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Relative maturity group and its relationships with the non preferential sowing season in soybean

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ABSTRACT

The cultivation of soybeans is the main agricultural commodity in Brazil, the increase in the cultivated area in recent years and the productivity of grains is interconnected with numerous factors such as sowing time, water availability, temperature and photoperiod. The objective of this work was to evaluate the duration of phenological sub-periods and the productivity of soybean cultivars from different groups of relative maturation, sown in two seasons in the off-season in the northwest region of the State of Rio Grande do Sul (RS). The experiment was carried out at Agropecuária Bubans geographically located in the county of Ijuí in the state of RS, considered medium locality. The experiment was carried out using a randomized block design with four replications, the experimental units consisted of four lines, four meters long, 0.50 m apart. The treatments were eight soybean cultivars with different groups of relative maturity (4.8, 5.8, 5.9, 6.2, 6.3, 6.4, 6.7 and 7.8) sown on January 5 and 22, 2019 (from agricultural zoning, the preferred season for sowing in this region is from october to december), constituting an 8 x 2 factorial experiment (Cultivars x sowing times). Assessments of the duration of phenological sub-periods and of the yield components of the culture were carried out, being measured with total plant height, first pod insertion height, number of lateral branches, number of reproductive nodes on the main stem, total number of nodes on the main stem, number of pods with one, two, three and four grains, pods mass of one, two, three and four grains, total grain mass per plant, thousand seed mass and grain yield. The most productive relative maturity group is 6.3 being sown in the first non-preferential season for soybeans in Rio Grande do Sul. The second sowing time changed the dynamics of association of the measured variables, with changes in the cycle, reductions in the vegetative and reproductive period.

Keywords: Strategic positioning, contrasting growth and development, production system, development cycle, management practices, photoperiodic sensitivity.

INTRODUCTION

Soybean is one of the main crops of agriculture, with a relevant socioeconomic role, with Brazil being the second largest world producer of oilseeds. In the 2018/2019 harvest, the crop occupied an area of 35.8 million hectares in the country, with a 1.9% increase in planted area compared to the previous harvest, with an estimated production of 114.4 million tons of grains (Companhia Nacional de Abastecimento [CONAB], 2019; Hanyu, Costa, Cecon, & Matsuo, 2020; Soares, Sediyama, & Matsuo, 2020; Ferreira et al., 2020; Frota et al., 2020; Carvalho et al., 2021).

This increase in grown area and soybean yield in Brazil is due to the incorporation of new technologies to the production system, such as the use of early cultivars (maturity group less than 6.4), with an undeterminate growth type, in substitution of cultivars from medium to long cycle, with determinate growth type (Zanon et al., 2015). It should also be noted that the increase in production in Rio Grande do Sul (RS) is due to the fact that many farmers are carrying out early (late September and early October) and late (late December and January) sowing, thus allowing two crops in the same crop season (Meotti, Raphael, Beche, & Munaro, 2012). Soybean is a short-day plant, influenced by the photoperiodic conditions characteristic of each latitude, especially with regard to the duration of the period of emergence to flowering, and, as the photoperiod decreases, the available solar radiation also decreases (hours of light) (Ting-ting et al, 2015).

This photoperiodic sensitivity varies with the genotype, and the degree of response to the photoperiodic stimulus is the main determinant of the adaptation area of the different cultivars. In sensitive soybean cultivars, the response to the photoperiod is quantitative, not absolute, which means that flowering will occur anyway. However, the time required for this will depend on the length of the day, induction is quicker on short days than on long days. In this way, floral induction causes the transformation of vegetative meristems (differentiation of stems and leaves) into reproductive ones (floral origins), determining the final size of the plants (number of nodes) and, therefore, their yield potential (Rodrigues, Didonet, Lhamby, Bertagnolli, & Luz, 2001).

With the relative maturity groups (RMG) classification, based on the response to the photoperiod, management and general area of adaptation of soybean cultivars, it made it possible to visualize in a more realistic way the factors that affect the duration of the development cycle. When cultivars with different RMGs are sown in the same region, it is expected that the higher the RMG, the longer the development cycle of this cultivar will be (Zanon et al., 2015). When the sowing time is delayed, there is a reduction in the duration of the development cycle, regardless of the RMG of the cultivar. From this new classification of cultivars through RMGs, the precision in estimating the duration of the development cycle of soybean cultivars sown near the first half of November is greater (Zanon et al., 2018). Despite this advance, RMG is not able to have a good precision in representing the duration of the development cycle in sowing carried out at the end of September and beginning of October or even after the second half of December, due to the variation in temperature and photoperiod, with the time of sowing crops (Zanon et al., 2015) especially in subtropical regions, such as the southern region of Brazil and part of Argentina.

However, this grain yield is intertwined with numerous factors such as sowing time, water availability, temperature, photoperiod and available solar radiation. Noting that, throughout the soybean growing season in the state of RS, the intensity of solar radiation, photoperiod and average air temperature increase in the months from September to December, and decrease in the months from January to April (Zanon et al., 2015), therefore, the choice of cultivar that adapts to the place and the sowing season is extremely important, since cultivars sown at inappropriate times do not express their full growth potential, and consequently, its productive potential.

Thus, studies are needed that describe in detail the development of soybean cultivars, in response to the different edaphoclimatic availabilities in Rio Grande do Sul and Brazil. This is because with the characterization of the duration of the phases and the development cycle, depending on the maturity group and the type of growth, there is extremely relevant information, which becomes support tools for technicians and farmers in the decision making of which management practices to carry out, to reach the productive potential of each cultivar (Zanon et al., 2015). Mainly studies related to the development and productive performance of soybean cultivars sown in the off-season, since they are scarce, not allowing the desirable clarification of the subject (Braccini et al., 2003).

In this sense, the objective of this study was to evaluate the duration of phenological sub-periods, development and yield of soybean cultivars in the off-season period containing different maturity groups grown in two seasons in Rio Grande do Sul, Brazil.

MATERIAL AND METHODS

The experiment was carried out at Agropecuária Bubans geographically located in the county of Ijuí in the state of Rio Grande do Sul, at 28°29'11"S 53°50'44" W, with an altitude close to 328 meters above sea level, with a soil classified as Red Latosol (Oxisol). The climate of the region is classified as Cfa (subtropical humid) according to the climatic classification of Köeppen, being characterized by the occurrence of hot summers and without prolonged droughts, with cold and humid winter, with frequent occurrence of frosts. With regard to annual rainfall, they are around 1600 mm, with greater rainfall in the winter period.

The experiment was carried out using a randomized block design with four replications, the experimental units consisted of four lines, four meters long, 0.50 m apart (8 m^2). The treatments were eight soybean cultivars with different groups of relative maturity (4.8, 5.8, 5.9, 6.2, 6.3, 6.4, 6.7 and 7.8) (Table 1) sown on January 5 and 22, 2019, constituting an 8 x 2 factorial experiment (Cultivars x sowing times). The relative maturity group (GMRs) is the duration of the soybean development cycle (sowing to physiological maturity). This classification in GMRs allows the indication of cultivars for each region of cultivation, with the duration of the development cycle between 125 to 140 days for all GMRs. When cultivars with different GMRs are sown in the same location, it is expected that the higher the GMR, the longer the cultivar's development cycle will last (Zanon et al., 2015). However, when the sowing time is delayed, there is a reduction in the duration of the development cycle, regardless of the GMR of the cultivar.

The seeds were treated with Pyraclostrobin, Methyl Thiophanate and Fipronil in the dosage of 200ml/100 kg of seeds being the main products used for the treatment of seeds in this region and inoculated with *Bradyhizobium japonicum*, using the peat inoculant in the proportion of 250g of inoculant per 50 kg of seed (600,000 bacteria/seed), on the day of sowing in order to subsequently perform biological nitrogen fixation. Fertilization management was carried out based on soil analysis and recommendation of the liming and fertilization manual for the states of Rio Grande do Sul and Santa Catarina, using 350 kg ha^{-1} of the formula fertilizer 2-23-23. The management of invasive plants, diseases and pest insects were carried out preventively in order to minimize the biotic effects in the experiment.

Table 1. Soybean cultivars, maturity group and growth habit described by breeders.

Cultivars	RMG	Growth habit
NS 4823 RR	4.8	Indeterminate
DM 5958 RSF IPRO	5.8	Indeterminate
M 5947 IPRO	5.9	Indeterminate
TMG 6203 IPRO	6.2	Semi-determinate
LG 60163 IPRO	6.3	Semi-determinate
M 6410 IPRO	6.4	Indeterminate
6968 RSF (Brasmax Valente)	6.7	Indeterminate
TEC 7849 IPRO	7.8	Indeterminate

To evaluate the phenology of the crop, five plants were selected at random in each plot evaluated daily based on the phenological scale of soybean, proposed by Fehr and Caviness (1977), being evaluated the duration in days of the following development periods: Emergence (VE), Emergence - R1 (VE - R1), R1 - R3, R3 - R5, R5 - R7, R8 - Harvest (R8 - C), R1 - R5, R1 - 8 and Emergence - R8 (VE - R8) for different RMGs at both sowing times.

For the evaluation of the yield components, ten plants were evaluated per plot in R8, with total plant height (PH, cm), first pod insertion height (FPIH, cm), number of lateral branches (NLB, units), number of reproductive nodes on the main stem (NRNMS, units), total number of nodes on the main stem (TNNMS, units) number of reproductive nodes on the lateral branches (NRNLB, units), number of total nodes on the lateral branches (TNNLB, units), number of pods on the main stem (NPMS, units), number of pods on the lateral branches (NPLB, units), lateral branch length (LBL, cm), number of pods with one, two, three and four grains (NP1, NP2, NP3, NP4, units), pods mass of one, two, three and four grains (PM1, PM2, PM3, PM4, g), number of pods on lateral branches of one, two, three and four grains (NPLB1, NPLB2, NPLB3, NPLB4, units), pod mass on lateral branches with one, two, three and four grains (PMLB1, PMLB2, PMLB3, PMLB4, units), total grain mass per plant (TGM, g), thousand seed mass (TSM, g) and grain yield (GY, kg ha^{-1}). After the whole plot was harvested manually. It was tracked and cleaned to measure weight and correct grain moisture to 13%.

The data were submitted to the assumptions of the statistical model, normality, homogeneity and additivity of the model, afterwards the analysis of variance was carried out in order to identify significant interaction between non-preferential sowing times x groups of relative soybean maturity, these significant were dismembered to the simple effects by the Tukey probability matrix. After, the phenotypic linear correlation with significance based on 5% of specific probability for each sowing period was evidenced, as well as, the linear correlation between the agronomic attributes of interest and the definitions of the plastochrome at 5% of specific probability, using the average Euclidean algorithm to construct the dendrogram and the Biplot main components to define affinities of the sources of variation with the measured variables using software R.

RESULTS AND DISCUSSION

The results obtained for eight soybean cultivars from different maturity groups sown in two sowing dates, considered as off-season soybeans because they are outside the recommended sowing time for the crop that covers the period from early September to the end of December, according to Ordinance No. 154, OF JULY 25, 2018. There was a significant effect for the interaction between sowing time x relative maturity group (T x RMG) and also significant effect for RMG alone, for all variables except for number of pods with four grains (NP4), pod mass with one grain (PM1), pod mass with four grains (PM4), number of pods on the lateral branch with four grains (NPLB4) and pod mass on the lateral branch with four grains (PMLB4). For the isolated season effect, the variables that showed significance were the pod mass with one grain (PM1), total grain mass (TGM), thousand seed mass (TSM) and grain yield (GY) and for the treatment RMG alone, the variables that showed significance were the number of pods with 3 grains (NP3), pod mass with 4 grains (PM4) and grain yield (GY) (Table 2).

For the variables total plant height (PH) as the RMG increase occurs, tends to increase the plant height within the season and when compared to the seasons as sowing is delayed, the plant has a lower height, this is also associated with the variable first pod insertion height (FPIH) (Table 3). Studies carried out by Peixoto et al. (2000) affirm that in late sowing for smaller RMGs, there is early flowering, reduced cycle and plant height. Thus, the shorter the exposure of the plants to long photoperiods, the flowering will occur in advance when the plant still has low vegetative size.

For the variables total number of nodes on the main stem (TNNMS) and reproductive nodes (NRNMS) in addition to the number of total nodes on the lateral branches (TNNLB), number of reproductive nodes on the lateral branches (NRNLB) and lateral branch length (LBL) showed a reduction, as a consequence of the lower plant height, which directly influences the final yield of these cultivars. This is because the delay of the second season for the off-season causes the plant to reduce its morphological structures due to the reduction of the vegetative period, which can also compromise its reproductive structures.

The number of nodes is one of the indirect components of yield and is associated with the evolution of the leaf area of the plant that intercepts solar radiation used in photosynthesis, whose process refers to the production and accumulation of phytomass, and that determines grain yield (Streck, Paula, Camera, Menezes, & Lago, 2008). The final number of nodes is one of the most important development variables because it is linked to the duration of the plant cycle, and because it is the place where pods are associated. As soybean plants respond to the photoperiod, changing their cycle according to the photoperiod in which they are submitted, according to studies carried out by Weber (2017) 19 knots per plant would correspond to the production potential of 6.0 Kg ha^{-1}.

For the variable NP1, the cultivars with RMG that stood out with this greatest characteristic, in the first season were: 5.8, 5.9, 6.2 and 6.7 and in the second season were 5.8, 5.9 and 6.4. For the number of pods on the branches with one grain (NPLB1), the cultivars that stood out were 5.8, 5.9, 6.3 and 6.4 in the first season, this may have been a response to some type of stress suffered by the plant. For NP2, cultivars with RMG 6.7 and 7.8 stood out for the first sowing season, whereas for the second the cultivars did not differ. For the number of pods on the branches with two grains, (NPLB2) the cultivars that stood out were those with RMG 6.3 in the first season and 6.2 and 6.4 in the second season. This variable being the one that presents the least variation between different growing situations (Mundstock & Thomas, 2005). Several works show a uniform improvement in the search for plants with an average production of two to three grains per pod. According to Weber (2017), the average value of two grains per pod, remains a value that allows reaching high yields.

For NP3, cultivars with RMG of 5.8, 5.9, 6.2 and 6.3 were the ones that stood out for the first sowing season, while for the second were cultivars with RMG of 5.8, 5.9 and 6.7. For the number of pods on the branch with three grains (NPLB3), the cultivars that showed the best performance were with RMG of 5.9, 6.3, 6.4 in the first season and 6.2 and 6.4 in the second season. What may be related to the duration of the period between R1 and R5, where translocation of this photoassimilates occurs for the formation of pods and grain filling, a period favored by weather conditions, without problems of water stress.

For the variables number of pods on the main stem (NPMS) cultivars with RMG 6.2 and 6.7 in the first season and 5.8, 5.9 and 6.7 for the second season and for the number of pods on the branches (NPLB) for cultivars with RMG 6.3 in the first season and 6.2 and 6.4 in the second season, it can be observed in general for these variables as the RMG increases, consequently the number of pods increases, due to the increase in plant height, as previously reported and when sowing is extended, the plant tends to develop fewer pods due to less crop growth. This component of yield can be considered the most variable with the modification of the plant arrangement, suffering the greatest modifications through the use of management practices, since the amount of pods is dependent on the amount of flowers produced and fixed during the crop reproductive period (Mundstock & Thomas, 2005).

For the variables of pod mass with two grains (PM2), the cultivars that stood out were with RMG 4.8 for the first sowing season and for the second season were those with 5.8, 5.9, 6.2, 6.3, 6.7, and 7.8. For the pod mass with three grains (PM3), the RMG that stood out in the first season were 6.2 and 6.3 and in the second season were cultivars 5.8, 5.9, 6.3 and 6.4. For the pod mass on the branches with one grain (PMLB1), the cultivars with the highest averages were those with RMG 5.2 and 5.9 only for the first sowing season, for the second it was not significant. For the pod mass on the branches with two grains (PMLB2) and three grains (PMLB3) the cultivars that stood out for the first season were those with RMG of 6.3 and for the second season they were those with 6.2 and 6.4, for both variables. The grain mass and the number of grains per pod are components influenced by genetics and the environment (Hanway & Thompson, 1994).

Regarding the thousand seed mass (TSM) in both sowing times, the cultivar 7.8 presented greater mass, being this related to the genetic characteristics of the cultivar (Pandey & Torrie, 1973), but which depends on the environment (precipitation, mainly) and management (sowing density and protection against the attack of sucking insects and diseases) to express its potential. According to studies carried out by Weber (2017), the thousand grain mass that maximizes yield is 190 g, however, stresses in the grain filling phase, can influence the final grain mass.

Analyzing the grain yield variable, we found that for the first season, the RMG 6.7 and 6.3 cultivars showed the highest yields, with 3853.24 and 3802.16 kg ha^{-1} respectively. For the second sowing season, the RMG 6.3 cultivar was the most productive with 3516.66 kg ha^{-1}. Since grain yield is a complex variable, which expresses the interaction of genetics with the environment and is directly related to management practices (sowing density, seed quality, positioning of cultivars, etc.), which can enhance grain yield.

The use of linear correlations (Figure 1) aims to demonstrate the relationship between two variables, the correlation for the first sowing season, to increase grain yield (GY), there is an increase in the number of reproductive nodes of the stem (NRNMS), thus indirectly influencing the number of pods per plant, which is one of the components of crop yield. Plants with a higher total plant height (PH) tend to have a higher first pod insertion height (FPIH). To increase the number of lateral branches (NLB), there is an increase in the number of reproductive nodes on the lateral branches (NRNLB), lateral branch length (LBL) and a reduction in the number of pods with two grains (NP2).

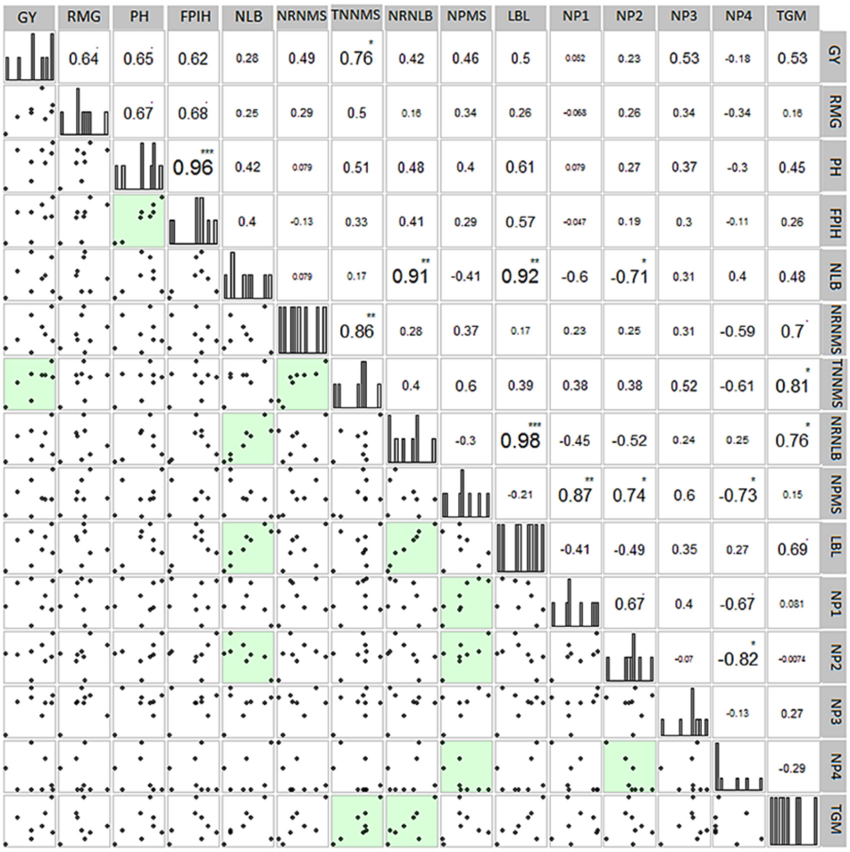

Figure 1. Phenotypic linear correlations for the effects of the first sowing season x relative maturity group.
* significant at 5% probability by t test. GY: grain yield kg/ha^{-1}; RMG: relative maturity group; PH: total plant height; FPIH: first pod insertion height; NLB: number of lateral branches; NRNMS: number of reproductive nodes on the main stem; TNNMS: total number of nodes on the stem nodes; NRNLB: number of reproductive nodes on the lateral branches; NPMS: number of pods on the main stem; LBL: lateral branch length; NP1, NP2, NP3, NP4: number of pods with one, two, three and four grains; TGM: total grain mass per plant.

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Table 2. Summary of the analysis of variance for the interaction between non-preferred sowing times x maturity group at 5% probability.

		MEAN SQUARES														
SV	DF	PH	FPIH	NLB	NRNMS	TNNMS	NRNLB	TNNLB	NPMS	NPLB	LBL	NP1	NP2	NP3	NP4	PM1
Blocks	3	0.01343	0.00124	0.41991	0.26086	1.19951	5.74913	8.31401	5.27568	13.69757	0.00441	0.78464	1.24222	5.79782	0.16375	0.0353
RMG	7	0.05237	0.00879	3.02374	3.57378	10.40976	63.44071	71.89637	147.75985	139.74399	0.02935	4.27404	31.17017	74.28424*	0.275	0.08262
Time (E)	1	0.01294	0.00391	1.91822	0.00345	13.15876	57.66504	81.06751	7.847	80.05776	0.01891	11.85081	50.1264	62.35076	0.03062	0.85794*
T x RMG	7	0.01571*	0.00368*	1.677658*	3.00524*	3.55097*	46.2854*	54.36166*	60.23847*	109.5331*	0.01951*	3.28597*	23.2211*	18.39041**	0.1467	0.06163
CV (%)	-	6.56	10.07	13.78	5.7	4.48	17.52	16.45	10.69	25.78	27.55	23.99	13.46	14.67	27.49	30.02
Average	-	0.69	0.16	1.07	11.79	15.29	5.17	5.57	33.39	7.8	0.12	3.75	14.82	14.67	0.14	0.58

		MEAN SQUARES												
SV	DF	PM2	PM3	PM4	NPLB1	NPLB2	NPLB3	NPLB4	PMLB1	PMLB2	PMLB3	PMLB4	TGM	TSM	GY
Blocks	3	0.04738	2.07545	0.01003	1.35844	3.12265	1.081	0.32641	0.05012	0.40843	0.20692	0.03828	11.52835	0.16053	45706.39374
RMG	7	2.9654	10.7233*	0.03271	1.86769	26.94921	26.2076	0.92641	0.04753	2.52751	5.16635	0.23401*	39.06268	14.68397	2274119.22197*
Time (E)	1	21.1715*	0.89066	0.06891	3.15063	38.73506	3.55794	0.87891	0.08483	5.77201	3.67201	0.05941	113.12981*	117.64114*	3702271.44658*
T x RMG	7	2.76732**	2.6261*	0.02452	1.99498*	32.49282**	17.4023*	0.87891	0.06381**	2.9835*	3.06757*	0.5941	16.06006*	12.94426**	468401.80358**
CV (%)	-	15.49	6.64	38.52	30.00	33.21	29.54	23.98	33.45	27.67	24.45	26.65	16.56	2.00	6.45
Average	-	4.59	16.15	0.04	0.9	3.69	3.08	0.12	0.13	1.09	1.32	0.06	14.68	14.69	2865.7854

*significant at 5% probability by the F test.DF: degrees of freedom; SV: source of variation; CV: Coefficient of variation; PH: with total plant height; FPIH: first pod insertion height; NLB: number of lateral branches; NRNMS: number of reproductive nodes on the main stem; TNNMS: total number of nodes on the main stem; NRNLB: number of reproductive nodes on the lateral branches; TNNLB: number of total nodes on the lateral branches; NPMS: number of pods on the main stem; NPLB: number of pods on the lateral branches; LBL: lateral branch length; NP1, NP2, NP3, NP4: number of pods with one, two, three and four grains; PM1, PM2, PM3, PM4: pods mass of one, two, three and four grains; NPLB1, NPLB2, NPLB3, NPLB4: number of pods on lateral branches of one, two, three and four grains; PMLB1, PMLB2, PMLB3, PMLB4: pod mass on lateral branches with one, two, three and four grains; TGM: total grain mass per plant; TSM: thousand seed mass; GY: grain yield kg ha^{-1} .

Table 3: Average for the effects of the interaction between non-preferred sowing times x relative maturity group.

	Non-preferred sowing times							
	Jan 5	Jan 22	Jan 5	Jan 22	Jan 5	Jan 22	Jan 5	Jan 22
RMG	PH		FPIH		NP3		PM2	
4.8	0.5475 cA	0.4900 cA	0.1200 cA	0.0875 eB	7.8000 cB	11.8750 cA	5.5100 aA	4.3250 aB
5.8	0.7000 bA	0.6900 aA	0.1700 bA	0.1275 dB	14.0250 aB	18.3500 aA	4.7350 aA	3.9150 aA
5.9	0.7750 aA	0.6150 bB	0.1775 bA	0.1025 eB	14.2500 aB	18.6000 aA	5.4625 aA	4.5125 aA
6.2	0.5950 cB	0.7200 aA	0.1225 cB	0.1475 dA	17.000 aA	15.6750 bA	5.3275 aA	3.3200 aB
6.3	0.7550 aA	0.7225 aA	0.1700 bA	0.1675 cA	14.1575 aA	15.7000 bA	5.4750 aA	3.6450 aB
6.4	0.7100 bA	0.7700 aA	0.1800 bB	0.2325 aA	15.1250 aA	14.8250 bA	2.6600 bB	4.1625 aA
6.7	0.8150 aA	0.7550 aA	0.2075 aA	0.1425 dB	15.6250 aB	21.2000 aA	5.7375 aA	3.7500 aB
7.8	0.7775 aA	0.6850 aB	0.1950 aA	0.1900 bA	11.5000 bA	9.0500 cA	6.4325 aA	4.5075 aB
RMG	NLB		NRNMS		PM3		NPLB1	
4.8	0.1750 dA	0.0000 bA	10.8750 cA	11.3500 bA	4.0675 cA	5.1225 cA	0.0250 bA	0.000 aA
5.8	1.3000 cA	0.9250 bA	11.7250 cA	12.6500 aA	6.8825 bA	8.1050 aA	2.3000 aA	0.5500 aB
5.9	1.5250 bA	0.4759 bB	11.4000 cB	13.1500 aA	6.9725 bA	7.4875 aA	1.2250 aA	0.5500 aB
6.2	0.5250 dB	2.1250 aA	12.8500 aA	11.1750 bB	7.8275 aA	6.2475 bB	0.2500 bB	1.6750 aA
6.3	2.2250 aA	0.9750 bB	13.4250 aA	11.9500 aB	8.0300 aA	7.9950 aA	2.0250 aA	0.4000 aB
6.4	2.5250 aA	1.6250 aB	10.5750 cA	10.6250 bA	5.8475 bA	6.5050 bA	1.7325 aA	1.2000 aA
6.7	0.5200 dA	0.6750 bA	11.3075 cA	12.1750 aA	6.5125 bA	7.9375 aA	0.6425 bA	0.5500 aA
7.8	1.1500 cA	0.3750 bB	12.1500 bA	11.3500 bA	6.0775 bA	4.7250 cA	0.8000 bA	0.5250 aA
RMG	TNNMS		NRNLB		NPLB2		NPLB3	
4.8	13.025 cA	12.8000 cA	1.0000 dA	0.0000 cA	0.7750 cA	0.0000 bA	0.6750 bA	0.000 bA
5.8	16.3750 bA	15.8500 aA	8.5250 bA	4.0250 cB	6.5750 bA	3.1500 bB	3.450 bA	2.1000 bA
5.9	15.6750 bA	15.9000 aA	7.6000 bA	2.2500 cB	5.1250 bA	1.8500 bB	4.9000 aA	1.4250 bB
6.2	16.5500 bA	15.0000 bB	1.5750 dB	9.8250 aA	1.4500 cB	7.6500 aA	1.0750 bA	7.1000 aA
6.3	17.9250 aA	15.0750 bB	12.9750 aA	5.4000 bB	9.8750 aA	1.9750 bB	6.6500 aA	3.5500 bB
6.4	13.7750 cB	15.0250 bA	9.1250 bA	7.2500 bA	5.39550 bA	5.2250 aA	6.1350 aA	5.2250 aA
6.7	16.2050 bA	14.6750 bB	2.9875 dA	3.3000 cA	2.3525 cA	2.2750 bA	1.6375 bA	2.3750 bA
7.8	16.4500bA	14.4000 bB	5.2250 cA	1.7750 cB	4.2000 bA	1.1750 bB	2.0750 bA	1.0500 bA
RMG	TNNLB		NPMS		PMLB1		PMLB2	
4.8	1.1250 dA	0.0000 cA	27.8500 cA	30.0750 bA	0.0050 bA	.0000 aA	0.2375 dA	0.0000 bA
5.8	9.7500 bA	4.2000 bB	32.8500 bA	37.8500 aA	0.3850 aA	0.0850 aB	2.1850 bA	0.8175 bB
5.9	8.3000 bA	2.3000 cB	35.2500 bA	38.9500 aA	0.2425 aA	0.0650 aA	1.8600 bA	0.4450 bB
6.2	1.7500 dB	10.3750 aA	38.9000 aA	31.4250 bB	0.0375 bA	0.1875 aA	0.4325 dB	1.8675 aA
6.3	13.8750 aA	5.5000 bB	32.7925 bA	29.2000 bA	0.3825 aA	0.0550 aB	3.1850 aA	0.7325 bB
6.4	9.8500 bA	7.8250 aA	27.3500 cB	32.5250 bA	0.1275 bA	0.2425 aA	1.1925 cA	1.5400 aA
6.7	3.3075 dA	3.5000 bA	41.7350 aA	39.5000 aA	0.0850 bA	0.0825 aA	0.6075 dA	0.5900 bA
7.8	5.6500 cA	1.9000 cB	33.2250 bA	24.8250 cB	0.1200 bA	0.0850 aA	1.4975 cA	0.4000 bB
RMG	NPLB		LBL		PMLB3		TGM	
4.8	1.4750 cA	0.0000 bA	0.175 cA	0.0000 cA	0.3125 cA	0.0000 bA	12.0475 cA	9.8800 bA
5.8	12.3250 bA	5.8000 bB	0.1850 aA	0.1025 bB	1.6175 cA	0.8275 bA	18.5525 bA	14.4475 aB
5.9	11.2500 bA	3.8250 bB	0.1700 aA	0.0825 bB	2.1125 bA	0.5725 bB	17.5900 bA	13.7100 aB
6.2	2.7750 cB	16.4250 aA	0.0425 cB	0.2250 aA	0.4800 cB	2.3950 aA	14.8650 cA	14.4000 aA
6.3	18.5750 aA	7.8250 bB	0.2475 aA	0.1000 bB	3.7225 aA	1.4500 aB	21.7075 aA	14.9475 aB
6.4	13.2625 bA	11.6500 aA	0.2100 aA	0.2025 aA	2.6000 BA	2.0200 aA	13.1875 cA	15.0875 aA
6.7	4.6323 cA	5.2000 bA	0.1100 bA	0.0775 bA	0.6375 cA	0.8850 bA	14.3150 cA	13.6375 aA
7.8	7.0750 cA	2.7500 bA	0.1225 bA	0.0400 cB	1.0725 cA	0.5725 bA	15.8175 cA	10.7000 bB
RMG	NP1		NP2		TSM		GY	
4.8	3.6750 bA	3.0500 bA	16.1000 bA	15.1000 aA	17.1400 bA	12.2075 cB	1900.8750 eA	2061.3600 eA
5.8	4.3500 aA	4.6500 aA	14.0750 bA	14.2000 aA	16.1225 cA	11.9275 cB	3566.4350 bA	2798.8725 bB
5.9	5.1750 aA	4.3500 aA	15.8250 bA	15.9500 aA	16.1750 cA	12.0500 cB	2388.9400 dA	2303.5875 dA
6.2	5.4500 aA	2.9750 bB	16.4500 bA	12.5500 aB	15.6700 dA	13.0050 bB	2969.9100 cA	2668.8700 cB
6.3	3.5125 bA	2.1750 bB	15.0725 bA	11.3250 aB	17.3975 bA	11.8875 cB	3808.3650 aA	3516.6575 aB
6.4	2.4500 bA	3.8750 aA	9.1750 cB	13.8250 aA	14.6400 eB	16.7725 aA	2960.1275 cA	2332.4725 dB
6.7	5.2725 aA	3.000 bB	20.8375 aA	15.3000 aB	13.5150 fA	11.9300 cB	3853.2425 aA	2425.5950 dB
7.8	3.6000 bA	2.5250 bA	18.1250 aA	13.2500 aB	17.7500 aA	16.9375 aB	3408.5175 Ba	2894.7400 bB

*Lower case letters compare the RMGs within each season in the column. * Capital letters compare the times within each RMG on the line. *Averages followed by the same letter do not differ with a 5% probability of error by the Tukey probability matrix. RMG: relative maturity group; PH: total plant height; FPIH: first pod insertion height; NP3: number of pods with, three grains; PM2: pods mass of two grains; NLB: number of lateral branches; NRNMS: number of reproductive nodes on the main stem; PM3: pods mass of three grains; NPLB1: number of pods on lateral branches of one grain; TNNMS: total number of nodes on the main stem; NRNLB: number of reproductive nodes on the lateral branches; NPLB2: number of pods on lateral branches of two grains; NPLB3: number of pods on lateral branches of three grains; TNNLB: number of total nodes on the lateral branches; NPMS: number of pods on the main stem; PMLB1: pod mass on lateral branches with one grain; PMLB2: pod mass on lateral branches with two grains; NPLB: number of pods on the lateral branches; LBL: lateral branch length; ; PMLB3: pod mass on lateral branches with three grains; TGM: total grain mass per plant; NP1: number of pods with one grain; NP2: number of pods with two grains; TSM: thousand seed mass; GY: grain yield.

Table 4. Duration of the subperiods, S-VE: sowing - emergence; VE-R1: emergence - R1; R1-R3; R3-R5; R5-R7; R8-C: R8-harvest; R1-R5; R1-8 and VE-R8: emergence - R8.

Jan 5									
RMG	S-VE	VE- R1	R1-R3	R3-R5	R5-R7	R8-C	R1-R5	R1-R8	VE-R8
4.8	5	52	14	29	15	14	43	58	110
5.8	5	56	17	27	20	9	44	64	120
5.9	5	59	19	26	18	9	45	63	122
6.2	5	60	18	28	17	5	46	63	123
6.3	5	62	19	28	15	7	47	62	124
6.4	5	65	22	25	21	14	47	68	133
6.7	5	71	22	24	18	16	46	64	135
7.8	5	79	23	33	18	12	56	74	153
Jan 22									
RMG	S- VE	VE-R1	R1-R3	R3-R5	R5-R7	R8 - C	R1-R5	R1-R8	E-R8
4.8	6	39	16	18	19	15	34	53	92
5.8	6	42	18	17	18	15	35	53	95
5.9	6	42	18	18	17	14	36	53	95
6.2	6	44	20	17	17	12	37	54	98
6.3	6	44	21	18	15	12	39	54	98
6.4	6	46	22	17	15	10	39	54	100
6.7	6	50	22	22	22	12	44	66	116
7.8	6	56	25	15	15	10	40	55	111

As the number of reproductive nodes on the main stem (NRNMS) increases, the number of total nodes on the main stem (TNNMS) also increases. As the latter tends to increase, influences the increment in the total grain mass, which is influenced by the number of pods per plant. For the number of total reproductive nodes on the lateral branches, the moment the branch increases, the branch length increases and there is a greater total grain mass (TGM). In order to increase the number of pods on the main stem (NPMS), there is an increment in the number of pods with one and two grains (NP1 and NP2) and a reduction in the number of pods with 4 grains (NP4), which may be related to the breeding of the soybean crop, where there is a tendency to select genotypes with pods with fewer seeds. The same is true for the number of pods with two grains (NP2).

For the second sowing season, the linear correlation (Figure 2) shows that for grain yield (GY), as it increases, it tends to decrease the number of pods with two grains (NP2), indirectly tends to maximize other yield components although they were not significant by the model. The total plant height (PH), as the increase occurs, tends to increase the first pod insertion height (FPIH) and increase the total grain mass (TGM), which may be related to a better source/drain ratio resulting in greater grain mass. To increase the number of lateral branches (NLB), there is an increase in the number of reproductive nodes on the lateral branches (NRNLB), lateral branch length (LBL), which results in an increase in the total grain mass (TGM). To increase the total number of nodes on the main stem (TNNMS), there is the maximization of the total grain mass (TGM), which may be related to the number of pods present on the main stem. To increase the number of pods on the main stem (NPMS), there is an increase in the number of pods with three grains (NP3). For the lateral branch length (LBL), as it increases, it tends to increase the total grain mass, due to the greater number of pods available.

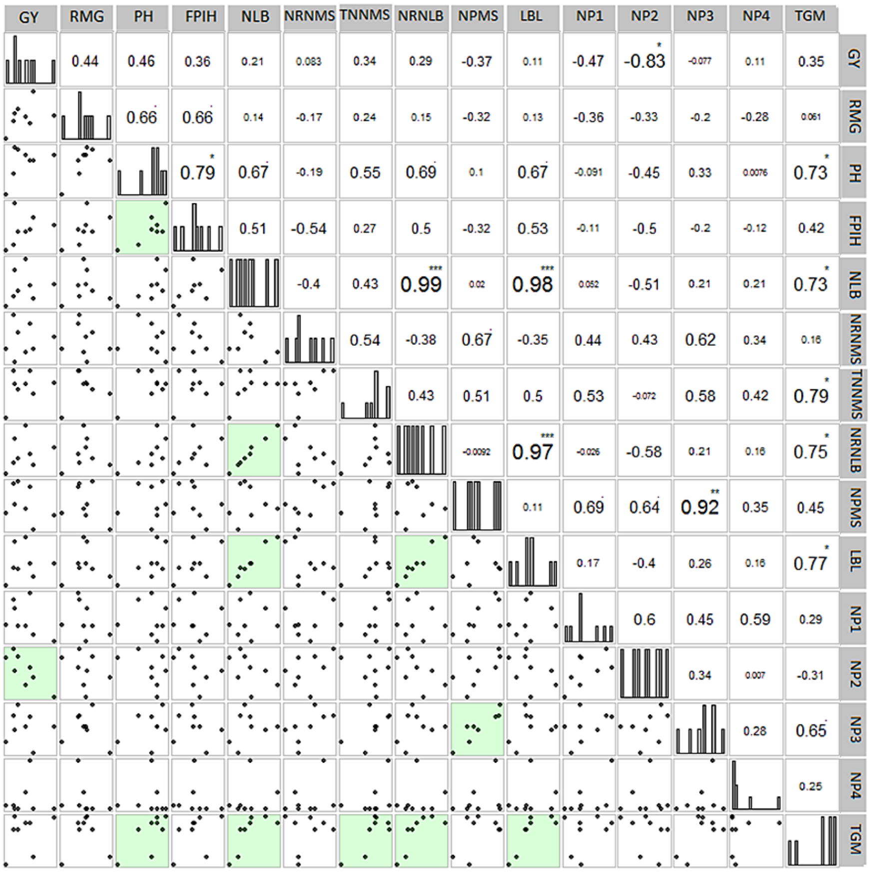

Figure 2. Phenotypic linear correlation for the second sowing time x relative maturity group.
*significant at 5% probability by t test. GY: grain yield kg/ha^{-1}; RMG: relative maturity group; PH: total plant height; FPIH: first pod insertion height; NLB: number of lateral branches; NRNMS: number of reproductive nodes on the main stem; TNNMS: total number of nodes on the stem nodes; NRNLB: number of reproductive nodes on the lateral branches; NPMS: number of pods on the main stem; LBL: lateral branch length; NP1, NP2, NP3, NP4: number of pods with one, two, three and four grains; TGM: total grain mass per plant.

The climatic conditions (Figure 5) showed that throughout the vegetative period of both sowing seasons, there was an accumulated rainfall volume of 521 mm, being well distributed throughout this period, at the end of this subperiod we can observe that after the emergence, temperatures occurred below 15 °C, however they did not compromise the flowering sub-period, pod emission and grain filling, therefore, not influencing the grain yield of the respective cultivars.

The linear correlation (Figure 3) represents the variables responsible for soybean growth, so when we sow cultivars with different RMGs in the same region, the higher the RMG, the longer the development cycle of this cultivar and the lower the RMG, the smaller the cycle (Zanon et al., 2015). Thus, the results include what is in the literature, as late sowing occurs, tends to reduce the number of days of the crop between VE/R1, R3/R5, R1/R5, R1/R8, cycle and TSM. As the RMG increases, there is an increment in the days between the soybean stages, which are VE/R1, R1/R3, R1/R5, cycle and grain yield. This is due to the higher the RMG, the plant needs more photoperiod to complete its cycle, it tends to have a longer vegetative and reproductive period, which ultimately results in greater grain yield. For the VE stage, as the days of crop emergence increase, it directly influences the reduction of the vegetative period until the reproductive period of the crop, mainly VE/R1, R3/R5, R1/R5, R1/R8, cycle and TSM. The increase in days of the R3/R5 stage consequently results in an increase in the days of R1/R5, R1/R8, cycle and also the TSM. The increase in the days of R5/R7, tends to increase the period of days of the stages of R1/R8. According to Peske et al. (2012) at the end of the phenological stage R5 there is 80% of the accumulation of dry matter in the seeds, therefore, it appears that there was a greater accumulation of photoassimilates and this is directly influenced by the vegetative structures that are responsible for developing reserve organs of photoassimilated products that will be translocated to the grains during the filling period (Rodrigues, Alvim, Brito, Brandão, & Gomes, 2011).

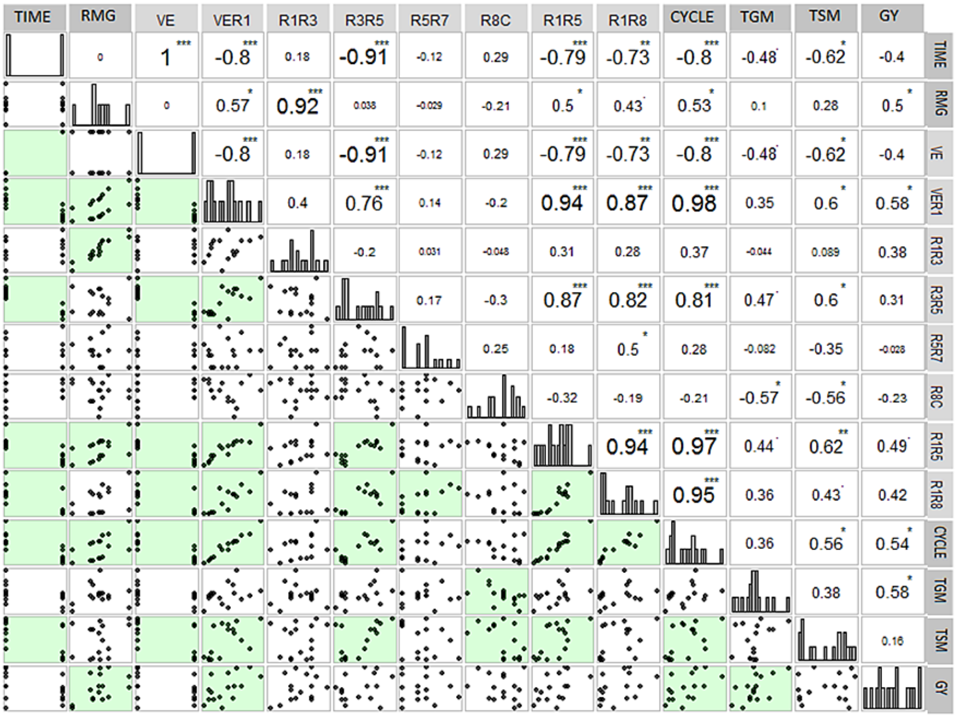

Figure 3. Phenotypic linear correlation for soybean growth x relative maturity group.
*significant at 5% probability by t test. RMG: relative maturity group; VE: emergence; VER1: emergence - R1; R1R3: R1 - R3; R3R5: R3 - R5; R5 - R7: R5 - R7; R8 – C: R8 – Harvest; R1R5: R1-R5; R18: R1-8; VE - R8: emergence - R8; TGM: total grain mass; TSM: thousand seed mass; GY: grain yield.

When there is an increase in the period from R8 until harvest (R8/C) this increase tends to cause a reduction in TGM and TSM, because the grains were constantly exposed to various variations in the environment, which can compromise the quality of this seed. As the period of R1/R5 increases, the period of R1/R8, Cycle and TSM increases. For this period there is a volume of precipitation of 180 mm, which is extremely important, because in this subperiod there is the differentiation of vegetative structures in reproductive, flower emission, pod formation and grain filling, where situations of water stress may result in the miscarriage of flowers, pods or a reduction in the rate of grain filling depending on its intensity, duration and period of occurrence.

In the same way that the period of R1/R8 increases, there is an increase in the cycle, and with the increase of the cycle there is a tendency to increase the TSM and grain yield (GY). The increase in TGM contributes to the increase in grain yield.

The dendrogram (Figure 4) taking into account the average and deviations of the distance shows the similarity of treatments for the first sowing period, regardless of the variables, what we can analyze is that the treatments were divided into two large groups, for blue there was an affinity between treatments 5.8 and 7.8, this is due to the fact that between the two treatments, some variables did not show significant differences by the means test (table 3), and they did not directly influence yield. For treatments 6.7 and 6.3, due to their proximity to the cycle, similarity in plant height occurred, which resulted in a greater number of pods with three grains and yield. The cultivars with RMG 6.4 and 6.2, also due to their proximity to the cycle, which differs from the previous one, which shows significance for the total grain mass. The other group of cultivars was with RMG 5.9 and 4.8, for these treatments the variables with the total number of nodes on the main stem and branches stood out, but not influencing the yield, so it can be said that there was a smaller number of reproductive nodes for these cultivars.

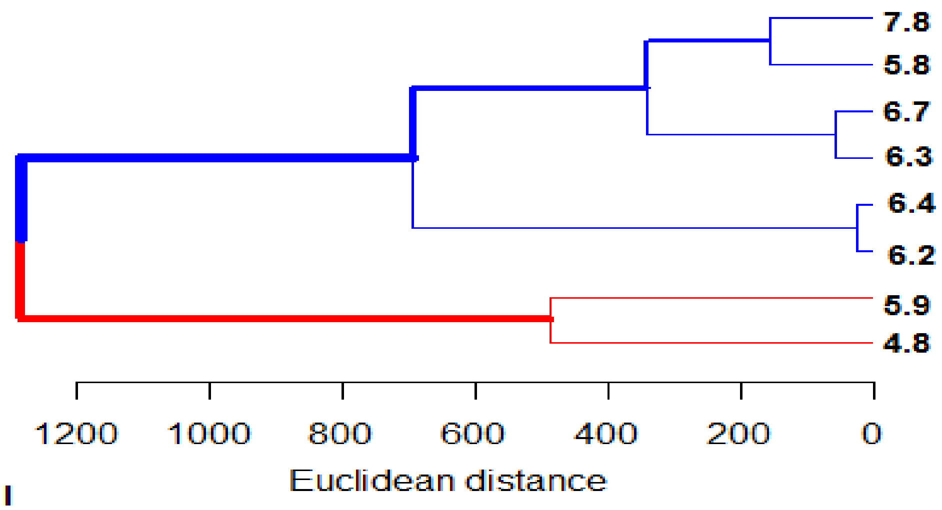

Figure 4. Dendrogram obtained for linear for the effects of the first sowing season x relative maturity group, using the average Euclidean algorithm with all measured variables.

For the second sowing season, (Figure 5) the dendrogram shows that from the average and the distance deviations, the treatments that showed the greatest similarity were the cultivars with RMG 5.9 and 6.4, mainly due to the issue of the number of pod with one and two grains. For cultivars with RMG 5.8 and 7.8, this similarity occurred in quite a few variables, but plant height and grain yield stand out, which may have been caused by some climatic adversity.

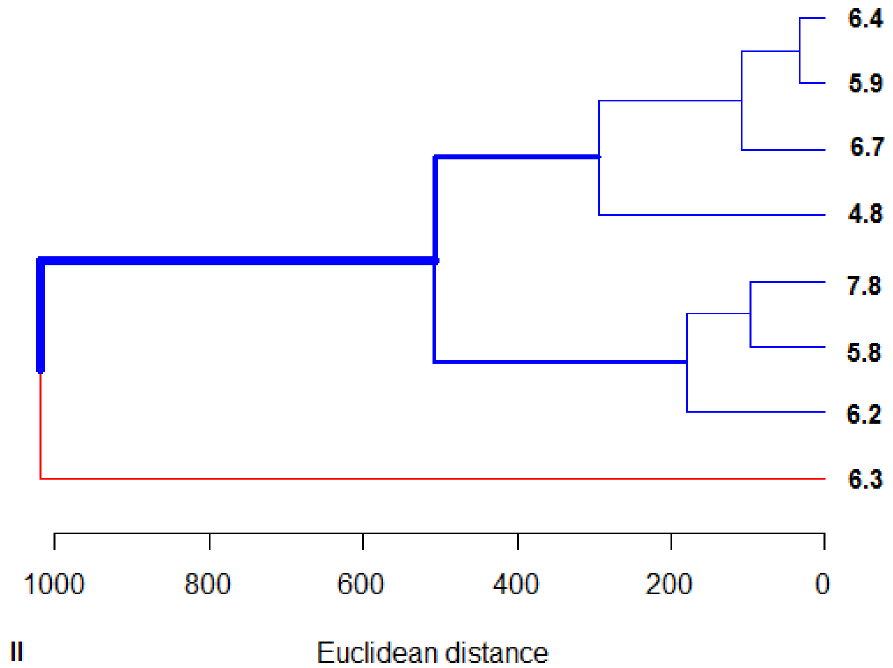

Figure 5. Dendrogram obtained for linear for the effects of the second sowing season x relative maturity group, using the average Euclidean algorithm with all measured variables.

The BIPLOT graph (Figure 6) shows the variable/treatment ratio, with the first sowing time and the cultivars with the highest RMG, being 6.4, 6.7 and 7.8, showing the best results for the variables analyzed. These cultivars, in general, have a longer duration of the crop cycle, thus increasing the number of days between the phenological stages of the crop, resulting in higher grain yield in the end. The cultivars with the smallest RMG tend to reduce the cycle, resulting in less total grain mass and thousand seed mass.

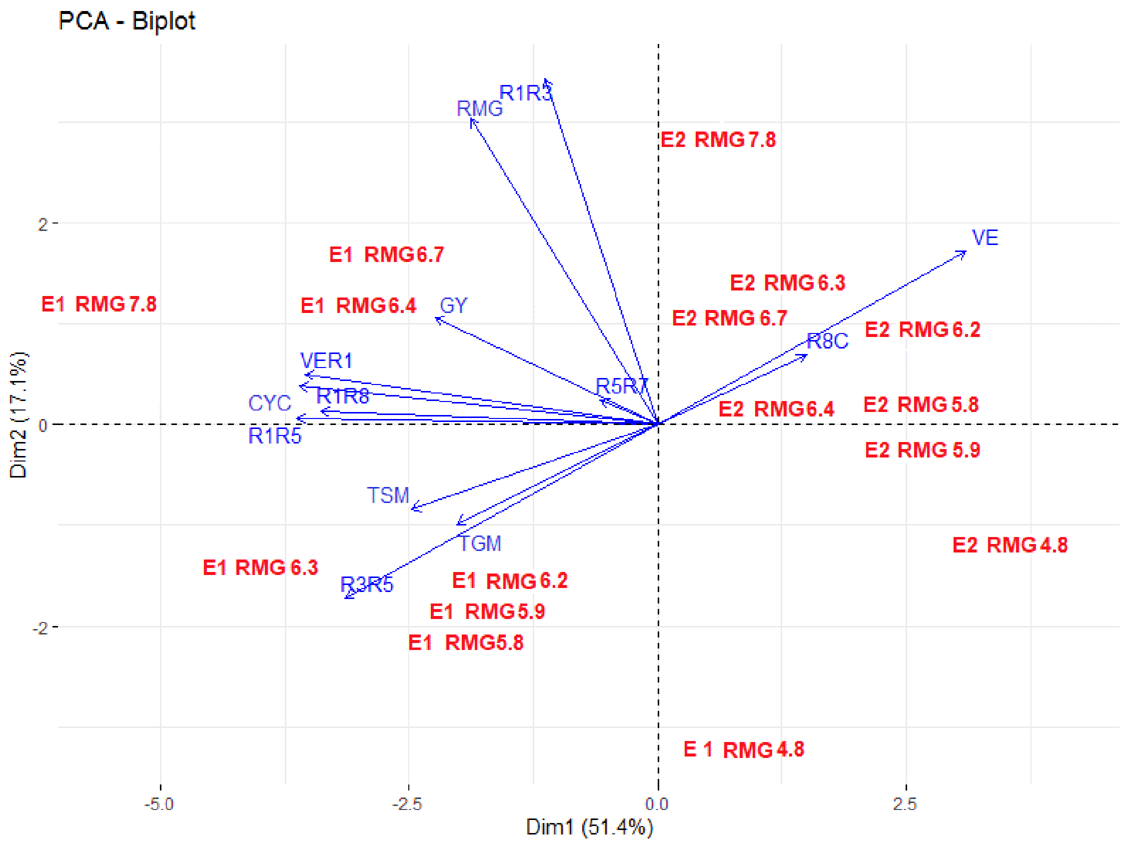

Figure 6. Biplot principal components based on the effects of the interaction between non-preferred sowing times of soybean x relative maturity groups, for the variables VE: emergence; VER1: emergence - R1; R1R3: R1 - R3; R3R5: R3 - R5; R5R7: R5 - R7; R8C: R8 - harvest; R1R5: R1-R5; R18: R1-8; VER8: emergence - R8; CYC: cycle; RMG: relative maturity group; TGM: total grain mass; TSM: thousand seed mass; GY: grain yield.

CONCLUSIONS

The most productive relative maturity group is 6.3 being sown in the first non-preferential season for soybeans in Rio Grande do Sul.

The second sowing time changed the dynamics of association of the measured variables, with changes in the cycle, reductions in the vegetative and reproductive period.

The agronomic attributes that are decisive for soybean yield in a non-preferential season are intrinsic to the phenology and response of the relative maturity groups to the photoperiod.

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