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CROP PRODUCTION

Agronomic performance of transgenic soybean cultivars in Brazilian Cerrado

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ABSTRACT. The productive capacity of soybeans is associated with the adaptation of the culture to the cultivation environment. Factors such as a high number of pods, the weight of a thousand grains, and grain number are essential factors in determining cultivars of high productive potential. The launching of new varieties associated with new technologies makes it necessary to know the performance of these varieties in different growing environments. This study aimed to analyze the agronomic performance of transgenic soybean cultivars under Cerrado conditions. The experimental design used completely randomized blocks; six of the twelve cultivars used RR_1 technology and the remaining six used RR_2BT. The cultivars were grown in five distinct locations in the southwest region of Goiás. The results demonstrated no increments in the grain yield of the RR_1 or RR_2BT technologies and the precocity of the cultivars also did not favor an increase in grain yield. The localities of Jataí and Rio Verde did not influence the cultivar cycle.

Keywords: environments; improvement production; technology.

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Introduction

Soybeans are gaining in agricultural importance worldwide due to the great diversity of the use of their oilseed in addition to the continued increase of global food demand. The world soybean production for the 2016/17 crop is estimated at 324.20 million tons, of which Brazil produces approximately 32% (USDA, 2016). Brazil's national soy production is estimated at 103 million tons for the 2016/17 harvest, of which the Cerrado region produces approximately 45% (CONAB, 2016). In addition, the region has potential for increasing the production area in the coming years.

Due to the expansion of soybean production in Goiás, there are varied environments growing soybeans especially in the Cerrado of Goiás, which makes it possible to observe the effects of these environments on grain yield. The Cerrado contains environments with variations of 500 m in altitude within radii of less than 100 km, which influences temperature and precipitation factors (Tannura, Irwin, & Good, 2008; Hassol, 2009; Mariano, 2010) and, consequently, the behavior of the cultivars (Dixon, Hollinger, Garcia, & Tirupattur, 1994).

In this regard, breeding programs are of crucial importance, since genetic gains contribute significantly to productivity and are obtained through breeding (Rocha & Vello, 1999; Machado, 2014; Xu, Hennessy, Sardana, & Moschini, 2013). To increase the yield of soybean cultivars, three main components should be selected for and evaluated to improve the agronomic performance of each cultivar (Mauad, Bertoloze, Almeida, & Abreu, 2011): the number of pods per plant, the number of grains per pod and the average weight of a thousand grains (Navarro Júnior & Costa, 2002; Guzman et al., 2007; Zhang et al., 2015).

Due to the difficulties with weeds and Lepidoptera for soy production, new herbicidetolerant soybean cultivars with different mechanisms of action and resistance to Lepidoptera have been launched (Bernardi et al., 2012; Mateus & Silva, 2013). These technologies allow the cultivars to express their full potential and give producers increased options for the management of weeds.

Due to the difficulty of recommending cultivars as a function of the genotype x environment interaction, it is necessary to perform tests on a larger number of sites (Carvalho et al., 2002; Toledo et al., 2006). In the state of Goiás, for example, there is a wide variability of growing conditions. This factor is intensified with the development of new transgenic cultivars, and the behavior of these cultivars has yet to be evaluated (Paterniani, 2001).

In Brazil, there are six transgenic events approved for soybean cultivation (Mateus & Silva, 2013). With a higher commercial representation to date, we use RR_1 soybeans which are tolerant to the glyphosate herbicide and, subsequently, RR_2BT soybeans, which have a combined resistance to insects of the order Lepidoptera and tolerance to the herbicide glyphosate. Both biotechnological events contribute to the ease of crop management and consequently a better yield.

The objective of this work was to evaluate the agronomic performance of cultivars of transgenic soybean in Cerrado conditions in the agricultural crops of 2013/14 and 2014/15.

Material and methods

The trials were conducted in the agricultural crops of 2013/14 and 2014/15 at the following five representative sites of soybean cultivation in the southwestern region of Goiás: Maurilândia (18° 02'20"S, 50° 22'25" W, altitude of 480 m), Bom Jesus de Goiás (18°01'75" S, 50°05'61'' W, altitude of 650 m), Rio Verde (17° 51'82" S, 50°55'72" W, altitude of 750 m), Jataí (18°06'44" S, 51°52'16" W, altitude of 889 m), and Montividiu (17°34'24" S, 51°17'24" W, altitude of 985 m).

The experimental design used randomized blocks with four replications. The treatments were composed of twelve cultivars of soybean representative of the cultivation in the region, as described in Table 1. The plots were composed of four rows, each row with a width of 0.50 m and a length of 5.0 m. Data was measured from the two central rows, disregarding 0.50 m from each end, totaling 4.0 m².

Table 1. Characteristics of cultivars transgenic soybeans used in the agronomic performance tests, under conditions of the Brazilian Cerrado, in crop years 2013/14 and 2014/15.

Cultivars	Technology	Cycle	Maturity Group	Company	Plants ha^{-1}
BMX Desafio RR	RR_1	Medium	7.4	BRASMAX	400,000
BMX Ponta IPRO	RR_2BT	Precocious	7.0	BRASMAX	440,000
BMX Potência RR	RR_1	Precocious	7.0	BRASMAX	440,000
BMX Prisma IPRO	RR_2BT	Longer	7.5	BRASMAX	360,000
M 7110 IPRO	RR_2BT	Medium	7.1	MONSOY	400,000
M 7739 IPRO	RR_2BT	Longer	7.7	MONSOY	360,000
NA 5909 RR	RR_1	Precocious	6.8	NIDERA	440,000
NA 7337 RR	RR_1	Longer	7.5	NIDERA	360,000
NS 7000 IPRO	RR_2BT	Precocious	7.0	NIDERA	440,000
NS 7338 IPRO	RR_2BT	Medium	7.3	NIDERA	400,000
W 712 RR	RR_1	Medium	7.1	WHERMAN	400,000
W 787 RR	RR_1	Longer	7.6	WHERMAN	360,000

Information provided by the companies holding the cultivars.

The sowing was performed in the rainy season on the following dates: Maurilândia (Nov. 1st, 2013 and Nov. 5th, 2014), Bom Jesus de Goiás (Oct. 31st, 2013 and Nov. 4th, 2014), Rio Verde (Nov. 15th, 2013 and Nov. 30th, 2014), Jataí (Oct. 22nd, 2013 and Oct. 28th, 2014), and Montividiu (Oct. 16th, 2013 and Oct 22nd, 2014). In all localities, soybean was grown in no-till systems. The desiccation of the weeds was accomplished by using 960 g of a.i. glyphosate ha^{-1} and 50 g of a.i. saflufenacil ha^{-1} applied with a trailing sprayer with a volume of 150 L ha^{-1}. For fertilization recommendations, the results of soil samples were taken into account and are described for each of the locations in Table 2.

Table 2. Physical and chemical characteristics of the soils at the cultivation sites.

Lacation	Clay (%)	Silt (%)	Sand (%)	% O.M. (g dm^{-3})	pH ($CaCl_2$)	Ca^{+2}	Mg^{+2}	Al^{+3}	H+Al	K^{+}	CTC ($cmol_c$ dm^{-3})	P	Cu (mg dm^{-3})	Zn (mg dm^{-3})	Fe (mg dm^{-3})
Bom Jesus de Goiás	16	8	76	14	4.2	0.23	0.10	0.53	2.92	0.05	3.31	11.11	1.44	0.17	38.90
Jataí	61	12	26	46	4.3	0.60	0.11	0.53	6.76	0.21	7.98	34.26	1.04	5.42	40.57
Maurilândia	49	8	43	37	5.0	1.66	0.43	0.05	3.72	0.19	6.00	10.64	2.27	0.88	28.74
Montividiu	53	8	38	43	5.1	2.23	0.58	0.04	3.6	0.26	6.68	23.42	1.15	5.36	27.23
Rio Verde	32	4	64	39	5.3	1.96	0.61	0.03	3.04	0.27	5.89	8.02	0.60	3.42	29.30

Rainfall data were collected at each cultivation site and are shown in Figure 1. Herbicides, insecticides and fungicides were applied to keep the plants under optimal development and growing conditions for all of the cultivation sites, thus offering the necessary conditions for the cultivars to yield as optimally as possible.

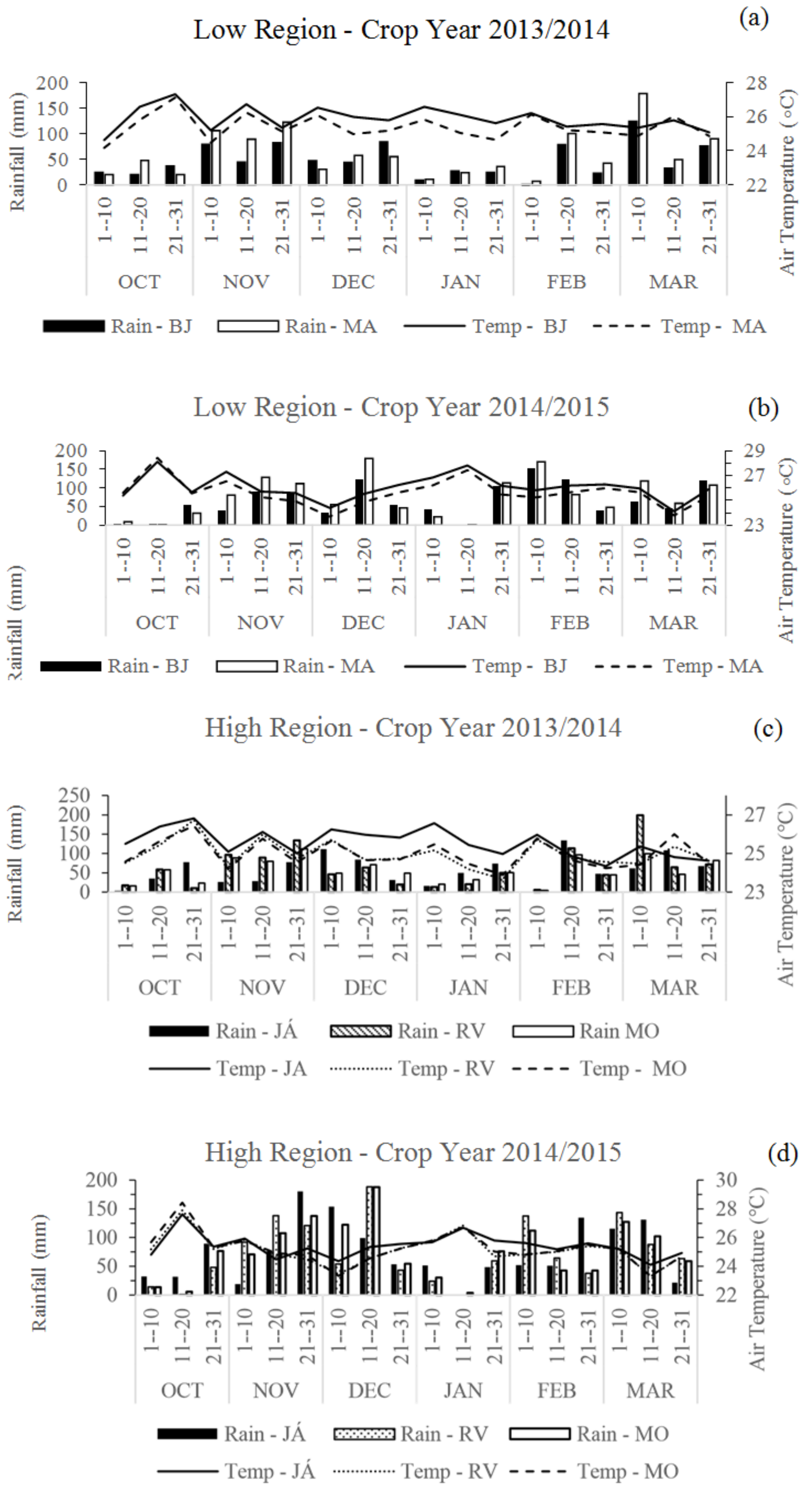

Figure 1. Mean temperature and accumulated precipitation per decant, for the duration of the study.

The following agronomic characteristics were determined: yield of grains and weight of a thousand grains, with moisture correction to 13%; number of pods per plant; and number of grains per plant. The physiological maturity (cycle) was evaluated at the reproductive stage R_7, when the pods became yellow and 50% of the leaves became yellowish (Sediyama, 2013).

The variables were submitted for a homogeneity test. When the homogeneity was verified, a joint analysis of the data was performed. After detecting significance for a given source of variation, the Scott-Knott test at 5% probability was used to compare the means of the treatments. The analyses were performed using the Sisvar program (Ferreira, 2011).

Results and discussion

The analysis of variance verified significance for genotype x year x local interaction for all variables (Table 3). This shows that the behavior of transgenic soybean cultivars was influenced by the cultivation sites in the cerrado and agricultural crops, as verified by other authors (Beavis & Keim, 1996).

Table 3. Summary of the joint variance analysis for grain yield (kg ha^{-1}) (Yield), weight of a thousand grains (WTG), pod number (PN), number of grains (NG), and Cycle of Cultivars of transgenic soybeans, under conditions of the Brazilian Cerrado, in the 2013/14 and 2014/15 crop years.

FV	FD	Yield	WTG	PN	NG	Cycle
Rep (Year*Location)	30	ns	ns	ns	ns	**
Genotype (G)	11	**	**	**	**	**
Year (Y)	1	**	**	ns	ns	ns
Location (L)	4	**	**	**	**	**
G*Y	11	**	**	**	**	**
G*L	44	**	**	**	**	**
Y*L	4	**	**	*	ns	**
G*Y*L	44	**	**	**	**	**
CV (%)		13.97	7.38	20.00	20.41	1.74
General Average:		3,237	141	40	95	110

When analyzing the productive performance of cultivars in low-lying municipalities, it can be seen that only M 7110 IPRO and BMX Desafio RR had higher grain yields in Maurilândia and Bom Jesus, respectively, in the two agricultural crops. However, in the higher altitude municipalities, the cultivars showed a different behavior, characterizing the presence of a genotype x environment interaction (Cucolotto, Garbuglio, Pipolo, Fonseca Junior, & Kamikoga, 2007). In Rio Verde, the productive performances of BMX Desafio RR, M 7110 IPRO, W 712 RR and W787 RR were significant. In the municipality of Jataí, the productive performances of BMX Desafio RR, M 7739 IPRO and NS 7338 IPRO were significant, while in Montividiu, the highest grain yields were obtained with BMX Potência RR, BMX Prisma IPRO, NA7337 RR, NS 7338 IPRO, and W 787 RR.

Table 4. Mean values of grain yield (kg ha^{-1}) of transgenic soybean cultivars, under Brazilian Cerrado conditions, in the 2013/14 and 2014/15 crop years.

Cultivars	Crop Year 2013/14					Crop Year2014/15					
	MA	BJ	RV	JA	MO	MA	BJ	RV	JA	MO	Mean
BMX Desafio RR	3,550 Bb	4,463 Aa	2,650 Ca	4,688 Aa	4,700 Aa	1,691 Cb	3,153 Ba	2,828 Ba	4,564 Aa	2,669 Bb	3,495
BMX Ponta IPRO	3,613 Bb	4,363 Aa	2,625 Ca	3,750 Bc	4,625 Aa	2,735 Ba	2,678 Bb	1,418 Cb	4,734 Aa	2,375 Bb	3,291
BMX Potência RR	3,688 Bb	4,350 Aa	2,338 Ca	4,338 Ab	4,363 Aa	2,294 Ca	2,600 Cb	1,194 Dc	4,415 Aa	3,389 Ba	3,297
BMX Prisma IPRO	3,713 Ab	3,400 Ac	1,925 Bb	3,925 Ac	4,275 Aa	1,880 Bb	3,658 Aa	1,670 Bb	3,564 Ab	3,766 Aa	3,178
M 7110 IPRO	4,100 Ba	4,988 Aa	2,513 Da	3,575 Cc	5,025 Aa	2,381 Ba	1,920 Bc	2,338 Ba	4,646 Aa	2,848 Bb	3,433
M 7739 IPRO	4,281 Ba	3,963 Bb	2,463 Ca	5,238 Aa	4,788 Aa	1,489 Cb	3,445 Ba	1,861 Cb	4,560 Aa	2,976 Bb	3,506
NA 5909 RR	3,238 Bb	3,763 Bb	1,900 Cb	4,150 Ab	4,338 Aa	2,738 Ba	1,070 Cd	859 Cc	4,035 Ab	2,208 Bb	2,830
NA 7337 RR	3,400 Bb	1,475 Cd	1,650 Cb	3,500 Bc	4,544 Aa	2,563 Ca	3,336 Ba	1,483 Db	4,265 Aa	3,178 Ba	2,939
NS 7000 IPRO	3,338 Bb	3,613 Bb	2,163 Cb	4,175 Ab	4,388 Aa	2,494 Ba	2,461 Bb	2,230 Ba	4,524 Aa	2,836 Bb	3,222
NS 7338 IPRO	4,125 Ba	3,875 Bb	2,163 Cb	4,713 Aa	4,525 Aa	1,158 Cb	3,265 Ba	1,623 Cb	4,915 Aa	3,505 Ba	3,387
W 712 RR	3,788 Bb	3,275 Cc	2,350 Da	3,000 Cc	4,438 Aa	2,181 Ba	2,465 Bb	2,475 Ba	4,230 Aa	2,340 Bb	3,054
W 787 RR	3,775 Ab	2,938 Bc	2,325 Ba	4,338 Ab	3,888 Aa	2,445 Ba	3,039 Aa	2,259 Ba	3,570 Ab	3,654 Aa	3,223
Mean	3,717	3,705	2,255	4,116	4,491	2,171	2,757	1,853	4,335	2,979	

Means followed by the same capital letter in the rows and lowercase in the columns do not differ from one another by the Scott-Knott test, at 5% probability. MA: Maurilândia; BJ: Bom Jesus; RV: Rio Verde; JA: Jataí; MO: Montividiu.

When analyzing the positioning of soybean cultivars to explore their productive potential, it can be seen that in Jataí, most of the cultivars had higher yields of grains, especially

BMX Desafio RR, BMX Potência RR, BMX Prisma IPRO, M 7739 IPRO, NA 5909 RR, NS 7000 IPRO, NS 7338 IPRO, and W 787RR. It should be noted that the BMX Prisma IPRO produced similar grain yield in the municipalities of Bom Jesus and Montividiu. Similar factors occurred with the cultivar W 787 RR in Montividiu.

In the evaluation of the performance of the cultivars in each municipality, it is observed that BMX Desafio RR conferred higher yields of grains in Bom Jesus de Goiás, Rio Verde, and Jataí, in two consecutive agricultural harvests (Table 4). This demonstrates the good performance of the cultivar in low, medium and high altitude regions, respectively. The highest performances in regions of higher altitude were observed for BMX Desafio RR (Rio Verde and Jataí), W 787 RR (Rio Verde and Montividiu), and NS 7338 IPRO (Jataí and Montividiu).

The highest yields of grains obtained in the regions of higher altitude are due to the lower average nocturnal temperatures, which allows the greater storage of photoassimilates because of the reduction of respiration rate in the plants (Daroish, Hassan, & Ahad, 2005). Consequently, there is a greater amount of reserves to be transported to the grains, thus contributing to the increase of soybean yield (Fageria & Santos, 2008).

On the other hand, all cultivars, except BMX Desafio RR, showed the lowest grain yields in Rio Verde during both crop years. It was expected that this locality would provide intermediate yield values between the regions of higher and lower altitudes. However, the irregular distribution of rainfall (Figure 1c and d) coinciding with the reproductive stages of the cultivar negatively influenced the development of the soybeans, which reduced grain yield (Canfalone, & Navarro Dujmovich, 2012).

It is important to note that the highest grain yields in the higher altitude regions were obtained, mostly by longer cycle cultivars. Therefore, it can be observed that the longer the development period of the plants, either in the vegetative or reproductive phases, associated with a lower night temperature condition, makes it possible to obtain higher yields of grains (Rocha & Vello, 1999).

The analysis of the weight of one thousand grains verified effects for different soybean growing environments during both crop years, except for Montividiu, which presented similar and superior results to the other environments (Table 5). Notably, the heavier weights of the one thousand grains of the cultivars BMX Desafio RR, M 7110 IPRO, and W 712 RR, in Rio Verde, contributed to higher grain yields. In this case, there was no direct relationship between the maturation group and the weight of a thousand grains. Most likely, this result can be attributed to the phenotypic plasticity of soybean cultivars in compensating the yield components (Peluzio, Afférri, Monteiro, Melo, & Pimenta, 2010).

Table 5. Mean values of the thousand grains (grams) (GMO) and weight of transgenic soybean cultivars under Cerrado conditions in the 2013/14 and 2014/15 crop years in Brazil.

Cultivars	Crop Year 2013/14					Crop Year2014/15					
	MA	BJ	RV	JÁ	MO	MA	BJ	RV	JA	MO	Mean
BMX Desafio RR	153 Ab	127 Bb	151 Aa	162 Ab	145 Ac	130 Ba	163 Aa	99 Ca	135 Bc	171 Aa	143
BMX Ponta IPRO	135 Bc	150 Aa	152 Aa	145 Bc	158 Ac	94 Bc	143 Ab	85 Bb	145 Ab	157 Ab	136
BMX Potência RR	138 Bc	150 Aa	139 Ba	145 Bc	156 Ac	112 Cb	170 Aa	88 Db	141 Bc	158 Ab	140
BMX Prisma IPRO	126 Bd	119 Bb	125 Bb	118 Bd	172 Ab	121 Bb	163 Aa	99 Ca	121 Bd	162 Ab	132
M 7110 IPRO	156 Bb	168 Aa	149 Ba	158 Bb	175 Ab	112 Cb	146 Bb	103 Ca	169 Aa	178 Aa	151
M 7739 IPRO	148 Bb	128 Cb	149 Ba	154 Bb	187 Aa	117 Cb	151 Cb	85 Db	142 Bc	177 Aa	144
NA 5909 RR	135 Bc	156 Aa	150 Ba	139 Bc	170 Ab	104 Cc	113 Cc	83 Db	136 Bc	153 Ab	134
NA 7337 RR	117 Bd	93 Cc	115 Bb	140 Bc	146 Ac	134 Ba	144 Bb	81 Cb	147 Bb	177 Aa	129
NS 7000 IPRO	166 Ba	160 Ba	161 Ba	177 Aa	190 Aa	114 Db	140 Cb	101 Da	160 Ba	177 Aa	154
NS 7338 IPRO	141 Bc	135 Bb	153 Aa	155 Ab	155 Ac	110 Bb	159 Aa	96 Ba	152 Ab	170 Aa	142
W 712 RR	166 Ba	154 Ba	164 Ba	170 Ba	181 Aa	110 Cb	148 Cb	112 Ca	153 Bb	169 Aa	153
W 787 RR	138 Ac	132 Ab	124 Ab	134 Ac	148 Ac	145 Ba	152 Bb	98 Da	123 Cd	178 Aa	137
Mean	143	139	144	150	165	117	149	94	144	169	

Means followed by the same capital letter in the rows and lowercase in the columns do not differ from one another by the Scott-Knott test, at 5% probability. MA: Maurilândia; BJ: Bom Jesus; RV: Rio Verde; JA: Jataí; MO: Montividiu.

It can be assumed that the higher number of pods would provide a higher number of grains per plant, as observed for M 7739 IPRO cultivated in regions of lower altitude (Maurilândia and Bom Jesus de Goiás). However, the contribution of this variable in increasing grain yield was only observed for the cultivar NA

7337 RR in Montividiu, during both crop years (Table 6). Probably this lack of relationship between the components of the yield can be attributed to the phenotypic plasticity of the evaluated cultivars, as observed in other research studies (Navarro Júnior & Costa, 2002; Mauad et al., 2011).

Table 6. Mean values of the number of pods (NP) of transgenic soybean cultivars, under Brazilian Cerrado conditions, in the 2013/14 and 2014/15 crop years.

Cultivars	Crop Year 2013/14					Crop Year 2014/15					
	MA	BJ	RV	JÁ	MO	MA	BJ	RV	JA	MO	Mean
BMX Desafio RR	33 Ab	35 Ab	27 Ab	31 Ab	37 Ab	41 Ab	43 Ab	39 Aa	40 Ab	38 Ac	36
BMX Ponta IPRO	43 Aa	42 Ab	38 Aa	35 Ab	35 Ab	29 Ac	42 Ab	31 Aa	32 Ab	38 Ac	36
BMX Potência RR	37 Ab	36 Ab	33 Ab	34 Ab	41 Ab	25 Bc	45 Ab	39 Aa	49 Aa	33 Bc	37
BMX Prisma IPRO	44 Ba	65 Aa	33 Cb	50 Ba	35 Cb	52 Ab	47 Ab	34 Aa	45 Ab	43 Ab	45
M 7110 IPRO	47 Aa	39 Ab	35 Aa	33 Ab	42 Ab	27 Ac	41 Ab	35 Aa	33 Ab	33 Ac	36
M 7739 IPRO	52 Aa	60 Aa	37 Ba	52 Aa	34 Bb	64 Aa	61 Aa	38 Ba	54 Aa	48 Bb	50
NA 5909 RR	26 Ab	34 Ab	29 Ab	27 Ab	40 Ab	26 Ac	23 Ac	20 Ab	34 Ab	29 Ac	29
NA 7337 RR	54 Ba	73 Aa	43 Ca	49 Ca	59 Ba	49 Bb	66 Aa	41 Ca	34 Cb	59 Aa	53
NS 7000 IPRO	31 Ab	32 Ab	28 Ab	33 Ab	31 Ab	27 Bc	40 Ab	39 Aa	29 Bb	26 Bc	32
NS 7338 IPRO	38 Ab	43 Ab	28 Bb	33 Bb	31 Bb	44 Bb	46 Bb	37 Ba	57 Aa	45 Bb	40
W 712 RR	48 Aa	47 Ab	42 Aa	42 Aa	50 Aa	31 Bc	50 Ab	40 Aa	32 Bb	42 Ab	42
W 787 RR	50 Ba	65 Aa	36 Ba	40 Ba	42 Bb	52 Bb	54 Ba	44 Ba	64 Aa	45 Bb	49
Mean	42	48	34	38	40	39	46	36	42	40	

*Means followed by the same capital letter in the rows and lowercase in the columns do not differ from one another by the Scott-Knott test, at 5% probability. * MA: Maurilândia; BJ: Bom Jesus; RV: Rio Verde; JA: Jataí; MO: Montividiu.

It is also important to note that the contribution of the number of pods per plant in increasing grain yield can be observed for cultivars M 7110 IPRO, W 712 RR and W 787 RR in Rio Verde, for M 7739 IPRO in Jataí and for NA 7337 RR in Montividiu, in both agricultural crops (Tables 4 and 6). In both crop years, cultivar M 7739 IPRO obtained the largest number of pods in all environments, except in Montividiu. This cultivar, together with NA 7337 IPRO and W 787 RR, formed the largest number of pods in Bom Jesus de Goiás and Rio Verde, and the latter also stood out in Jataí.

The longest cycle contributed to obtaining higher grain yields for cultivars W 787 RR (in Rio Verde and Montividiu) and for BMX Prisma IPRO in Montividiu. Conversely, the cultivar NA 5909 RR was the most precocious in all the localities. Together with this cultivar, the early behavior of BMX Potência RR in Maurilândia was also outstanding (Table 7).

Table 7. Mean values of the number of grains (NG) of transgenic soybean cultivars, under conditions of the Brazilian Cerrado, in the 2013/14 and 2014/15 crop years.

Cultivars	Crop Year 2013/14					Crop Year 2014/15					
	MA	BJ	RV	JA	MO	MA	BJ	RV	JA	MO	Mean
BMX Desafio RR	67 Ab	84 Ab	68 Aa	78 Ab	93 Ab	103 Ac	110 Ab	94 Aa	113 Ab	88 Ab	90
BMX Ponta IPRO	103 Aa	108 Ab	99 Aa	92 Ab	89 Ab	77 Bd	109 Ab	79 Ba	76 Bc	99 Aa	93
BMX Potência RR	91 Ab	91 Ab	89 Aa	80 Ab	97 Aa	57 Bd	97 Ab	89 Aa	112 Ab	78 Bb	88
BMX Prisma IPRO	109 Ca	156 Aa	88 Ca	123 Ba	89 Cb	130 Ab	121 Aa	78 Ba	112 Ab	109 Aa	111
M 7110 IPRO	112 Aa	98 Ab	86 Aa	82 Ab	105 Aa	73 Ad	106 Ab	91 Aa	82 Ac	84 Ab	92
M 7739 IPRO	114 Aa	130 Aa	84 Ba	117 Aa	79 Bb	157 Aa	140 Aa	79 Ca	112 Bb	111 Ba	112
NA 5909 RR	60 Ab	80 Ab	67 Aa	61 Ab	90 Ab	61 Ad	54 Ac	46 Ab	80 Ac	69 Ab	67
NA 7337 RR	106 Ba	129 Aa	86 Ba	93 Bb	120 Aa	98 Bc	136 Aa	81 Ba	82 Bc	122 Aa	105
NS 7000 IPRO	74 Ab	78 Ab	66 Aa	80 Ab	75 Ab	67 Bd	102 Ab	94 Aa	70 Bc	63 Bb	77
NS 7338 IPRO	86 Ab	95 Ab	67 Aa	78 Ab	74 Ab	99 Bc	111 Bb	83 Ba	135 Aa	104 Ba	93
W 712 RR	110 Aa	113 Ab	99 Aa	97 Ab	114 Aa	75 Bd	116 Ab	94 Aa	73 Bc	99 Aa	99
W 787 RR	119 Aa	140 Aa	83 Ba	93 Bb	101 Ba	124 Bb	126 Ba	96 Ba	153 Aa	111 Ba	115
Mean	96	108	82	89	94	94	111	84	100	95	

Means followed by the same capital letter in the rows and lowercase in the columns do not differ from one another by the Scott-Knott test, at 5% probability. MA: Maurilândia; BJ: Bom Jesus; RV: Rio Verde; JA: Jataí; MO: Montividiu.

It was expected that the localities, due to the difference in altitude, and consequently temperature, would influence the cycle of soybean varieties, even though they were all cultivated in the microregions of 301 and 302. However, this was not observed; each variety reached physiological maturity in all environments within the same number of days (Table 8). This can be justified by the juvenile period characteristic of each cultivar, which defines the rate of maturation (Destro, Carpentieri-Pípolo, Kiihl, & Almeida, 2001; Sediyama, 2009). However, in all localities, a differentiated development was observed, with a longer cycle for NA 7337 RR (Maurilândia, Jataí, and Montividiu), BMX Prisma IPRO (except in Rio Verde) and W 787 RR (in all localities).

Table 8. Mean values of the cycle (days) of transgenic soybean cultivars under Cerrado de Goiás, in the 2013/14 and 2014/15 crop years.

Cultivars	Crop Year 2013/14					Crop Year 2014/15					
	MA	BJ	RV	JÁ	MO	MA	BJ	RV	JA	MO	Mean
BMX Desafio RR	109 Ac	114 Ab	115 Ab	111 Ab	111 Ac	108 Ac	110 Ac	109 Ae	114 Ac	112 Ac	111
BMX Ponta IPRO	103 Ae	110 Ad	106 Ad	106 Ac	111 Ac	99 Af	110 Ac	110 Ae	111 Ad	103 Af	107
BMX Potência RR	103 Ae	107 Ae	106 Ad	103 Ad	102 Ae	102 Ae	102 Ae	97 Ah	107 Ae	106 Ae	103
BMX Prisma IPRO	114 Ab	119 Aa	118 Aa	116 Aa	120 Aa	118 Aa	119 Aa	118 Ab	121 Aa	122 Aa	118
M 7110 IPRO	103 Ae	111 Ad	108 Ad	106 Ac	108 Ad	103 Ae	107 Ad	111 Ad	108 Ae	107 Ae	107
M 7739 IPRO	110 Ac	116 Ab	117 Aa	117 Aa	118 Ab	117 Aa	116 Ab	115 Ac	117 Ab	121 Aa	116
NA 5909 RR	98 Af	104 Ae	99 Ae	103 Ad	99 Af	99 Af	98 Af	94 Ai	102 Af	103 Af	100
NA 7337 RR	117 Aa	117 Aa	119 Aa	116 Aa	116 Ab	117 Aa	115 Ab	114 Ad	120 Aa	121 Aa	117
NS 7000 IPRO	102 Ae	110 Ad	106 Ad	105 Ac	109 Ad	101 Af	109 Ac	107 Af	103 Af	105 Af	105
NS 7338 IPRO	109 Ac	113 Ac	112 Ac	113 Ab	112 Ac	112 Ab	109 Ac	112 Ad	115 Ac	116 Ab	112
W 712 RR	107 Ad	109 Ad	107 Ad	105 Ac	103 Ae	105 Ad	105 Ad	103 Ag	108 Ae	109 Ad	106
W 787 RR	119 Aa	119 Aa	119 Aa	114 Aa	122 Aa	116 Aa	119 Aa	121 Aa	120 Aa	120 Aa	119
Mean	108	112	111	110	111	108	110	109	112	112	

Means followed by the same capital letter in the rows and lowercase in the columns do not differ from one another by the Scott-Knott test, at 5% probability. MA: Maurilândia; BJ: Bom Jesus; RV: Rio Verde; JA: Jataí; MO: Montividiu.

There was no precocity relation with higher grain yield, except for BMX Potência RR, cultivated in Jataí, in both crop years (Tables 4 and 8). The advantage of precocity is that corn (Silva, Teixeira, Martins, Simon, & Francischini, 2014; Silva, Francischini, & Goulart, 2015) and sorghum can be cultivated after the soybean crop (second or winter season crop), which can increase producer income from annual crops. This is a common practice for producers in the central - west region, especially since many producers already have the infrastructure and machinery necessary for the cultivation of soy and cereal in succession (Silva, Francischini, & Martins, 2015).

Searching for earlier yielding cultivars, with the aim of implementing a second or winter season crop may not be an adequate strategy in having higher yields of soybean grains. During this study, it was observed that the early cultivars did not provide higher grain yields, contrary to that observed for the longer cycle cultivars.

Therefore, the adoption of soybean cultivars with differing cycles, independent of the transgenic technology, is important consideration for soybean cultivation in the Cerrado, as it will help the producer to schedule the harvest at different times. In this way, the diversification of cultivars is fundamental to the sustainability of soybean cultivation, since it allows the exploration of genetic variability as a form of phytosanitary management, or even as a strategy to escape water stresses, which is common in the central - west region of Brazil.

Conclusion

The following cultivars were highlighted for grain yield in higher altitude environments: BMX Desafio RR, M 7110 IPRO, W 712 RR and W 787 RR in Rio Verde; BMX Desafio RR, M 7739 IPRO, and NS 7738 IPRO in Jataí; BMX Potência RR, BMX Prisma IPRO, NA 7337 RR, NS 7338 IPRO, and W 787 RR in Montividiu.

The higher yields were independent of transgenic technology and the localities didn´t influence the cycle of the cultivars.

The greater precocity of the cultivars didn´t contribute to increases grain yield, as opposed to medium and longer cycle cultivars, especially in higher altitude locations.

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