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CULTIVAR X ENVIRONMENT INTERACTION ON OIL AND LIGNIN CONTENT IN THE GRAINS OF SOYBEANS

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Abstract–Because of the economical and physiological importance of the chemical components of soybean grain and the effects of environmental factors on these components, eight experiments were conducted in the central region of the State of Tocantins, four in the 2014/15 harvest and four in the 2015/16 harvest. The experimental design was a randomized block with three replications and eight treatments. The evaluated cultivars were: 8473RSF RR, 8576 RSF, 8579RSF IPRO, ST 820 RR, TMG 132 RR, 9086RSF IPRO, M8644 IPRO, and M9144 RR. The evaluated characteristics were: oil and lignin content in the grain. A study of adaptability and stability was carried out using the methods of Eberhart and Russell (1966) and Lin and Binns (1988) modified by Carneiro (1998), and of environment, stratification using Lin (1982) and Cruz and Castoldi (1991). The adaptability methods proposed by Eberhart and Russel and Lin and Binns, as well as those of environmental stratification proposed by Lin (1982), Cruz and Castoldi (1991), and by Pearson's correlation, were in agreement for most interpretations. The adaptability methods, well as those of environmental stratification, were in agreement for most interpretations. The cultivars 8579RSF IPRO and M8644 IPRO, for oil content, and 8579RSF IPRO, for lignin content, showed general adaptation and can be grown in all environments. There was no similarity between the environments, for the oil and lignin contents, demonstrating the need to conduct in a greater number of essays.

INTRODUCTION

Producing more than one million hectares, the State of Tocantins is the main soybean grower of the Brazilian Northern region, with averages of production and yield increasing year by year. Soybean represents the first crop in terms of participation in the gross domestic product of the aforementioned state, wherein in the 2019/20 harvest occupied an area of approximately 1.08 million hectares and produced close to three million tons, representing 52% and 50%, respectively, of the total observed for the Brazilian Northern region in the same period (Conab, 2020).

The soybean grain presents a high content of protein (40%) and oil (20%), which are the main commodities, 25% of carbohydrates, 10% of minerals and fibers (cellulose, hemicellulose, and lignin), and 5% of moisture (Embrapa, 2019).

Among the chemical components of the grain, the oil has the excellent quality, being used both for human consumption, in food preparation, and representing 92% of edible oils (Faria *et al.,* 2018), and in the industrial sector for the production of biodiesel and refined oil (Amorim, 2011).

Lignin is an important molecule that contributes to obtaining seeds with high physiological potential. In addition to protecting against mechanical damage, it is responsible for controlling the moisture content of the seeds (Huth, 2015).

The expression of the grain chemical characteristics is highly influenced by the environments where the plants develop (Almeida *et al.,* 2018; Toller *et al.,* 2018; Evangelista *et al.,* 2017; Reina *et al.,* 2014). As most of the environments under study are distinct, cultivar x environment interaction (C x E) occurs, which affects the selection gain and arise demands of studies to estimate the magnitude and nature of the interaction (Oda *et al.,* 2019; Capone *et al.,* 2018).

The most used alternatives to mitigate the impacts of the C x E interaction have been the identification and use of cultivars with wide adaptability and stability, and the stratification of environments in homogeneous sub-regions (Evangelista *et al.,* 2017; Bicalho, 2018).

According to Carvalho *et al.* (2013a), the method selection to investigate adaptability and stability depends on the experimental data, the number of environments, and the required precision. Among the methods used, Eberhart and Russell (1966) is based on linear regression, and Lin and Binns (1988) modified by Carneiro (1998), which involves non-parametric analysis.

As for environmental stratification, the methods of Cruz and Castoldi (1991) have been used, which measures the partition of these two fractions, grouping the pairs of environments whose interaction is predominantly of the simple and significant fraction. Also, Lin's algorithm (1982) has been employed, which consists of estimating the sum of squares of the interaction between cultivars and pairs of environments, followed by grouping the environments whose interaction is not significant.

However, there are few studies on cultivars' chemical grain composition in different environments, represented by year, location, or sowing time, so that regionalized tests to quantify the response of cultivars to environments becomes necessary.

Thus, the objective was to study the cultivar x environment interaction in soybean cultivars, as to the content oil and lignin of grains, from tests carried out in the central region of the state of Tocantins, in the agricultural years 2014/15 and 2015/16.

MATERIAL AND METHODS

Eight cultivar comparative performance experiments were conducted, four in 2014/15 and four in the 2015/16 growing season. In each agricultural year, two experiments were carried out in the municipality of Porto Nacional - TO (Location 1 - Serra Azul Farm, 234 m altitude, 10°422 273S, and 48°242513W), and two in Santa Rosa - TO (Location 2 - Mariana Farm, 288 m altitude, 11°26′31′′S and 48°7′2′′W).

Sowing was carried out on two dates in each location, the first being on November 3rd in Porto Nacional and November 15th in Santa Rosa. The second date occurred 15 days after the first planting, being November 18th in Porto Nacional and November 30th in Santa Rosa, respecting the planting window of the two locations.

The experimental design used was a randomized block with three replications and eight treatments. The treatments consisted of eight cultivars, namely: 8473RSF RR (Desafio RR), 8576 RSF (Raça RR), 8579RSF IPRO (Bônus IPRO), ST 820 RR, TMG 132 RR, 9086RSF IPRO (Opus IPRO), M8644 IPRO, and M9144 RR.

The temperature and rainfall data, recorded in the 2014/2015 and 2015/2016 harvests, were obtained monthly through data collection at the testing site (Table 1).

Each competition trial was characterized as an environment, totalizing eight distinct environments, classified from 1 to 8, distributed as follows by sowing date: Environment 1: (Porto Nacional, November 3rd, 2014); Environment 2: (Porto Nacional, November 18th, 2014); Environment 3: (Santa Rosa, November 15th, 2014); Environment 4: (Santa Rosa, November 30th, 2014); Environment 5: (Porto Nacional, November 3rd, 2015); Environment 6: (Porto Nacional, November 18th, 2015); Environment 7: (Santa Rosa, November 15th, 2015); Environment 8: (Santa Rosa, November 30th, 2015).

The grains from each cultivar in each year, location, and sowing date were harvested, identified, ground, and stored in the form of soybean meal in a cold chamber, at the Federal University of Tocantins - Gurupi Campus, under controlled temperature and humidity, aiming at maintaining the chemical quality of the grain.

Subsequently, the samples were submitted to physical-chemical analysis in the industrial raw material laboratory of the Federal University of Tocantins – Palmas Campus. The grain composition of each cultivar was determined as to oil content (Bligh-Dyer, 1959), and lignin content (Hatfield *et al.,* 1994).

After obtaining the data, individual analysis of variance was performed, followed by joint analyses of the experiments, in which the smallest residual mean square did not differ by more than seven times from the largest. Then, analyzes of adaptability and stability, stratification, and environmental dissimilarity were carried out.

The adaptability and stability methods used were Eberhart and Russel (1966) and Lin and Binns (1988), modified by Carneiro (1998).

According to the methodology of Eberhart and Russell (1966), cultivars with a regression coefficient equal to the unit ($\beta 1=1$) have general or wide adaptability; cultivars with $\beta 1>1$ show specific adaptability for favorable environments; cultivars with $\beta 1<1$ show specific adaptability to unfavorable environments. The ideal cultivar presents production above the general average, regression coefficient equal to the unit ($\beta 1 = 1$), and predictable behavior ($\sigma^2 d = 0$). The stability is estimated by the deviations from the regression ($\sigma^2 d$) or by the coefficient of determination (R^2), which have an opposite relationship, i.e. stable cultivars will present higher values of R^2 and smaller $\sigma^2 d$.

Lin and Binns' (1988) methodology is based on the estimation of the Pi parameter, which measures the deviation of a given character of a genotype from the maximum in each environment. Carneiro (1998) proposed an improvement of the method to enable the determination of genotypes behavior in specific environments (favorable and unfavorable). The ideal genotype, i.e. with broad adaptability/stability for each environment, is the one with a high average and lowest Pi value.

Environmental stratification and dissimilarity were performed according to Lin's (1982) algorithm. The simple and complex fraction of the interaction between cultivar and environment were also estimated, according to the method of Cruz and Castoldi (1991) and, finally, Pearson's correlation between the pairs of environments evaluated. The analyzes were performed using the computational program Genes, version 2007 (Cruz, 2007).

RESULTS AND DISCUSSION

The joint analysis of variance showed a significant effect of the environment and the environment x cultivar interaction for all evaluated characteristics (Table 2) and, this being of the complex type for the great majority of pairs of environments (Table 3),

Table 1. Monthly temperature and precipitation data for two agricultural years, 2014/15 (year 1) and 2015/16 (year 2), in the municipalities of Porto Nacional and Santa Rosa.

Month	2014/2015		2015/2016		2014/2015		2015/2016	
	Temperature (°C)				Precipitation (mm)			
	Porto Nacional	Santa Rosa	Porto Nacional	Santa Rosa	Porto Nacional	Santa Rosa	Porto Nacional	Santa Rosa
October	28	28	27	27	155	148	90	90
November	27	28	28	27	206	206	136	215
December	26	27	31	28	245	237	123	142
January	27	25	27	25	312	210	452	518
February	27	26	29	27	185	145	68	75
March	28	26	27	26	125	158	138	382
Harvest average	27	27	28	27	205	184	168	237
Total average					1228	1104	1007	1422

Table 2. Summary of the joint analysis of variance of two chemical characteristics evaluated in experiments carried out in Porto Nacional and Santa Rosa - TO, in two sowing dates and with eight soybean cultivars, in the 2014/15 and 2015/16 agricultural years.

Source of variation	DF	Mean Square	
		Oil	Lignin
Block/Environment	16	1,46	0,01
Cultivar	7	12,77^{NS}	0,04^{NS}
Environment	7	89,54**	0,05**
Environment*cultivar	49	11,13**	0,04**
Error	112	1,06	0,01
Mean	23,52	0,624	
CV (%)	4,376	13,01	

**, NS = significant at 1% probability and not significant, respectively, by the F-test.

combined with the low correlation magnitude between environments (Table 3), indicates that cultivars present differentiated behavior due to environmental factors from a different location, years, and/or sowing dates to which they are subjected, thus justifying analyzes to investigate stability, adaptability, and stratification environmental.

The coefficients of variation (CV) obtained varied between 4.37 and 13.01, being considered as low and medium, respectively, similar to the results obtained by Faria et al. (2018), demonstrating good precision in the experiment execution.

Environment 1 (Sowing November 3rd, Porto Nacional, 2014/15 harvest); Environment 2 (Sowing November 18th, Porto Nacional, 2014/15 harvest); Environment 3 (Sowing November 15th, Santa Rosa, 2014/15 harvest); Environment 4 (Sowing November 30th, Santa Rosa, 2014/15 harvest); Environment 5 (Sowing November 3rd, Porto Nacional, 2015/16 harvest); Environment 6 (Sowing November 18th, Porto Nacional, 2015/16 harvest); Environment 7 (Sowing November 15th, Santa Rosa, 2015/16 harvest); Environment 8 (Sowing November 30th, Santa Rosa, 2015/16 harvest).

The environmental index, for the four characteristics studied, is shown in Table 4. According to Eberhart and Russel (1966), a favorable environment is one whose average is higher than the general average of all studied environments, resulting in a positive index. On the other hand, an unfavorable environment is one whose average is lower than the general average, providing a negative index.

Environment 1 (Sowing November 3rd, Porto Nacional, 2014/15 harvest); Environment 2 (Sowing November 18th, Porto Nacional, 2014/15 harvest); Environment 3 (Sowing November 15th, Santa Rosa,

Table 3. Estimates of simple (%SF) and complex (%CF) fraction of the C x E interaction and the correlation (r) between the pairs of environments, of eight soybean cultivars, based on the contents of oil, and lignin of the grain, in tests, carried out in Porto Nacional and Santa Rosa - TO, under two sowing dates, in the 2014/15 and 2015/16 harvests, based on the method of Cruz & Castoldi (1991) and Pearson's correlation.

Oil content				Lignin content			
Pairs	%FS	% FC	R	Pairs	%FS	% FC	R
1 x 2	-11.3	111.3	-0.26	1 x 2	47.1	52.9	0.69
1 x 3	30.9	69.1	0.45	1 x 3	2.3	97.7	0.03
1 x 4	33.6	66.4	0.50	1 x 4	47.6	52.4	0.49
1 x 5	9.3	90.7	0.16	1 x 5	-16.1	116.1	-0.51
1 x 6	-9.5	109.5	-0.23	1 x 6	-8.8	108.8	-0.20
1 x 7	-22.8	122.8	-0.51	1 x 7	-18.8	118.8	-0.59
1 x 8	-8.5	108.5	-0.42	1 x 8	31.1	68.9	0.19
2 x 3	4.2	95.8	-0.08	2 x 3	32.2	67.8	0.46
2 x 4	-22.3	122.3	-0.51	2 x 4	17.6	82.4	0.18
2 x 5	0.0	100.0	-0.06	2 x 5	-17.1	117.1	-0.42
2 x 6	11.2	88.8	0.21	2 x 6	0.8	99.2	0.01
2 x 7	37.4	62.6	0.59	2 x 7	-11.5	111.5	-0.30
2 x 8	20.8	79.2	0.25	2 x 8	40.2	59.8	0.46
3 x 4	23.2	76.8	0.17	3 x 4	-4.4	104.4	-0.50
3 x 5	5.3	94.7	0.08	3 x 5	28.4	71.6	0.27
3 x 6	34.3	65.7	0.41	3 x 6	-1.5	101.5	-0.09
3 x 7	10.6	89.4	0.12	3 x 7	31.6	68.4	0.30
3 x 8	11.2	88.8	-0.26	3 x 8	17.9	82.1	-0.13
4 x 5	-6.7	106.7	-0.27	4 x 5	-18.1	118.1	-0.43
4 x 6	-19.3	119.3	-0.43	4 x 6	18.1	81.9	0.15
4 x 7	-27.4	127.4	-0.68	4 x 7	-27.2	127.2	-0.64
4 x 8	-21.5	121.5	-0.54	4 x 8	-0.2	100.2	-0.01
5 x 6	40.0	60.0	0.57	5 x 6	-21.5	121.5	-0.55
5 x 7	-17.9	117.9	-0.41	5 x 7	8.1	91.9	0.16
5 x 8	32.0	68.0	0.25	5 x 8	-20.9	120.9	-0.54
6 x 7	10.4	89.6	0.18	6 x 7	37.5	62.5	0.53
6 x 8	22.5	77.5	0.29	6 x 8	48.0	52.0	0.52
7 x 8	31.7	68.3	0.34	7 x 8	20.6	79.4	0.31

2014/15 harvest); Environment 4 (Sowing November 30th, Santa Rosa, 2014/15 harvest); Environment 5 (Sowing November 3rd, Porto Nacional, 2015/16 harvest); Environment 6 (Sowing November 18th, Porto Nacional, 2015/16 harvest); Environment 7 (Sowing November 15th, Santa Rosa, 2015/16 harvest); Environment 8 (Sowing November 30th, Santa Rosa, 2015/16 harvest).

Environments 5, 6, and 7, for oil content, were classified as favorable. Among these, environments 5 and 6 showed the highest means for oil content for the lignin content, only environments 1, 2, 6, and 8 were classified as favorable. Environments 2 and 8 (belonging to the same place and time) were considered favorable for lignin and unfavorable for oil content.

The environment classification, which is dependent on the characteristic studied, occurred in function of the differential behavior of the cultivars provided by the climatic differentiation (precipitation and temperature) that occurred in the two harvests/sowing seasons/locations (Table 1). In this sense, in the 2014/15 harvest, there was a more uniform distribution of rainfall and average temperatures without much fluctuation, when compared to the 2015/16 harvest, where irregularity in rainfall distribution was observed, associated with higher temperatures, mainly during the grain filling phase (February).

The occurrence of water stress and the presence of higher temperatures during the grain-filling phase promotes changes in the metabolic pathways (Naoe *et al.*, 2017), resulting in variations in oil contents (Faria *et al.*, 2018; Naoe *et al.*, 2017; Finoto *et al.*, 2017) and lignin content (Huth, 2015).

Table 4. Environmental index (Ij) of eight environments, for content (%) of oil and lignin, obtained by the method of Eberhart and Russell (1966), under two sowing dates, in Porto Nacional and Santa Rosa - TO, in 2014/15 and 2015/16 harvests.

Environment	% Oil		% Lignin	
	Mean	Index (Ij)	Mean	Index (Ij)
1	22.53	-0.99	0.66	0.03
2	22.07	-1.45	0.66	0.03
3	22.76	-0.77	0.61	-0.01
4	21.54	-1.98	0.58	-0.04
5	26.27	2.75	0.56	-0.06
6	26.32	2.80	0.64	0.01
7	24.59	1.07	0.60	-0.03
8	22.10	-1.42	0.69	0.07
Mean	23.52		0.62	

Soybean oil has gained importance in breeding programs with an increase in the search for raw materials for biofuels production (Oliveira et al., 2019). Thus, high-oil-containing cultivars with wide adaptation and product stability are the most envisaged (Bicalho, 2018).

The means and parameters of adaptability and stability of each cultivar, for oil content, obtained by the method of Eberhart and Russell (1966) and Lin and Binns (1988), modified by Carneiro (1988), are shown in Table 5.

According to the method of Eberhart and Russell (1966), all cultivars showed significant deviations from the regression (ó²d), indicating the non-predictability of behavior (instability), i.e. the cultivars present variations in the oil content of the grains according to the environmental condition to which are subject.

The cultivars 8579RSF IPRO and M8644 IPRO showed a regression coefficient greater than the unit (B_1>1) and a mean higher than the general mean of the group, being considered adapted to favorable environments, that is, where the technological level employed is high, by the Eberhart and Russell (1966) method. As for Lin and Binns (1988) modified by Carneiro (1998), the cultivars above mentioned, together with 9086RSF IPRO also presented the lowest Pi_F values. Cultivars with this characteristic are highly responsive to improvements in the environment, but they need an adequate positioning because if cultivated in unfavorable environments, where the technological level is low and/or adverse climatic conditions occur, they usually present a reduction in their contents (Faria *et al.*, 2018).

The cultivar 8576RSF RR presented a regression coefficient lower than the unit (B_1<1) and mean lower than the general mean of the group, by Eberhart and Russell (1966), and adaptability/high instability of behavior by the nonparametric method. As this cultivar presented a low mean, it is poorly adapted to low investment environments or is unable to exhibit increments in oil content when exposed to a high investment environment. In this environment, the cultivar 9086RSF IPRO presents as ideal by the method of Lin and Binns (1988) modified by Carneiro (1998), since it presents a high mean and lower Pi_U value.

The cultivars 8473RSF RR and 9086RSF IPRO showed a regression coefficient equal to the unit (B_1=1) and high productive capacity (higher than the general mean), by the method of Eberhart and

Russell (1966), and Pi values from medium to low, demonstrating wide adaptation. By the methodology of Lin and Binns (1988) modified by Carneiro (1998), the cultivar 8579RSF IRPO also presented low Pi. These cultivars can respond satisfactorily to the improvement of the environment and present high productive capacity in adverse environmental conditions.

The cultivars ST820 RR, TMG132 RR, and M9144 RR, presented the regression coefficient equal to the unit (B_1=1) and production below the general mean, which enables us to classify them as poorly adapted to the studied environments. Similar results were obtained for the cultivar M9144 RR in studies conducted by Carvalho *et al.* (2013b) and Monteiro *et al.* (2017) for oil content in the State of Tocantins.

Lignin is an important polymer complex in water transport, mechanical support, and plant protection, in addition to providing rigidity and resistance to seed tissues (Huth, 2015). Cultivars with a high lignin content in the grain have a greater capacity to protect the radicle, greater resistance to attack by microorganisms, better control in the absorption and loss of water by the grain, less loss of quality during harvest, resulting in better quality grains and/or seeds (Huth, 2015).

The adaptability and stability parameters of each cultivar for lignin content are described in Table 6, according to the methods proposed by Eberhart and Russell (1966) and Lin and Binns (1988) - Modified by Carneiro (1988).

All cultivars showed significant deviations from the regression (σ^2d), indicating the non-predictability of behavior, using the method of Eberhart and Russell (1966).

Considering Eberhart and Russell's (1966) method, the cultivars 8473RSF IPRO, 8576RSF IPRO, and M8644 IPRO presented a value of B_1>1, showing adaptation to high investment environments. Among these, the first two presented means higher than the general mean and, by the method of Lin and Binns (1988) modified by Carneiro (1998), all presented the lowest Pi_F values.

The cultivars ST820 RR, TMG132 RR, and M9144 RR showed B_1<1, by the method of Eberhart and Russell (1966), and only ST820RR presented a mean higher than the general mean of the group. By the non-parametric method of Lin and Binns (1988) modified by Carneiro (1998), the cultivars ST820 RR and M9144 RR, together with 9086RSF IPRO and 8579RSF IPRO had the lowest Pi_F values.

The cultivars 8579RSF IPRO and 9086RSF IPRO presented values of regression coefficient equal to the unit (B_1=1) and high mean for lignin content, according to the methodology of Eberhart and Russell (1966). By the method of Lin and Binns (1988) modified by Carneiro (1998), 8579RSF IPRO, together with 8576RSF RR and 8473RSF RR presented low Pi values.

The grouping of environments, for all characteristics studied, by the method proposed by Lin (1982), is shown in Table 7.

Table 5. Parameters of adaptability (B_1) and stability (σ^2d) for oil content (%) obtained by the method of Eberhart and Russell (1966) and Lin and Binns (1988) - Modified by Carneiro (1988) (Pi, Pi_F, and Pi_U), in experiments carried out in Porto Nacional and Santa Rosa - TO, under two sowing dates and with eight soybean cultivars, in the 2014/15 and 2015/16 harvests.

	Oil content							
Cultivar	Means	Eberhart & Russell					Lin & Binns	
		B_1	σ^2d	Pi	Pi_F	Pi_U		
8473RSF RR	24.028	1.154	ns	3.050	**	3.333	1.500	4.433
8576RSF RR	22.944	0.004	**	1.770	**	6.718	12.365	3.329
8579RSF IPRO	24.353	1.246	*	3.102	**	2.451	1.020	3.309
ST820 RR	22.865	1.169	ns	1.912	**	6.321	2.222	8.780
TMG132 RR	22.582	1.177	ns	2.357	**	8.002	2.979	11.016
9086RSF IPRO	24.348	1.060	ns	0.790	**	1.962	0.632	2.760
M8644 IPRO	23.998	1.231	*	2.717	**	3.746	0.472	5.710
M9144 RR	23.053	0.960	ns	6.577	**	7.021	7.367	6.813
General mean	23.521							

B_1= regression coefficient; σ^2d= deviations from the regression; Pi= superiority index; Pi_F= adaptation to favorable environments; Pi_U = adaptation to unfavorable environments; **, *, ns= significant at 1%, 5%, and e not significant, respectively, by the t-test.

For oil and lignin contents, no groups of similar environments were formed. Thus, for these characteristics, it is recommended to conduct as many tests as possible in different years/sowing dates/locations.

For oil and lignin contents, the complex fraction present in 100% of the pairs and Pearson's low correlation between environments, reveals the need to conduct all experiments represented by years/ locations and/or sowing dates. These results agree with the non-formation of groups of similar environments from Lin's method (1982) (Table 7).

When the complex fraction (% CF) has a very heavyweight on the C x E interaction, it shows the great difference between environments and reinforces the necessity to evaluate the cultivars in different conditions (Carvalho *et al.*, 2013b).

As presented in Table 6, the methodologies of Cruz and Castoldi (1991) and Pearson's correlation are complementary and presented results close to those observed in Table 7 by Lin's methodology (1982). Therefore, the three methodologies can be used in an associated way to complement each other and provide more reliable results.

Conflict of Interest

There is no conflict of interest between the authors. All authors contributed directly to the article.

CONCLUSION

The adaptability methods, well as those of

Table 6. Parameters of adaptability (B_1) and stability (σ^2d) for lignin content (%) obtained by the method of Eberhart & Russell (1966) and Lin and Binns (1988) - Modified by Carneiro (1988) (Pi, Pi_F, and Pi_U), in experiments carried out in Porto Nacional and Santa Rosa - TO, under two sowing dates and with eight soybean cultivars, in the 2014/15 and 2015/16 harvests.

Cultivar	Means	Lignin content				
		Eberhart & Russell		Lin & Binns		
		B_1	σ^2d	Pi	Pi_F	Pi_U
8473RSF RR	6.48	2.129 *	0.03 *	0.11	0.05	0.16
8576RSF RR	6.75	1.897 **	0.07 **	0.09	0.02	0.17
8579RSF IPRO	6.63	1.443 ns	0.08 **	0.11	0.10	0.12
ST820 RR	6.32	0.088 *	0.02 *	0.14	0.19	0.09
TMG132 RR	5.55	-0.341 **	0.06 **	0.32	0.34	0.30
9086RSF IPRO	6.30	0.367 ns	0.19 **	0.15	0.21	0.09
M8644 IPRO	5.99	2.382 **	0.10 **	0.24	0.07	0.41
M9144 RR	5.93	0.035 **	0.08 **	0.23	0.32	0.14
General mean	6.24					

B_1= regression coefficient; σ^2d= deviations from the regression; Pi= superiority index; Pi_F= adaptation to favorable environments; Pi_U = adaptation to unfavorable environments; **, *, ns= significant at 1%, 5%, and e not significant, respectively, by the t-test.

Table 7. Grouping of the environments in which the soybean cultivars were evaluated based on the contents (%) of oil and lignin, according to the method proposed by Lin (1982), in experiments carried out in Porto Nacional and Santa Rosa - TO, under two sowing dates, in the 2014/15 and 2015/16 harvests.

% Oil		% Lignin	
Croup	Environments	Group	Environments
I	—	I	—
II	—	II	—
III	—	III	—
IV	—	IV	—

Environment 1 (Sowing November 3rd, Porto Nacional, 2014/15 harvest); Environment 2 (Sowing November 18th, Porto Nacional, 2014/15 harvest); Environment 3 (Sowing November 15th, Santa Rosa, 2014/15 harvest); Environment 4 (Sowing November 30th, Santa Rosa, 2014/15 harvest); Environment 5 (Sowing November 3rd, Porto Nacional, 2015/16 harvest); Environment 6 (Sowing November 18th, Porto Nacional, 2015/16 harvest); Environment 7 (Sowing November 15th, Santa Rosa, 2015/16 harvest); Environment 8 (Sowing November 30th, Santa Rosa, 2015/16 harvest).

environmental stratification, were in agreement for most interpretations.

The cultivars 8579RSF IPRO and M8644 IPRO, for oil content, and 8579RSF IPRO, for lignin content, showed general adaptation and can be grown in all environments.

There was no similarity between the environments, for the oil and lignin contents, demonstrating the need to conduct in a greater number of essays.

REFERENCES

Almeida, B.C., Peluzio, J.M., Junior, W.P.O., Carvalho, E.V., Afférri, F.S. and Santos, W.F. 2018. Ambiente e densidade de semeadura em cultivares de soja para produção de biodiesel. *Revista Campo Digital.* 13(1): 19-26.

Amorim, F.A., Hmawaki, O.T., Sousa, L.B., Lana, R.M.Q. and Hamawaki, C.D.L. 2011. Época de semeadura no Potencial produtivo de Soja em Uberlândia-MG. *Semina: Ciências Agrárias.* 32(suplemento 1); 1793-1802.

Bicalho, T.F. 2018. *Influência da época de semeadura em caracteres agronômicos, adaptabilidade e estabilidade de cultivares de soja.* Uberlândia: Universidade Federal de Uberlândia. 70p. Dissertação de Mestrado.

Bligh, E. G. and Dyer, W. J. 1959. A rapid method of total lipid extraction and purification. *Canadian Journal Biochemistry Physiological.* 27(8): 911-917.

Capone, A., Santos, E., Santos, A., Dario, A. and Barros, H.B. 2018. Produtividade e qualidade de sementes de genótipos de soja para alimentação humana introduzidos em Tocantins, na entressafra. *Nucleus.* 15(1): 71-84.

Carneiro, P.C.S. 1998. *Novas metodologias de análise de adaptabilidade e estabilidade de comportamento.* Viçosa: Universidade Federal de Viçosa. 168p. Tese Doutorado.

Carvalho, E.V., Afférri, F.S, Peluzio, J.M., Rotilli, E.A., Dotto, M.A. and Santos, W.F. 2013b. Estratificação e dissimilaridade ambiental em genótipos de milho no Tocantins, com adubação e safras distintas. *Comunicata Scientiae*. 4(3): 277-284.

Carvalho, E.V., Peluzio, J.M., SANTOS, W.F., Afférri, F.S. and Dotto, M.A. 2013a. Adaptabilidade e estabilidade de genótipos de soja em Tocantins. *Revista Agro@mbiente On-line.* 7(2): 162-169.

Conab. 2020. *Acompanhamento da Safra Brasileira de Grãos:* Versão 7 - Safra 2019/20 - Oitavo levantamento. Brasília: Conab.

Cruz, C.D. 2007. *Genes Program:* Computational application in genetics and statistics. Viçosa: UFV.

Cruz, C.D. and Castoldi, F.L. 1991. Decomposição da interação genótipos ambientes em partes simples e complexa. *Revista Ceres.* 38: 422-430.

Eberhart, S.A. and Russell, W.A. 1966. Stability parameters for comparing varieties. *Crop Science.* 6(1) : 36-40.

EMBRAPA, 2019. *Soja na Alimentação* - composição química e propriedades. Londrina: Embrapa.

Evangelista, B.A., Silva, F.A.M., Simon, J. Campos, L.J.M. and Vale, T.M. 2017. *Zoneamento de risco climático para determinação de épocas de semeadura da cultura da soja na região MATOPIBA.* Palmas: Embrapa, 18p.

Faria, L.A., Peluzio, J.M., Santos, W.F., Souza, C.M., Colombo, G.A. and Afférri, F.S. 2018. Oil and protein content in the grain of soybean cultivars at different sowing seasons. *Revista Brasileira de Ciências Agrárias.* 13(2) : 1-7.

Finoto, E.L., Sediyama, T., Albuquerque, J.A.A., Soares, M.B.B., Galli, J.A., Junior, P.S.C. and Menezes, P.H.S. 2017. Antecipação e retardamento de colheita nos teores de óleo e proteína das sementes de soja, cultivar Valiosa RR. *Scientia Agropecuária.* 8(2) : 99-107.

Hatfield, R.D., Jung, H.G., Ralph, J., Buxton, D.R. and Weimer, P.J. 1994. A comparison of the insoluble residues produced by the klason lignin and acid detergent lignin procedures. *Journal of the Science of Food and Agriculture.* 65: 51-58.

Huth, C. 2015. *Lignina no tegumento de semente de soja:* deterioração por umidade e dano mecânico e tamanho de amostra para o teste de tetrazólio. Santa Maria: Universidade Federal de Santa Maria. 96p. Dissertação de Mestrado.

Lin, C.S. 1982. Grouping genotypes by cluster method directly related to genotype-environment interaction mean square. *Theoretical and Applied Genetics.* 62(3): 277-280.

Lin, C.S. and Binns, M.R. 1988. A superiority measure of cultivar performance for cultivars x location data. *Canadian Journal of Plant Science.* 68(1) : 193-198.

Monteiro, F.J.F., Peluzio, J.M., Afférri, F.S., Carvalho, E.V. and Santos, W.F. 2017. Adaptabilidade e estabilidade de cultivares de soja para produtividade de óleo nos grãos. *Revista Agrarian.* 10(35): 18-21.

Naoe, A.M.L., Peluzio, J.M. and Sousa, J.P. 2017. Estresse ambiental na cultura da soja. *Revista Integralização Universitária – RIU*. 12(16): 71-80.

Oda, M.C., Sediyama, T., Matsuo, E., Nascimento, M. and Cruz, C.D. 2019. Estabilidade e adaptabilidade de produção de grãos de soja por meio de metodologias tradicionais e redes neurais artificiais. *Scientia Agraria Paranaensis.* 18(2): 117-124.

Oliveira, E.C.A.M., Junior, W.P.O., Oliveira, J.D.D., Furmigare, N.S. and Peluzio, J.M. 2019. Divergência genética em linhagens de soja visando a produção de biodiesel no Estado do Tocantins. *Magistra.* 30(1): 113-122.

Reina, E., Peluzio, J.M., Afferri, F.S., Oliveira Junior, W.P. and Siebeneichler, S.C. 2014. Genetic divergence and phosphorus use efficiency in the soybean with a view to biodiesel production. *Revista Ciência Agronômica.* 45(2) : 344-350.

Toller, M., Peluzio, J.M., Reina, E., Lima, M.D., Hackenhaar, C., Hackenhaar, N. 2018. Adubação potássica e época de semeadura em soja para a produção de etanol. *Revista Agrogeoambiental.* 10(2): 75-88.