant difference between cultivars 1, 2 and 4, with the first two being statistically superior. This shows that this variable cannot identify the best or the worst cultivar in relation to seed quality. The study on the quality of seeds as a whole is of the utmost importance, with the germination and emergence of seedlings being considered the main characteristics of seed quality, through them, the sowing rates can be determined for the approval and seeds be certified for commercialization (Carvalho and Nakagawa, 2012). For the germination speed index (GSI), there was a similar behavior to the germination, indicating that the GSI and G are related, where seeds with a higher germination will have a higher germination speed index. This is related to the physiological quality of seeds. In general, the values indicate that the physiological quality of seeds may be associated with the genetic factors due to variation of varieties in studied factors. However, G is related to the number of germinated normal seedlings, whereas GSI is corresponding to the speed at which the seeds germinate, because some seeds germinate slowly (Tan et al., 2017). The authors also affirm that GSI is an indicator of seed vigor, which in this research gives greater vigor to the maturation group 8.5. The cultivars studied here were subjected to the same conditions, which are recommended for the study region. However, cultivars 4 and 5 were superior to the others, and cultivar 5 showed a better development for the plant growth and cultivar for components of crop yield and seed quality. It is evident that more studies on maturity groups and on soil and climatic conditions are required. So that, it can identify which cultivar stands out in stability and adaptability of planting and locality conditions.

Materials and methods

Conduction of study

The experiment was carried out in the agricultural year 2015/16 in the municipality of Monte Alegre do Piauí, State of Piauí, in the experimental field of Celeiro Farm (09º 21’12”S, 45º07’42”W and 453 m) located in Serra do Quilombo. Soil analysis (Table 1) and fertilization were performed according to the results required for soil chemical correction. The soil of experiment area was classified as Typical Dystrophic Yellow Latosol with a moderate medium texture at Cerrado flat relief (Santos et al., 2013). According to the Köppen classification, the climate of the region was classified as tropical hot humid, Aw, with the well-defined dry season, with an average rainfall of 1,000 mm, the average annual temperature of 26 °C. Average rainfall and temperature in the area during the growing period are shown in Figure 1.

Experimental design

The experiment was a randomized complete block (DBC) design with five treatments and four replications and each plot sown was 200 m^2 (10 m x 20 m), totaling 5130 m^2 of the experimental area. The sowing populations were established from the germination correction performed according to the germination percentage of each cultivar.

Plant genotypes as teratments

Five soybean cultivars with different maturity groups were used (Table 2).

Traits measured

Before sowing, seeds were treated with fungicides regularly used by the farm. Fertilization was also applied with the aid of a tractor and a fertilizer launcher. Potassium chloride at a dose of 200 kg ha^{-1} and a mix of Map + Supersamples + Mipceleiro at a dose of 220 kg ha^{-1}, with a ratio of 100-100-20 kg ha^{-1}, were used, respectively.

The sowing was carried out on 2016/01/11. The opening of sowing furrows was performed using mechanical traction, 0.50 m spaced apart.

The harvest was carried out on 2016/05/12, where four central rows were used, excluding 2.5 m at each side of the rows, as a border, totalizing a useful area of 20 m^2.

Evaluation of the field

In the field, the following characteristics were evaluated: Plant height: measured with a measuring tape, from the base of the plant to the end of the main stem in cm (Bohn et al., 2016); Length of pod (cm) and number of internodes (cm): measured using a digital caliper (1 mm), from the insertion to the tip of the pod and from one node to the other (Silva, 2013).

Number of pods per plant: the number of pods of 10 plants was recorded to obtain the number of grains per plant: counted the number of grains of each plant, separately, and averaged (Souza et al., 2013);

Number of grains per pod: number of grains was counted in each pod of the 10 selected plants (Bohn et al., 2016);

The weight of one thousand seeds was obtained by means of eight subsamples of 100 seeds, for each cultivar. Based on the weight of the subsamples, the mean, variance, standard deviation and coefficient of variations were calculated, obtaining the 1000-seed weight, with result expressed in grams (Brazil, 2009).

Productivity (Kg/ha) was obtained by manual harvesting in 10 m^2 of each experimental plot and then weighed and corrected to 13% moisture (BOHN et al., 2016).

Evaluation in laboratory

After the harvest, plants were subjected to mechanical threshing in the field and later taken to the Plant Science laboratory, Federal University of Piauí - UFPI, Campus Professor Cinobelina Elvas (CPCE).

In the laboratory, tests were carried out for water content, 1,000-seed weight, germination (germination speed, first count), seedling length and dry mass of seedlings. For germination test, 200 seeds were used (four subsamples of 50 seeds) for each cultivar, sown in germitest paper, soaked in water, in the amount equivalent to 2.5 times their weight and placed in BOD at 25ºC for eight days (Brazil, 2009). From the germination test, the first count (on the fifth day) and the final count (on the eighth day) were performed. Still, in the germination test, counts were made from the beginning of the germination of the seeds until the last count to define the germination rate. From the data obtained, the index was calculated, based on the formula proposed by Maguire (1962): GSI = (G1/D1) + (G2/D2) +...+ (Gn/Dn).

For the seedling length, four replications of 20 seeds per cultivar were carried out. Germitest paper rolls were kept in germination at 25 ºC for 5 days and the length of normal seedlings was measured using a graduated ruler (Carvalho and Nakagawa, 2012). The values were represented by the division of the sum of the verified lengths by the total number of normal seedlings of each repetition.

For the evaluation of the weight of the dry mass of the seedlings, the same procedure described for the evaluation of the seedling length. Five days after sowing, the normal seedlings were placed in paper bags and kept in a thermoelectric oven at 80 °C for 24 hours. After this period, each repetition had the mass on a scale accurate to 0.001g (Carvalho and Nakagawa, 2012).

Statistical analysis

The data were tested by analysis of variance and the mean values were compared using the Tukey's test ($p < 0.05$). The software ASSISTAT 7.7 beta (2016) was used.

Conclusions

For the traits plant height, internode length and pod length, cultivar TMG 2185 IPRO with maturity group 8.5 was superior to the others, while for the other variables the best option was the cultivar BÔNUS IPRO with maturity group value of 7.9. Cultivar TMG 2185 IPRO presented higher 1st count, G and GSI than the others. Taking into account that yield is the most important trait of production, cultivar BÔNUS IPRO was superior to the others under the conditions of this experiment in the agricultural year 2015/2016.

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