

Agronomic performance of soybean genotypes in Brazil sub-subtropical climate

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Abstract

Soybean is the main economic crop of Brazilian agribusiness, and the extreme south of the country is considered a new agricultural frontier. The objective of this study was to evaluate the components of the yield and agronomic performance of soybean genotypes in the south of Rio Grande do Sul as well as to verify the linear relationships of the measured characters. The study was carried out in the municipality of Pelotas, Rio Grande do Sul, Brazil, in the crop harvest 2016. The experimental design was a randomized complete block design, containing 25 soybean genotypes arranged in four replicates. The experimental units were composed of five sowing lines, spaced by 0.45 meters and three meters in length. The measured characters were: first pod insertion height, plant height, number of branches, length of branches, number of pods in the main stem, number of pods in the branches, number of pods with one, two, three and four seeds, contributing to the pod mass with one, two, three and four seeds. The data were submitted to analysis of variance at 5% of probability, where for the significant characters the averages were compared by the Duncan's test and Pearson's linear correlation was performed in order to identify the tendency of association among the measured characters. The genotypes DM 6159IPRO, BS2606 IPRO, BMX Magna, BMX Potência, TMG7062 IPRO, LG 60163 IPRO revealed superior characters, which can positively influence grain yield. There is a correlation among the morphological characters of the soybean cultivated in southern Brazil between the number of pods in the main stem and the number of pods in the branches, as well as between the number of pods with two seeds and the number of pods in the branches.

Keywords: *Glycine max* L; linear correlation; yield components.

Abbreviations: PH_plant height; NPMS_number of pods in the main stem; NPB_ number of pods in the branches; LB_ length of branches; NP1S_number of pods with one seed; NP2S_number of pods with two seeds; NP3S_number of pods with three seeds; NP4S_number of pods with four seeds; PM1S_contribution of seeds from pods with one seed; PM2S_contribution of seeds from pods with two seeds; NBMS_number of branches on the main stem.

Introduction

Soybean (*Glycine max* L. Merrill) is an annual crop with economic relevance due to its area of cultivation and grain yield. Production is constantly increasing with expectations of a 12.1% increase in the 2016/2017 national harvest (Conab, 2017). This is due to the technological advances, favorable climatic conditions and efficiency of the managements performed during the implantation and development of the crop (Constantinet al., 2009; Bariliet al., 2015).

Annually, new soybean genotypes are introduced, which present different morphological characteristics, cycle and yield. In this sense, breeding programs aim to obtain genotypes with high stability and wide productive adaptability, as well as, adaptable to specific environments. However, genotypes are recommended for large crop regions, but may show higher variation or performance,

when allocated to microregions with specified edaphoclimatic characteristics (Szarecki et al., 2016a). The South of Brazil has a large variation in soil and climatic conditions, which may reflect distinctly on the performance of soybean genotypes, due to the genotypes x environments interaction (Carvalho et al., 2017). In Rio Grande de Sul, about 20% of the soils correspond to the lowland conditions, and from these, less than one third is cultivated. The rest is kept fallow due to the natural difficulties imposed by the environment (Vemettiet al., 2009). In addition to the genetic variability of the genotypes and the edaphoclimatic differences among the cultivation regions, it is necessary to study the individual behavior of each genotype in specific crop regions (Santos et al., 2011, Follmann et al., 2016). In this context, the objective of this work is to evaluate the components of the yield and agronomic performance of soybean genotypes in the south

of Rio Grande do Sul, as well as to verify the linear relationships of the measured characters.

Results and Discussion

The analysis of variance revealed a significance of 5% of probability for the characteristics of plant height (PH), number of pods in the main stem (NPMS), number of pods in the branches (NPB), length of branches (LB), number of pods with one seed (NP1S), number of pods with two seeds (NP2S), number of pods with three seeds (NP3S), number of pods with four seeds (NP4S), contribution of seeds from pods with one seed (PM1S) and contribution of seeds from pods with two seeds (PM2S).

Plant height (PH) expressed superiority for genotype DM 6159 IPRO, followed by BMX Garra, Produza, TMG 7062 IPRO, BS 2606IPRO, BMX Potência and FSP Atlanta, while genotype AS 3570 IPRO showed the lowest plant height (Table 1). Possibly, this response is tied to the cycle of each genotype (Ludwig et al., 2007). This character directly influences the grain yield (Pires et al., 2012), because higher plants tend to show higher numbers of reproductive nodes and consequently pods per node, increasing grain yield per plant. The smaller plants, less than 50 cm, tended to produce pods at lower (one-third) canopies. This fact can cause considerable losses during the harvest. However, to facilitate this procedure the agronomic ideotype for this character is a minimum height of 65 cm (Silva et al., 2010; Pelegrin et al., 2017).

The number of pods in the main stem (NPMS) showed superiority for genotype BS 2606 IPRO and DM 6159 IPRO. However, the genotype TMG7062 IPRO showed the smallest magnitude (Table 1). For the number of pods in the branches (NPB), the highest magnitudes were verified for genotypes BS2606 IPRO and LG 60163 IPRO, followed by the BMX Magna RR genotype (Table 1). These results corroborate with those obtained by Santos et al. (1994), which showed a difference in the total number of pods in soybean genotypes due to the different genetic characteristics of each genotype (Torres et al., 2014). The length of the branches (LB) expressed superiority for the genotype Produza, BMX Magna RR and BS 2606 IPRO. In contrast, the NS5445 IPRO genotype revealed smaller magnitudes (Table 1). Plants with a long vegetative period have a longer branching length (Chaves, 2012). This character is dependent on the phenotypic plasticity and acclimatization of the plants to different environments, as well as on the arrangement of the canopy and the plant population used (Procópio et al., 2014; Strobel et al., 2016). The BMX Magna RR and BS 2606 IPRO genotypes showed higher number of pods with one seed (NP1S). However, the Produza genotype showed the smallest magnitude (Table 2). According to Santos et al. (2011), this attribute is related to grain yield, and in breeding practices can be used as a criterion for selection of superior genotype. The number of pods with two seeds (NP2S) was superior for genotype BS 2606, BMX Magna RR and AS 3610 IPRO. On the other hand, genotype NS 5445 IPRO showed the lowest number of pods with two seeds. For the number of pods with three seeds (NP3S), the genotype LG 60163 IPRO was superior, and the genotype BMX Elite IPRO expressed smaller magnitude.

The number of pods with four seeds (NP4S) was higher for genotypes BS 2606 IPRO, NS 5445 IPRO and Produza. However, genotypes DM 6159 IPRO and AS 3610 IPRO showed the smallest magnitudes for this character (Table 2). The number of seeds per pod is considered one of the main components of soybean yield (Chaves, 2012). The results obtained in this study corroborate with those obtained by Santos et al. (2011) and Szarecki et al. (2015) and Szarecki et al. (2016), where both authors evidenced that the magnitude of seeds obtained by pod is different, being dependent on the genetic constitution of the genotype and the effects of the growing environment.

The contribution of seeds from pods with one seed (PM1S) was verified that the BMX Magna RR and AS 3610 IPRO genotypes were superior. In contrast, the genotype M 6410 IPRO revealed inferior magnitude. For the contribution of seeds from pods with two seeds (PM2S), genotypes BS2606 IPRO and BMX Magna RR were performed better, while the genotypes BMX Vanguarda, NS 5445 IPRO, BMX Elite IPRO and BMX Potência RR were evidenced as inferior. The highest number of pods per plant does not always reflect high grain yield, but influences the influence of one thousand seed mass (Torres et al., 2015; Zimmer et al., 2016).

The linear correlation showed a positive association of the plant height (AP) with NPMS, LB, NP2S and NP3S (Table 4). Meottiet et al., (2012), showed that by reducing plant height, the number of seeds per plant is reduced. The number of pods in the main stem (NPMS) showed a significant positive correlation with NP1S, NP2S, NP3S, NP4S and PM2S. According to Nogueira et al. (2012), the number of pods per plant can be used in the indirect selection to increase grain yield. The number of pods in the main stem (NPMS) and the length of branches (LB) showed significant and positive magnitude with the characters PH, NPB, NP1S, NP2S, NP3S, NP4S, PM1S and PM2S, evidencing that plants with high amount of pods in the main stems should be selected because they promote the increase in grain yield (Kavalco et al., 2014; Carvalho et al., 2015). The number of pods with one seed (NP1S) showed a positive and linear correlation with NPMS, NPB, NBMS, LB, NP2S, PM1S and PM2S (Table 4). Moreover, the number of pods with two seeds (NP2S) showed significant and positive correlation with PH, NPMS, NPB, NBMS, LB, NP1S, NP3S, NP4S, PM1S and PM2S (Table 5). It was observed that the number of pods with three seeds (NP3S) showed a positive correlation with PH, NPMS, NPB, NBMS, LB, NP2S, NP4S and PM2S. The number of pods with four seeds (NP4S) also showed significant and positive correlation with PH, NPMS, NPB, NBMS, LB, NP2S, NP3S and PM2S (Table 5). The number of pods per plant showed a positive correlation with grain yield (Souza et al., 2013, Szarecki et al., 2015b) and can be used for the indirect selection of superior genotypes (Nogueira et al., 2012; Ferrari et al., 2016). PM1S showed a significant positive correlation with NPB, NBMS, LB, NP1S and NP2S, as well as the PM2S showed a significant positive correlation with NPMS, NPB, NBMS, LB, NP1S, NP2S, NP3S, NP4S and PM1S. The seed mass per plant correlates with the grain yield of the soybean and demonstrates that the character can be used to estimate grain yield (Dalchiavan and Carvalho, 2012). The results obtained in this study, such as plant height, first pod

Table 1. Performance of genotypes for plant height (PH), number of pods in the main stem (NPMS), number of pods in the branches (NPB), length of branches (LB). Pelotas, Rio Grande do Sul, Brazil, in the crop harvest 2016.

Genotypes	PH (cm)		NPMS(units)		NPB (units)		LB(cm)	
AS 3610 IPRO	64.22	cdef	20.24	cdefg	30.12	abc	29.74	abcd
NS5445IPRO	53.87	hi	24.93	abcde	9.35	g	8.84	i
FPS Solar	64.50	cdef	24.76	bcde	17.50	cdefg	18.82	efghi
Produza	70.83	abc	19.00	fgh	21.80	abcdef	36.68	a
TMG7062 IPRO	69.18	abc	15.98	g	21.03	bcdef	21.10	defg
BMX Elite IRPO	59.68	efgh	25.95	abcd	9.62	fg	14.25	fghi
NS5959IPRO	67.17	abcde	26.32	abcd	10.65	efg	12.78	ghi
BS2606IPRO	70.83	abc	30.12	a	35.17	a	33.12	abc
BMX Magna RR	66.82	bcde	22.50	cdefg	33.17	ab	35.22	ab
BMX Garra IPRO	73.82	ab	26.50	acbd	18.87	cdefg	17.93	defghi
BMX Potência RR	69.35	abc	21.70	bcdefg	21.57	abcdef	21.09	dfgh
FSP Atlanta	68.64	abc	22.27	cdefg	17.62	cdefg	23.19	cdefgh
DM5958 IPRO	64.33	cdef	24.76	abcd	14.33	defg	18.74	defghi
M 5947IPRO	64.25	cdef	26.80	abc	25.05	abcd	21.25	defgh
TEC 6702 IPRO	67.00	bcde	21.25	bcdefg	23.25	abcdef	24.38	bcdef
M 5730 IPRO	58.16	fgh	21.65	bcdefg	23.80	abcdef	19.19	defghi
BMX Tornado	58.54	fgh	22.00	bcdefg	22.82	abcdef	25.88	abcde
DM 6159 IPRO	75.24	a	27.67	ab	13.20	defg	18.40	defghi
M 6410 IPRO	68.05	abcd	24.77	abcde	29.72	abc	26.43	abcde
BMX Ponta IPRO	65.42	cdef	22.72	bcdef	24.67	abcde	23.92	bcdefgh
BMX Vanguarda	56.16	hg	19.87	dfg	16.47	cdefg	16.53	efghi
NS 5909 RR	63.03	cdefg	17.40	fg	20.20	bcdeg	23.11	cdefgh
LG 60163 IPRO	64.79	cdefe	17.40	fg	35.22	a	27.91	abcde
NS6909 IPRO	60.19	defgh	25.60	abcd	16.36	cdefg	16.24	efghi
AS 3570 IPRO	48.64	i	22.42	cdefg	14.61	defg	11.99	hi
CV(%)	7.08		16.30		36.96		29.94	

*Averages followed by the same lowercase letter in the column do not statistically differ to Duncan with 5% of probability.

Table 2. Averages of genotypes for the number of pods with one seed (NP1S), number of pods with two seeds (NP2S), number of pods with three seeds (NP3S) and number of pods with four seeds (NP4S). Pelotas, Rio Grande do Sul, Brazil, in the crop harvest 2016.

Genotypes	NP1S (units)		NP2S (units)		NP3S(units)		NP4S (units)	
AS 3610 IPRO	8.52	bc	24.37	Abc	19.40	abcde	0.00	c
NS5445IPRO	5.35	defg	14.49	F	14.42	bcde	0.36	ab
FPS Solar	5.64	cdefg	18.20	Bcdef	16.95	abcde	0.14	abc
Produza	4.17	g	15.62	Ef	20.32	abcd	0.35	ab
TMG7062 IPRO	5.37	defg	18.39	Bcdef	17.16	abcde	0.26	abc
BMX Elite IRPO	8.25	bcd	16.82	Def	9.62	e	0.05	bc
NS5959IPRO	5.45	defg	15.52	Ef	14.27	bcde	0.32	abc
BS2606IPRO	11.21	a	30.27	a	23.36	abc	0.46	a
BMX Magna RR	11.59	a	25.02	ab	21.05	abcd	0.12	bc
BMX Garra IPRO	4.25	fg	21.27	bcdef	18.90	abcde	0.10	bc
BMX Potência RR	6.97	bcdefg	16.67	def	19.80	abcd	0.25	abc
FSP Atlanta	5.39	defg	18.49	bcdef	15.66	abcd	0.09	bc
DM5958 IRPO	8.30	bcd	19.46	bcdef	11.56	de	0.10	bc
M 5947IPRO	8.55	bc	24.05	abcd	19.20	abcde	0.05	bc
TEC 6702 IPRO	8.07	bcd	21.30	bcde	14.97	bcde	0.12	bc
M 5730 IPRO	8.65	b	20.32	bcdef	15.70	abcde	0.05	bc
BMX Tornado	7.25	bcdef	19.80	bcdef	17.27	abcde	0.12	bc
DM 6159 IPRO	4.74	efg	19.91	bcdef	16.74	abcde	0.00	c
M 6410 IPRO	5.70	cdefg	23.02	bcde	24.39	ab	0.02	bc
BMX Ponta IPRO	5.35	defg	19.15	bcdef	22.87	abc	0.30	abc
BMX Vanguarda	5.32	defg	17.20	cdef	13.77	cde	0.25	abc
NS 5909 RR	7.64	bcde	18.29	bcdef	12.57	de	0.07	bc
LG 60163 IPRO	5.38	defg	20.39	bcdef	25.66	a	0.25	abc
NS6909 IPRO	6.76	bcdefg	16.83	def	17.76	abcde	0.10	bc
AS 3570 IPRO	5.59	defg	16.50	ef	14.41	bcde	0.02	bc
CV(%)	24.04		20.7		31.54		110.72	

*Averages followed by the same lowercase letter in the column do not statistically differ to Duncan with 5% of probability.

Table 3. Averages between genotypes for the contribution of seeds from pods with one seed (PM1S), contribution of seeds from pods with two seeds (PM2S).Pelotas, Rio Grande do Sul, Brazil, in thecrop harvest 2016.

Genotypes	PM1S(g)		PM2S(g)	
AS 3610 IPRO	1.77	ab	6.67	abcdefg
NS5445IPRO	1.31	bcde	4.71	g
FPS Solar	1.50	bcde	5.14	fg
Produza	1.29	bcde	5.56	bcdefg
TMG7062 IPRO	1.48	bcde	5.91	abcdefg
BMX Elite IPRO	1.52	bcde	4.69	g
NS5959IPRO	1.27	bcde	5.08	fg
BS2606IPRO	1.62	bcd	8.06	a
BMX Magna RR	2.11	a	7.96	ab
BMX Garra IPRO	1.25	cde	6.60	abcdefg
BMX Potência RR	1.61	bcd	4.79	g
FSP Atlanta	1.36	bcde	5.52	cdefg
DM5958 IRPO	1.56	bcd	5.92	abcdefg
M 5947IPRO	1.48	bcde	7.54	abcd
TEC 6702 IPRO	1.66	abcd	7.18	abcdef
M 5730 IPRO	1.73	abc	7.68	abc
BMX Tornado	1.56	bcde	5.24	efg
DM 6159 IPRO	1.30	bcde	5.95	abcdefg
M 6410 IPRO	1.10	e	6.21	abcdefg
BMX Ponta IPRO	1.19	de	5.26	efg
BMX Vanguarda	1.24	cde	4.89	g
NS 5909 RR	1.63	bcd	5.32	defg
LG 60163 IPRO	1.30	bcde	7.45	abcde
NS6909 IPRO	1.74	abc	6.33	abcdefg
AS 3570 IPRO	1.48	bcde	4.96	fg
CV(%)	17.55		20.15	

*Averages followed by the same lowercase letter in the column do not statistically differ to Duncan with 5% of probability.

Table 4. Linear correlation for 11 morphological characters and soybean yield components.Pelotas, Rio Grande do Sul, Brazil, in thecrop harvest 2016.

	PH	NPMS	NPB	NBMS	LB	NP1S
PH	.					
NPMS	0.18	.				
NPB	0.20	0.12	.			
NBMS	0.31*	-0.09	0.83*	.		
LB	0.41*	-0.01	0.73*	0.75*	.	
NP1S	0.00	0.23*	0.56*	0.37*	0.36*	.
NP2S	0.21*	0.37*	0.85*	0.61*	0.56*	0.66*
NP3S	0.29*	0.39*	0.79*	0.67*	0.58*	0.06
NP4S	0.13	0.24*	0.34*	0.24*	0.26*	0.14
PM1S	0.03	-0.02	0.34*	0.31*	0.30*	0.72*
PM2S	0.21	0.31*	0.77*	0.57*	0.52*	0.65*

* Pearson's linear correlation coefficients (n = 91) significant at 5% of error probability. ⁽¹⁾PH: Plant height; NPMS: Number of pods in the main stem; NPB: Number of pods in the branches; NBMS: Number of branches on the main stem; LB: Length of branches; NP1S: Number of pods with one seed; NP2S: Number of pods with two seeds; NP3S: Number of pods with three seeds; NP4S: Number of pods with four seeds; PM1S: Seed mass from pods with one seed; PM2S: Seed mass from pods with two seeds.

Table 5. Pearson's linear correlation for 11 morphological characters and soybean yield components.Pelotas, Rio Grande do Sul, Brazil, in thecrop harvest 2016.

	NP2S	NP3S	NP4S	PM1S	PM2S
PH	0.21*	0.29*	0.13	0.03	0.21
NPMS	0.37*	0.39*	0.24*	0.02	0.31*
NPB	0.85*	0.79*	0.34*	0.34*	0.77*
NBMS	0.61*	0.67*	0.24*	0.31*	0.57*
LB	0.56*	0.58*	0.26*	0.30*	0.52*
NP1S	0.66*	0.19	0.14	0.72*	0.65*
NP2S	.	0.60*	0.24*	0.34*	0.86*
NP3S		.	0.41*	0.05	0.55*
NP4S			.	0.00	0.29*
PM1S				.	0.44*
PM2S					.

*Pearson's linear correlation coefficients (n = 91) significant at 5% of error probability. ⁽¹⁾PH: Plant height; NPMS: Number of pods in the main stem; NPB: Number of pods in the branches; NBMS: Number of branches on the main stem; LB: Length of branches; NP1S: Number of pods with one seed; NP2S: Number of pods with two seeds; NP3S: Number of pods with three seeds; NP4S: Number of pods with four seeds; PM1S: Seed mass from pods with one seed; PM2S: Seed mass from pods with two seeds.

insertion height, number of pods and grain mass of the pods, allow to infer that there are genotypes with favorable agronomic characteristics for soybean cultivation in the Southern region of the country.

Materials and Methods

Location and experimental design

This work was carried out in the experimental area of the Phytotechny Department of the Postgraduate Program in Seed Science and Technology, Eliseu Maciel Agronomy Faculty, at the Federal University of Pelotas, Rio Grande do Sul, Brazil. The altitude in the place is 13 meters, latitude 31°48'10.3 "and the longitude of 52°25'09". The climate is characterized by Köppen as subtropical Cfa, with rains well distributed throughout the year.

The experimental design was a randomized block design, containing 25 soybean genotypes, arranged in four replicates. The experimental units were composed of five sowing lines, spaced by 0.45 meters and three meters in length.

Soybean genotypes used

The genotypes used were: AS 3610 IPRO, NS 5445IPRO, FPS Solar, Produza, TMG7062 IPRO, BMX Elite IPRO, NS 5959IPRO, BS 2606IPRO, BMX Magna RR, BMX Garra IPRO, BMX Potência RR, FSP Atalanta, DM 5958 IRPO, M 5947IPRO, TEC 6702 IPRO, M 5730 IPRO, BMX Tornado, DM 6159 IPRO, M 6410 IPRO, BMX Ponta IPRO, BMX Vanguarda, NS 5909 RR, LG 60163 IPRO, NS 6909 IPRO and AS 3570 IPRO.

Management and farming practices

Before sowing, the area was fallowed, desiccated with Glyphosate 3500 mL⁻¹ and Cletodim 240g⁻¹ at dose of 450 mL⁻¹, done 30 days before sowing. The fertilization was carried out based on the interpretation of the soil analysis, proceeding the recommendation for the soybean crop (CQFS, 2004). Seeding was done manually in the second half of January 2016. Weed control, pest insects and diseases were carried out according to crop needs (Embrapa, 2014).

Measured characters

The characters of interest were measured in ten random plants in the central lines of each experimental unit. They were: first pod insertion height (FIH, cm), plant height (PH, cm), number of branches (NB, units), length of branches (LB, cm), number of pods in the main stem (NPMS, units), number of pods with one (NP1S, units), two (NP2S, units), three (NP3S, units) and four (NP4S, units) seeds, contribution of the pod mass with one (PM1S, grams), two (PM2S, grams), three (PM3S, grams) and four (PM4S, grams) seeds (Szareski et al., 2015).

Statistical analysis

The data were submitted to analysis of variance in order to verify the assumptions (Ramalho et al., 2000). Subsequently, they were submitted to analysis of variance at 5% of probability, where for the significant characters the averages

were compared by Duncan. In the same way, we performed a linear correlation with the purpose of identifying the tendency of association among the characters, the coefficients were weighted by Carvalho et al. (2004).

Conclusion

The genotypes DM 6159IPRO, BS2606 IPRO, BMX Magna, BMX Potência, TMG7062 IPRO, LG 60163 IPRO revealed superior agronomical characters, which can positively influence grain yield.

There is a positive correlation among the morphological characters of the soybean cultivated in southern Brazil, between the number of pods in the main stem and the number of pods in the branches, as well as between the number of pods with two seeds and the number of pods in the branches.

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