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RESEARCH ARTICLE

EVALUATION OF SOYBEANS GENOTYPES IN FIELD ENVIRONMENTS OF RIO GRANDE DO SUL STATE, BRAZIL

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ABSTRACT

Agronomic performance of soybean genotypes results from the genetic constitution, environmental conditions and genotype x environment interaction. We aimed to evaluate the traits with agronomic importance in elite soybean genotypes, with Roundup Ready® and Intact RR2 PRO® technologies in different sites of Rio Grande do Sul state, Brazil. The trials were carried out in 2013/2014 growing season in a randomized complete block design, arranged in a 4x10 (four soybeans genotypes and ten sites) factorial treatment design, with four replications. The sites were Frederico Westphalen-RS, Derrubadas-RS, Tapera-RS and Independência-RS. Tem used soybeans genotypees were: NS 5445 IPRO, TEC 6029 IPRO, 6458 RSF IPRO, 6061 RSF IPRO and CD 2611 IPRO with INTACTA RR2 PRO® technology and NS 6211 RR, TECIRGA 6070 RR, DMario 5.8i RR, Don Mario 5.9i RR and CD 2585 RR with Roundup Ready® technology. Assessed traits were: plant height, first pod insertion height, number of branches, number of pods in branches, number of pods on the main stem, total number of pods, number of pods with one kernel, number of pods with two kernels, number of pods with three kernels, grain yield and thousand-kernel weight. 6458RSF IPRO and NS 6211 RR genotypes show greater agronomic performance and can be indicated for Independência-RS environment. 6061 RSF IPRO genotype shows superior agronomic performance and can be recommended for Tapera-RS and Derrubadas-RS environments. NS 6211 RR genotype shows superior agronomic performance for Frederico Westphalen-RS environment. Based on assessed traits, Tapera-RS, Derrubadas-RS and Frederico Westphalen-RS cultivation environments, have more favorable soil and climatic conditions for growth and development of elite soybean genotypes.

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INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] stands out as one of the main oilseeds grown in the world, because of its high yield potential combined with its chemical composition and nutritional value. In Brazil, soybean is the main agricultural commodity, where it was developed a large agro-industrial and export complex for this crop. In 2015/2016 harvestingseason were seeded 33.08 million hectares with this crop in Brazil, resulting in a production of around 96.90 million tons (Conab, 2016). Of total sown area, 93.5 % was used genetically modified seed, in which 73.50% was seeded with Roundup Ready® technology and 20% with intact RR2 PRO® technology (Céleres, 2015). Soybean crop is distributed in all Brazilian agricultural regions, as result of major advances in genetic breeding programs and new technologies assigned to the crop. Another important factor associated with the expansion of the crop is linked to biotech progress, which led to Roundup Ready® technology, which confers resistance to glyphosate molecule. Latest INTACT RR2 PRO® technology which is characterized by resistance to the insect-pests of lepidopteran order such as the common Soybean Caterpillar (*Anticarsia gemmatalis*), Soybean Looper (*Pseudoplusia includens*) and Crocidosema (*Crocidosema aporema*), besides glyphosate tolerance, has becoming increasingly popular (Mateus and Silva, 2013). Soybean grain yield is a complex trait, resulting from expression and association of different yield components, among which stand out the number of pods

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per area, the number of kernel per pods and thousand-kernel weight (Mundstock and Thomas, 2005). Research performed by Nogueira *et al*. (2012), Carvalho *et al*. (2002) and Perini *et al*. (2012) showed the number of kernels and pods per plant are directly associated to the maximum yield of soybeans. Soybean yield is determined by genetic characteristics, with pronounceable effects of the environment, which can be limiting for growth and development of crop (Dybing, 1994; Carvalho *et al*., 2002). According to Gilioli *et al*. (1995), high yields are only obtained when the environmental conditions are favorable in all soybean development stages. Given this, the main environmental factors that influence the crop are the air relative humidity, soil water condition, air temperature, photoperiod, soil fertility, altitude and latitude (Sedyama *et al*., 2005). Soybean genotypes are usually subjected to evaluation in different environments, which generates genotype x environment interactions component, resulting indifferential responses of genotypes in relation to the environmental conditions (Carvalho *et al*., 2002). This interaction makes it difficult to identify superior and stable genotypes to several growing regions, as reported in studies by Rangel *et al*. (2007) Peluzio *et al*. (2010). Thus, knowledge of the agronomic performance of genotypes in different environments is crucial in decision making on the choice of soybean genotype with superior performance. In this context, we aimed to evaluate the traits of agronomic importance in elites soybean genotypes, with Roundup Ready® and Intact RR2 PRO® technologies in different cultivation sites in Rio Grande do Sul state, Brazil.

MATERIALS AND METHODS

Trials were carried out in the 2013/2014 growing season in four growth environments of Rio Grande do Sul state, Brazil. The characterization of growth environments (Table 1) shows the soil classification proposed by Santos *et al*. (2006), and climatic characterization as proposed by Koppen (Maluf, 2000). In all trials, a randomized complete block design, arranged in a factorial 4x10 (four growth environments and ten soybean genotypes) treatment design, arranged in four repetitions was used. Tested cultivation environments were Frederico Westphalen-RS, Derrubadas-RS, Tapera-RS and Independência-RS. Ten used soybeans genotypes were: NS5445 IPRO, TEC 6029 IPRO, 6458 RSF IPRO, 6061 RSF IPRO and CD 2611 IPRO with INTACTA RR2 PRO®technology and NS6211 RR, TECIRGA 6070 RR, DMario 5.8i RR, Don Mario 5.9i RR and CD 2585 RR with RoundupReady®technology. The genotypes used in the tests had indeterminate growth habit, and maturity group of 5.5, 6.0, 6.0, 6.0, 6.1, 6.2, 6.3, 5.5, 5.9 and 5.8 respectively.

Experimental units were composed of five 3-m long genotype rows, spaced by 0.45 m between lines totaling 6.75 m². To compose the useful area of the plot were considered just the three central rows, discarding 0.5 m from each end, totaling a useful area of 2.70 m². The plots were installed in areas previously cultivated with wheat during the winter period. Before sowing, desiccation of the areas was carried out. The grooves were made with no-till seeder, with base fertilization with 300 kg $ha^{-1}$of N-P-K 02-25-25 formulation. Sowing was manually carried out, and the seeds arranged the depth of three to five cm. Sowing density used followed recommended for each genotype, respecting the period of sowing in each site. Trial's sowing was carried out between November 15th, and November 19th, 2013. For the purposes of the experiment, all experimental units received the same cultural practices, seeking homogeneity and absence of interference from weeds, insect-pestsattack and diseases. Weed control was carried out with two applications of Ammonium Glyphosate salt in the V3 stage (Second fully-developed trifoliate leaf) and V6 (Fifth fully-developed trifoliate leaf). Fungicide applications were made at intervals of 18 days thus held four applications, starting at the R1 stage (onset of flowering). Insecticide applications were in accordance with the level of control of each insect-pest. Applications were performed in total area in each location, a fact that led to enhance the expression of yield components of each genotype. The phenological stages were defined according to phenological scale of Fehr and Caviness (1977).

Trial's harvests were carried out during the period from March 25th to April 5th, 2014. The experimental units were manually-collected and threshing of the pods was carried out withan electric thresher. The agronomically important traits evaluated in ten representative plants (replicates) of the useful area of each experimental unit were: Plant height (PH): measured from the base of the plant until the end of the main stem, with a graduated scale, results in centimeters (cm). First pod insertion height (FPI): measured from the plant base to the first pod of main stem of the plant, results in centimeters (cm). Number of branches (NB): measured by counting the total number of branches larger than 10 centimeters, results in units. Number of pods on branches (NPB): measured by counting the total number of pods present in branches, results in units. Number of pods on the main stem (NPMS): measured by the total number of pods on the main stem, results in units.

Total number of pods (TNP): measured by counting the total number of pods in the plant, results in units. Number of pods with one kernel (NP1K): obtained by counting the number of pods with one kernel, results in units. Number of pods with twokernel (NP2K): obtained by counting the number of pods with two kernels, results in units. Number of pods with threekernel (NP3K): obtained by counting the number of pods with three kernels, results in units. Grain yield (GY): measured by the total kernels mass in experimental unit, corrected to 13% moisture and converted to kg ha^{-1}. Thousand-kernel weight (TKW): measured by manual count of eight replications of 100 kernels, expanding its weight to the thousand-kernel weight, results in grams (g). Dataset was subjected to two-way ANOVA by the F test. Traits that reveled meaningful interaction between elite soybean genotypes x cultivation environments were dismembered to the simple effects. Traits without interaction were compared by Tukey test at 5% probability for each factor separately. Statistical analysis were performed using the Genes sofware (Cruz, 2013).

RESULTS AND DISCUSSION

Two-way ANOVA by F test ($p<0.05$) revealed meaningful interaction between cultivation environments x elite soybeans

Table 1. Soil and climate characteristics of the four growth environments of Rio Grande do Sul state

Growth environments	Latitude	Longitude	Level	Soil classification	Weather
Independência	S27°51'18"	O54° 17' 13"	315	Hapludox	*Cfa*
Tapera	S28°42' 1"	O52° 51' 25"	381	Haplorthox	*Cfa*
Derrubadas	S27°16'63"	O53° 47' 33"	430	EutricKandiudalf	*Cfa*
Frederico Westphalen	S27°39'56"	O53° 42' 94"	490	Haplortox	*Cfa*

Table 2. Average results for environments cultivation x soybean genotypes interactionfor the grain yield trait (kg ha^{-1})

Genotypes	Growth environments			
	Independência-RS	Tapera-RS	Derrubadas-RS	Frederico Westphalen-RS
NS 5445 IPRO	2949.72 ab B	3858.84 abc A	4132.40 ab A	3590.71 bc A
NS 6211 RR	3317.69 a C	4014.54 abc AB	3608.88 b BC	4382.96 aA
TEC 6029 IPRO	2875.55 ab B	4168.95 ab A	4076.02 ab A	4041.48 abc A
TECIRGA 6070RR	2865.73 ab B	3501.76 bc A	3648.30 b A	3581.85 bc A
6458 RSF IPRO	3471.01 a B	3782.11 abc AB	4248.24 ab A	4121.66 abc A
DMario 5.8i RR	2857.50 ab C	3348.98 c BC	3829.35 b AB	4155.09 abc A
6160 RSF IPRO	3129.26 ab B	4358.14 a A	4659.75 a A	4262.40 ab A
Don Mario 5.9i RR	296.68 ab B	4008.52 abc A	4078.37 ab A	4193.79 abc A
CD 2611 IPRO	2905.00 ab B	3684.35 abc A	3972.59 ab A	3828.15 abc A
CD2585 RR	2472.08 b B	3348.95 c A	3687.12 b A	3462.96 c A
General average of Intacta RR2 Pro ® technology			3805.82 a	
General average of Roundup Ready® techonology			3566.61 b	
CV (%)			9.29	

*Means followed by the same lower letter for the genotypes, and capital letter for the cultivation environments do not differ statistically by Tukey test at 5% probability.

Table 3. Average results for the cultivation environments x soybean genotypes interaction for thousand-kernel weight trait (g)

Genotypes	Growth environments			
	Independência-RS	Tapera-RS	Derrubadas-RS	Frederico Westphalen-RS
NS 5445 IPRO	157.02 cd B	179.02 bcd A	150.71 ab B	152.84 ef B
NS 6211 RR	145.90 d B	166.48 d A	125.66 cd C	156.43 def AB
TEC 6029 IPRO	190.22 aA	195.16 ab A	153.56 ab B	185.12 ab A
TECIRGA 6070RR	168.28 bc A	179.41 bcd A	128.43 cd B	172.83 bc A
6458 RSF IPRO	181.04 ab B	192.18 abc AB	153.78 ab C	195.47 aA
DMario 5.8i RR	151.92 d B	175.68 d A	137.67 bc C	163.19 cde AB
6160 RSF IPRO	150.44 d B	172.43 d A	137.77 bc B	172.37 bcd A
Don Mario 5.9i RR	144.70 d C	178.37 cd A	140.70 bc C	162.84 cde B
CD 2611 IPRO	196.62 a AB	197.01 aA	164.70 a C	183.75 ab B
CD2585 RR	121.58 e B	148.76 e A	120.78 d B	142.05 f A
General average of Intacta RR2 Pro ® technology			173.06 a	
General average of Roundup Ready® techonology			151.58 b	
CV (%)	4.36			

*Means followed by the same lower letter for the genotypes, and capital letter for the cultivation environments \do not differ statistically by Tukey test at 5% probability.

Table 4. Average results for the cultivation environments x soybean genotypes interaction for the first pod insertion height trait, in centimeters (cm)

Genotypes	Growth environments			
	Independência-RS	Tapera-RS	Derrubadas-RS	Frederico Westphalen-RS
NS 5445 IPRO	19.12 abc B	26.51 cd A	19.27 cde B	27.27 de A
NS 6211 RR	21.63 abc B	31.95 abc A	23.07 abc B	29.72 bcd A
TEC 6029 IPRO	21.90 abc B	28.67 bcd A	22.27 abcd B	30.65 bcd A
TECIRGA 6070RR	20.85 abc C	31.52 abc A	26.20 a B	33.55 abc A
6458 RSF IPRO	24.30 a B	32.84 ab A	21.80 abcd B	34.82 ab A
DMario 5.8i RR	16.80 c B	19.77 e AB	15.45 e B	23.67 e A
6160 RSF IPRO	18.50 abc B	27.42 bcd A	21.45 abcd B	29.02 bcde A
Don Mario 5.9i RR	18.10 bc C	23.87 de B	20.12 bcde BC	28.85 cde A
CD 2611 IPRO	23.22 ab B	35.57 aA	25.30 ab B	37.35 aA
CD2585 RR	18.72 abc BC	23.09 de AB	16.52 de C	27.70 cde A
General average of Intacta RR2 Pro ® technology			26.36 a	
General average of Roundup Ready® techonology			23.56 b	
CV (%)	10.27			

*Means followed by the same lower letter for the genotypes, and capital letter for the cultivation environments do not differ statistically by Tukey test at 5% probability.

genotype for the traits, grain yield (GY), thousand-kernel weight (TKW), first pod insertion height (FPI), number of pods on the main stem (NPMS), number of pods in the branches (NPB), number of branches (NB), number of pods with one kernel (NP1K), number of pods with two grains (NP2K) , number of pods with three kernels (NP3K). Thus, the occurrence of meaningful interaction between these traits is provided by the differential effect of cultivation environment on the genotypes, resulting on alteration of physiological and biochemical factors of the genotypes (Ramalho *et al.*, 2005). The plant height (PH) and total number of pods (TNP) traits did not reveled meaningful interaction;

Table 5. Average results for environments cultivation x soybean genotypes interation for the number of pods on the main steam (NPMS) in units

Genotypes	Growth environments			
	Independência-RS	Tapera-RS	Derrubadas-RS	Frederico Westphalen-RS
NS 5445 IPRO	22.27 ab A	27.05 aA	31.35 abcd A	27.85 aA
NS 6211 RR	27.31 ab AB	30.75 a AB	21.62 cd B	32.22 aA
TEC 6029 IPRO	20.66 ab B	24.50 a AB	32.75 abcd A	32.55 aA
TECIRGA 6070RR	24.36 ab A	26.35 aA	27.93 bcd A	27.15 aA
6458 RSF IPRO	21.67 ab B	25.78 a AB	34.26 abc A	28.90 a AB
DMario 5.8i RR	26.30 ab A	27.72 aA	31.97 abcd A	32.90 aA
6160 RSF IPRO	23.50 ab B	28.02 a AB	34.73 ab A	32.92 a AB
Don Mario 5.9i RR	29.00 ab A	27.40 aA	30.37 abcd A	29.77 aA
CD 2611 IPRO	19.30 b B	27.25 a AB	20.66 d AB	30.50 aA
CD2585 RR	32.60 aA	36.25 aA	41.95 aA	37.25 aA
General average of Intacta RR2 Pro ® technology			27.79 a	
General average of Roundup Ready® techonology			30.55 b	
CV (%)	10.51			

*Means followed by the same lower letter for the genotypes, and capital letter for the cultivation environments do not differ statistically by Tukey test at 5% probability.

Table 6. Average results for soybean crop genotypes x environments interaction to the number of branches trait (NR) in units

Genotypes	Growth environment			
	Independência-RS	Tapera-RS	Derrubadas-RS	Frederico Westphalen-RS
NS 5445 IPRO	0.47 e B	1.76 cd A	1.60 c A	0.59 d B
NS 6211 RR	2.03 d A	1.57 d AB	1.82 c A	0.72 d B
TEC 6029 IPRO	2.90 cd B	3.89 aA	3.97 aA	2.80 ab B
TECIRGA 6070RR	4.70 aA	3.07 ab B	3.57 a B	3.35 a B
6458 RSF IPRO	3.42 bc AB	3.71 ab A	4.10 aA	2.45 ab B
DMario 5.8i RR	2.82 cd B	3.22 ab B	4.22 aA	2.25 ab B
6160 RSF IPRO	4.37 ab A	3.60 ab A	4.20 aA	2.35 ab B
Don Mario 5.9i RR	2.95 cd AB	2.67 bcd B	3.84 aA	2.02 bc B
CD 2611 IPRO	2.05 d A	1.75 cd AB	2.11 bc A	0.87 cd B
CD2585 RR	2.12 d A	2.89 abc A	3.10 ab A	2.45 ab A
General average of Intacta RR2 Pro ® technology			2.65 a	
General average of Roundup Ready® techonology			2.77 a	
CV (%)	19.56			

*Means followed by the same lower letter for the genotypes, and capital letter for the cultivation environments do not differ statistically by Tukey test at 5% probability.

Table 7. Average results for environments cultivation x soybean genotypes interaction for number of pods in branches (NPB) trait, in units

Genotypes	Growth environments			
	Independência-RS	Tapera-RS	Derrubadas-RS	Frederico Westphalen-RS
NS 5445 IPRO	1.97 d A	4.14 d A	5.82 d A	1.71 c A
NS 6211 RR	10.16 bcd A	4.85 cd AB	7.35 d AB	1.92 c B
TEC 6029 IPRO	10.42 bc A	16.70 ab A	15.93 bc A	11.05 ab A
TECIRGA 6070RR	15.45 ab AB	12.42 bc B	20.59 ab A	10.30 ab B
6458 RSF IPRO	11.57 bc BC	16.11 ab AB	19.12 ab A	9.25 abc C
DMario 5.8i RR	15.27 ab B	12.92 bc B	26.97 aA	12.65 a B
6160 RSF IPRO	20.80 a AB	22.37 aA	25.40 aA	14.40 a B
Don Mario 5.9i RR	12.55 abc B	13.60 b B	23.04 ab A	10.42 ab B
CD 2611 IPRO	6.90 cd A	5.20 cd A	7.68 cd A	3.12 bc A
CD2585 RR	10.72 bc B	14.26 ab B	22.32 ab A	10.50 ab B
General average of Intacta RR2 Pro ® technology			11.48 a	
General average of Roundup Ready® techonology			13.41 a	
CV (%)	29.06			

*Means followed by the same lower letter for the genotypes, and capital letter for the cultivation environments do not differ statistically by Tukey test at 5% probability.

Table 8. Average results for environments cultivation x soybean genotype interaction for number of pods with one kernel (NP1K), results in units

Genotypes	Growth environments			
	Independência-RS	Tapera-RS	Derrubadas-RS	Frederico Westphalen-RS
NS 5445 IPRO	2.57 bc B	4.09 bc AB	4.97 bc A	3.08 ab AB
NS 6211 RR	4.91 ab AB	3.55 bc B	5.95 ab A	4.07 ab AB
TEC 6029 IPRO	3.10 abc B	3.87 bc AB	5.93 ab A	5.67 aA
TECIRGA 6070RR	5.60 aA	6.20 ab A	6.21 ab A	4.72 ab A
6458 RSF IPRO	3.30 abc C	5.95 ab AB	7.62 ab A	4.60 ab BC
DMario 5.8i RR	3.77 abc B	5.25 bc AB	7.27 ab A	4.77 ab B
6160 RSF IPRO	4.42 ab A	5.85 ab A	5.66 ab A	4.30 ab A
Don Mario 5.9i RR	5.37 a AB	4.12 bc B	7.08 ab A	4.42 ab B
CD 2611 IPRO	1.02 c A	2.97 c A	2.47 c A	2.27 b A
CD2585 RR	5.05 ab B	8.33 aA	8.20 aA	4.45 ab B
General average of Intacta RR2 Pro ® technology			4.18 b	
General average of Roundup Ready® techonology			5.46 a	
CV (%)	25.15			

*Means followed by the same lower letter for the genotypes, and capital letter for the cultivation environments do not differ statistically by Tukey test at 5% probability

Table 9. Average results for growth environments x soybean genotypes interaction fornumber of pods with two kernels (NP2K), in units

Genotypes	Growth environment			
	Independência-RS	Tapera-RS	Derrubadas-RS	Frederico Westphalen-RS
NS 5445 IPRO	9.07 de B	11.54 ef AB	15.02 d A	10.31 de B
NS 6211 RR	16.59 abc A	12.12 ef B	15.92 d AB	12.45 cde AB
TEC 6029 IPRO	12.17 cd B	19.52 abc A	20.35 cd A	17.90 ab A
TECIRGA 6070RR	15.67 abc A	14.42 cde A	17.07 cd A	14.15 bcd A
6458 RSF IPRO	13.05 bcd B	15.67 bcde B	21.37 bc A	15.12 bcd B
DMario 5.8i RR	18.27 ab B	17.72 bcd B	27.42 aA	18.25 ab B
6160 RSF IPRO	19.77 a B	20.75 ab B	26.44 ab A	17.70 abc B
Don Mario 5.9i RR	16.77 abc AB	13.62 def B	18.85 cd A	15.22 abcd AB
CD 2611 IPRO	5.50 e A	8.95 f A	9.07 e A	8.72 e A
CD2585 RR	19.22 a C	24.63 a AB	27.62 aA	20.60 a BC
General average of Intacta RR2 Pro ® technology			14.90 b	
General average of Roundup Ready® techonology			17.83 a	
CV (%)	14.42			

*Means followed by the same lower letter for the genotypes, and capital letter for the cultivation environments do not differ statistically by Tukey test at 5% probability.

Table 10. Average results for growth environment x soybean genotypes for number of pods with three kernels (NP3K), in units

Genotypes	Growth environments			
	Independência-RS	Tapera-RS	Derrubadas-RS	Frederico Westphalen-RS
NS 5445 IPRO	12.12 b A	14.59 b A	16.47 b A	15.94 b A
NS 6211 RR	15.71 ab A	19.62 ab A	17.42 b A	17.62 ab A
TEC 6029 IPRO	15.37 ab B	17.21 ab AB	21.90 ab A	19.62 ab AB
TECIRGA 6070RR	19.15 a B	17.95 ab B	25.41 aA	18.62 ab B
6458 RSF IPRO	16.85 ab B	22.11 a AB	25.40 aA	18.10 ab B
DMario 5.8i RR	18.87 a AB	17.22 ab B	22.97 ab A	21.30 ab AB
6160 RSF IPRO	20.00 a B	22.15 a AB	26.85 aA	23.95 a AB
Don Mario 5.9i RR	19.02 a B	20.97 ab B	26.94 aA	20.37 ab B
CD 2611 IPRO	18.85 a B	21.15 ab B	26.76 aA	22.77 a AB
CD2585 RR	18.72 ab BC	16.74 ab C	28.15 aA	22.97 a AB
General average of Intacta RR2 Pro ® technology			19.90 a	
General average of Roundup Ready® techonology			20.29 a	
CV (%)	14.55			

*Means followed by the same lower letter for the genotypes, and capital letter for the cultivation environments do not differ statistically by Tukey test at 5% probability.

thus, were compared to its main effects of each factor separately. Regarding to the GY, in Independência-RS it was observed the NS 6211 RR e 6458 RSF IPRO genotypes showed the largest magnitudes differing from CD 2585 RR genotype (Table 2). In Tapera-RS environment,6160 RSF IPRO genotype showed the best performance for this trait, differing of TECIRGA 6070 RR, RR, DMario 5.8i RR and CD 2585 RR genotypes.Similar result was observed in Derrubadas-RS, with largest increase in GY obtained in 6160 RSF IPRO genotype, however, also differ of the NS-6211 RR genotype. In Frederico Westphalen-RS, NS 6211 RR genotype showed a higher increase GY, differing to the CD RR 2585and NS 5445 IPRO genotypes. Thus, genotypes did not keep its productive performance in order to the specific soil and climatic conditions of each environment. The results corroborate previously studies by Carvalho *et al*. (2002) and

Table 11. Average results for plant height (PH)and total number of pods (TNP) traits, assessed in elite soybean genotypes

Genotypes	PH(cm)	TNP (unid.)
NS 5445 IPRO	89.51 bc	30.55 e
NS 6211 RR	76.33 e	36.44 cd
TEC 6029 IPRO	95.86 ab	41.14 bc
TECIRGA 6070RR	101.81 a	41.14 bc
6458 RSF IPRO	100.34 a	41.67 bc
DMario 5.8i RR	80.48 ed	46.68 ab
6160 RSF IPRO	85.68 cd	50.54 a
Don Mario 5.9i RR	81.20 ed	44.04 b
CD 2611 IPRO	96.85 a	32.50 de
CD2585 RR	99.51 a	51.46 a
General average of Intacta RR2 Pro ® technology	93.64 a	39.57 b
General average of Roundup Ready® techonology	87.86 b	44.37 a
CV (%)	6.91	12.05

*Means followed by the same letter do not differ statistically by Tukey test at 5% probability

Table 12. Average results for plant height (PH) and total number of pods (TNP) assessed in four soybean-growing environments

Growth environment	PH(cm)	TNP (unid.)
Independência-RS	69.63 d	36.28 c
Tapera-RS	98.40 b	40.37 b
Derrubadas-RS	85.60 c	50.90 a
Frederico Westphalen-RS	109.39 a	39.73 b
CV (%)	6.91	12.05

*Means followed by the same letter do not differ statistically by Tukey test at 5% probability.

Pires *et al*. (2012), which showed different behaviors of soybean genotypes depending on the cultivation environment. Specific characteristics of growth environment such as the physical and chemical conditions of the soil and climate conditions differently affect the response of genotypes (Rangel *et al*., 2007; Yuyama, 1991). Thus, the studied genotypes were significantly influenced by environmental conditions that occur in growth environments. For NS 6211 RRgenotype, Frederico Westphalen-RS environment showed the largest increase in GY, differing to the Derrubadas-RS and Independência-RS environments (Table 2). DMario 5.8i RR genotype presented higher GY in Frederico Westphalen-RS environment, differing from the Tapera-RS and Independência-RS environments. The other genotypes showed similar performance in Derrubadas-RS, Frederico Westphalen-RS and Tapera-RS and these environments have shown superiority to the Independência-RS environment in which were found lower averages for this traits. This response may be associated with the stability and adaptation of genotypes to the environment as shown by Peixoto *et al*. (2000). The TWK trait shows great variation among the genotypes. This trait transmits information of size and density of the kernels, as the state of maturity and sanity (Santos *et al*., 2003). The TWK together with the number of pods per plant and the number of kernels per pod, are considered the three main soybean grain yield components (NavároJúnior and Costa, 2002). Thus, in Independência-RS environment as evidenced greater magnitudes were observed in CD 2611 IPRO and TEC 6029 genotypes (Table 3). Similar results for this trait were observed in other environments, where CD211 IPRO, 6458 RSF IPRO and TEC 6029 IPRO genotypes, reveled increments in TKW. Kernel's weight is influenced by the number of kernel per plant, since, as the number of kernels increases, individual weight decreases (Perini *et al*., 2012), because of assimilates production be partitioned among a greater number of sinks. Thus, with the exception of 6458RSF IPRO genotype, it is observed the genotypes with higher grain yield had intermediate averages thousand-kernel weight. Studies from Bizeti *et al*. (2004) showed soybean genotypes have ability to regulate the number of kernels and kernels mass without significant variation in grain yield. Furthermore, in studies performed by Perini *et al*. (2012) the thousand-kernel weight showed low direct effect on grain yield per plant. Thousand-kernel weight is a genetically determinated trait (Pandey and Torrie, 1973), however, as it is controlled by several genes is highly influenced by environment conditions (Naváro Júnior and Costa, 2002).Thus, we can see the NS 6211 RR, 6458 RSF IPRO, D Mario 5.8i RR, Don Mario 5.9i RR and CD 2611 IPRO genotypes were more affected due to the modification of the culture environment (Table 3).Unanimously, soil and climatic conditions of Tapera-RS environment positively influenced the increase on thousand-kernel weight, since for both genotypes the largest values were observed in this environment. Thus, it can be associated with the occurrence of factors such as soil moisture, air temperature, solar radiation and photoperiod on favorable levels during the kernel development stages, resulting in increase of assimilates production in the plant, which are translocated and accumulated in the kernels, providing greater dry matter accumulation in it. Rambo *et al*. (2003) reported that in favorable soil and climatic conditions the largest increases in thousand-kernel weight are shown.

CD 2611 IPRO, TECIRGA 6070 RR, 6458 RSF IPRO genotypes showed the greatest magnitudes for the FPI (Table 4), with means ranging from 20,85 to 37,35. To these genotypes are indicated changes in the spacing and plant density in order to improve the photosynthetic efficiency in lower-third of plants. Largest FPI, above 20 cm, reduces the productive potential of the genotype, once that the soybean's ideotype consist of smallest FPI and largest plant height. Because of this, a largest range for formation of the reproductive structures, and consequently largest number of pods per plant is provided (Pires *et al*., 2012). In Independência-RS, Tapera-RS, Derrubadas-RS and Frederico Westphalen-RS environmentsthe CD 2585 RR, NS 5445 IPRO, Don Mario 5.9i RR, DMario 5.8i RR and 6160 RSF IPRO genotypes reveled the smallest magnitudes to FPI(Table 4). However, as the magnitude observed for these genotypes were greater than 15 centimeters, they have no restrictions with regard to mechanical harvesting, since in elite soybeans genotypes FPH should range from 10 to 15 cm, reducing losses during mechanical harvesting (Sediyama *et al*., 2005). First pod insertion height is a genetically defined trait, however, is greatly influenced by environmental factors such as water supply, air temperature and soil fertility (Bergamaschi and Barni, 1978). Thus, the measure that changes the growth environment, the availability of these resources is changed, influencing the increase or decrease of trait. Thus, it is observed in Tapera-RS and Frederico -RS environments provided favorable conditions for this trait's increase (Table 4). Largest FPI in these environments is associated with the smallest utilization of solar radiation in the lower-third of the plant, as there is correlation with the light use in the lower layer of the canopy and the FPI, where more incident photo synthetically active light on the layer-lower of the canopy, closer to the ground will be the node with first pod (Zabot, 2009). The NPMS trait showed significant differences among genotypes only in the Independência-RS and Derrubadas-RS environments where the greatest range for this feature observed in Derrubadas-RS environment where the magnitudes ranged from 41.95 to 20.66, to CD 2585 and CD 2611 genotypes IPRO RR, respectively (Table 5). In Tapera-RS and Frederico Westphalen-RS environments, no difference was detected among genotypes. The largest NPMS is associated with the ability to grow to produce reproductive structures in this region, together with the greater conversion rate of flowers in viable pods. Corroborating the results found by Carvalho *et al*. (2002), which showed the number of nodes on the main stem has an important effect on grain yield.

The responses of NS 6211 RR, TEC 6029 IPRO, 6458 RSF IPRO, 6160 RSF IPRO and CD 2611 IPRO genotypes for the NPMS trait was changed as the growth environment has modified. Thus, soil and climatic conditions afforded by cultivation environments involved interpenetrate the responses of these genotypes. Among the environmental factors, photosynthetically active solar radiation and light quality are the ones that influence the response of the genotype for this trait, since competition for these environmental components provides reduced number of reproductive nodes on the main stem, increasing the internode length and consequently the shading (Bianchi *et al*., 2006). This reduces the flower formation and increases the floral abscission, reducing the number of pods on the main stem. For the NB trait it was observed in Tapera-RS, Derrubadas-RS and Frederico Westphalen-RS environments, TEC 6029 IPRO, TECIRGA 6070RR, 6458 RSF IPRO, DMario 5.8i RR, 6160 RSF IPRO and CD 2585 RR genotypes had the highest magnitude for this trait (Table 6). In Independência-RS environment, the highest values were observed in TECIRGA 6070 RR and 6160RSF IPRO genotypes, which differed from the other genotypes. The branches are formed from buds located mainly in the lower part of the plant, and have a similar structure to the main stem. In addition to leaves, flowers and pods also are developed.

The lateral branches emission capacity is dependent of the genetic constitution and of the interaction of genotype with the growth environment (Mundstock and Thomas, 2005). Regarding to this trait, it was showed that the NS 5445 and NS 6211 IPRO RR genotypes had the lowest NB per plant. Measurement of the genotype's ability to develop lateral branches is of paramount importance, since it becomes possible to determine the plant density and appropriate spacing between lines for each genotype, in order to increase the yield. Thus, genotypes with less potential emission side branches require higher plant population while genotypes with the greatest potential outweigh any problems with density and spatial distribution of plants. Studies by Tourino *et al*. (2002) point out that the soybean plants have plasticity to overcome certain shortcomings of plants caused by the low quality of seeds and / or seeding process, mainly due to branch emission capacity, which increases the number of pods per plant, offsetting the grain yield. Cultivation environment has implications on the NB per plant, with that, to the extent that change soil and climatic characteristics genotype seeks morphologically and physiologically adjust itself in order to enhance their intraspecific competitive ability by factors such as light, water and nutrients (Thomas *et al*., 1998), resulting in the increase or decrease in the number of ramifications. This is evidenced in genotypes NS 5445 IPRO IPRO and TEC 6029, which had higher increases on this trait in Tapera-RS and Derrubadas-RS environments and that differed from Indepenência-RS and Frederico Westphalen-RS environment. In contrast, the genotype TECIRGA 6070 RR presented in Independence-RS environment the greater the NB, differing from the other environments (Table 6). The results corroborate with CervieriFilho (2005), which states that the NB may change depending on the soil and climate characteristics afforded by agricultural crops and cultivation environments. The NPB showed a close association with the number of branches, with the largest number of branches resulted in greater numbers of pods in the branches in both environments the 6160 RSF IPRO genotype showed the greatest NPB (Table 7). Thus, the number and size of branches provide increased number of sites for the formation of the reproductive structures, adding the number of fertile nodes in the plant, and consequently the number of pods, and contributing to grain yield increase (Rambo *et al*., 2003). Thomas (1992) states that the pods produced in plant's branches contribute up to 70% of grain yield.

Cultivation environments did not results in significant effects on the response of NS 5445 IPRO, TEC 6029 IPRO and CD 2611 IPRO genotypes to NPB trait, so it is considered that these genotypes are more stable for this trait (table 7). For other genotypes was no significant contribution to the interaction with the growth environment, thus, environment has implications on the response of cultivating the NPB trait. The environmental factors that influence the number of pods on the main stem and number of branches also play influence on the number of pods on branches, since change the production and division of produced assimilates in the plant (Nardino *et al*. , 2015). The number of kernels per pod is vital to the soybean yield, since it has direct and indirect effects on grain yield (NavároJúnior and Costa, 2002), however, fluctuations in these associations may occur as changes the genetic makeup of genotypes. The occurrence of pods with one grain (NP1K) is due to floral structures that develop only one ovary in pods or because of ovarian/kernel abortion. In addition, insect pest attack in vegetables can reduce the number of kernels formed in the pod. For this trait, it is showed that the CD 2585 RR, 6160 RSF IPRO, 6458 RSF IPRO and TECIRGA 6070 RR genotypes remained among the top genotypes in both growing environments (Table 8). The kernel formed in pods with only one grain has greater mass and size when compared with the kernels formed in pods with three kernels, since there is no competition in partitioning of assimilates provided to the structure, however, this change partly offsets the increase of yield grains (Herbert and Litchfield, 1982). Derrubadas-RS growth environment showed the greatest magnitudes for NP1K and NP2K traits for both tested genotypes (Table 8 and Table 9). These results contributed to the superiority of this environment in the TNP trait (Table 12). The number of kernels per pod is determined during flowering stage (McBlain and Hume, 1981), therefore, specifics conditions of each environment during this phase can modify the response magnitudes of these traits coming to favor or disfavor the genotypes. CD 2585 RR genotype had the highest NP2K in both growth environments, however, did not differ from 6160 RSF IPRO genotype and differed of Don Mario 5.9i RR only in Tapera-RS environment (Table 9). The genotypes NS 5445 IPRO IPRO and CD 2611 revealed the smallest magnitudes for NP2K trait. Pods with two kernels are made from floral structures that develop later in the plant, thus, are less benefited in receiving assimilates producing vegetables with only two ovules (McBlain and Hume, 1981). The largest number of pods with two kernels can compensate grain yield in genotypes that have a smallest number of pods with three kernels (NavároJúnior and Costa, 2002). Regarding to NP3K trait, genotypes showed little variation among themselves in each growth environment (Table 10). According Mc Blain and Hume (1981) there is a strong tendency that the elite soybean genotypes produce larger number of pods with three kernels due to breeding programs advocate the selection of genotypes that contain three ovules per pod. For both genotypes Derrubadas-RS environment greater or equal NP3K in relation to other environments (Table 10). NS 5445 and NS 6211 IPRO genotypes were stable for this trait, since there were no differences among the growth environments. Heiffing (2002) considers that the number of kernels per pod is typically a genetic trait and little influenced by the environment, however, the results show that the environment exerts influence on trait's expression, becoming noticeable when observing the performance of the CD 2585 RR genotype among growth environments. Environment has a strong influence on the PH trait as it is controlled by several genes (Bergamaschi and Barni, 1978). Thus, the largest values for this trait were observed in TECIRGA 6070 RR, 6458 RSF IPRO, TEC 6029 IPRO, CD 2611 and CD 2585 IPRO RR genotypes (Table 11). NS 6211 RR genotype had the smallest PH, however, the value was above 65 centimeters, which is considered the minimum height in order to be not reducing grain yield depending on the grain losses in mechanized harvesting operation according to Bonetti (1983).

Total number of pods per plant observed in the tested genotypes ranged from 30.55 to 51.46 (Table 11), these values corroborating the study by Câmara (1998) which concluded that the soybean genotypes produce national average of 30 to 80 viable pods per plant. The largest values for the character were evident in 6160RSF IPRO and CD 2585 RR genotypes, however only 6160 RSF IPRO genotype the largest number of total pods was reflected in increased on grain yield. The largest number of pods per plant in CD 2585 RR genotype has not resulted in higher yield because the thousand-kernel weight was very small. This result corroborates Bárbaro *et al*. (2006), which state the TNP trait is one of the components that most influence grain yield, together with thousand-kernel weight. Frederico Westphalen-RS showed plants with largest height, differing from the other environments, however, Independência-RS environment revealed the smallest magnitude smaller this trait (Table 12). Thus, one can infer that the environments have different soil and weather conditions, once PH is influenced by photoperiod, moisture, temperature and soil fertility (Lam-Sanchez and Yuyama 1979). According Dybing (1994) PH has direct and indirect effects on grain production, because it is related to the greater amount of dry mass produced, resulting in greater potential for formation of reproductive structures. Highest TNP was evidenced in Derrubadas-RS environment, with an increase of more than 25% than Tapera-RS and Frederico Westphalen-RS environments (Table 12). Studies by Peluzio *et al*. (2010) showed there are positive correlations between the total number of pods per plant and grain yield, emphasizing that this is an important trait to the final grain yield. Thus, growth environments that enhance character can be considered favorable for achieving greater grain production. Overall, INTACT IPRO® RR2 technology was superior to Roundup Ready® technology for the grain yield, thousand-kernel weight, plant height, first pod insertion height and number of pods on the main stem. Roundup Ready® technology provided largest number of pods with one kernel, number of pods with two kernels and total number of pods. Number of pods in branches, number of branches and number of pods with three grains did not differ between INTACT RR2 IPRO® and Roundup Ready® technologies. Superiority in grain yield observed for INTACT IPRO® RR2 technology is associated with tolerance to insect-pests attack, coupled with the fact it is recently developed and launched to the market. In addition, it can assign part of this increase to advanced mapping techniques, selection and insertion of genes into DNA regions, which confer tolerance to insect-pests (Marcelino *et al*., 2007).

CONCLUSION

6458RSF IPRO and NS 6211 RR genotypes present superior agronomic performance and can be given for the Independência-RS environment. 6061 RSF IPRO genotype features superior agronomic performance and can be recommended for Tapera-RS and Derrubadas-RS environment. NS 6211 RR genotype features superior agronomic performance for Frederico Westphalen-RS environment. Based on assessed traits, Tapera-RS Derrubadas-RS and Frederico Westphalen-RS environments have soil and climatic conditions more favorable for the growth and development of elite soybean genotypes. Genotypes with INTACT RR2 IPRO® technologypresent agronomic performance superior to genotypes with Roundup Ready® technology.

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