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GENETIC DIVERGENCE REGARDING THE CHEMICAL COMPOSITION OF SOYBEANS IN TOCANTINS

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Abstract – Environmental conditions and genetic variability can result in changes in the chemical composition of the grains, reflecting in different groupings in the multivariate procedures. Thus, the present work was carried out aiming to study the genetic divergence of soybean cultivars, regarding the chemical composition of the grains, in tests represented by the combination of years/places/sowing times, out four were carried in the 2014/15 harvest and four in the harvest. 2015/16. The experimental design used, in each environment, was randomized blocks with three replications and eight treatments, represented by the cultivars: 8473RSF RR, 8576 RSF, 8579RSF IPRO, ST 820 RR, TMG 132 RR, 9086RSF IPRO, M8644 IPRO e M9144 RR. The chemical characteristics the evaluation of grains were oil, protein, carbohydrate, cellulose, hemicellulose and lignin content. Analysis of variance was performed for each assay, applying the Tocher grouping method and Singh's criterion (1981) to quantify the relative contribution of these characteristics to genetic divergence. The harvest, the place and the sowing times are influenced by the grouping of soybean cultivars. The cultivar M9144 RR was the most divergent and could be used as a parent in the future breeding program for chemical composition in grains. The characteristics of oil and cellulose content were the ones that most contributed to the genetic divergence of cultivars.

INTRODUCTION

Soy *(Glycine max)* is considered one of the most strategic oilseeds in the world, playing a very important role in Brazil's economy, contributing greatly to the expansion of agricultural borders, especially in regions under cerrado vegetation (Campos *et al*., 2016).

The State of Tocantins has gained national prominence among these soybean-producing regions, due to favorable climatic conditions, privileged geographical location and attractive lands for the implementation of the crop (Campos *et al*., 2016). In the 2019/20 crop, soybeans occupied approximately 1,08 million hectares of planting in the State (more than 50% of the total north) producing about 3 million tonnes (almost 50% of all volume produced in the North) (Conab, 2020).

Soybean is known to have a high oil content (average 20%), protein (measured 38%) and carbohydrates (average 25%), in addition to 10% minerals, fibers (cellulose, hemicellulose and lignin) and 5% moisture (Embrapa, 2019), and the expression of these components is highly influenced by the interaction with the environment (Daronch *et al*., 2018; Faria *et al*., 2018; Toller *et al*., 2018; Huth, 2015).

As the chemical composition of the grains depends on environmental conditions, the choice ofcultivar, depending on the site and sowing season, and the management strategies adopted, are extremely important to obtain high yields, especially when combined with knowledge of the limitations and/or benefits of the productive environment (Daronch *et al*., 2018; Petter *et al*., 2014).

With the search for raw material for biofuel

production, from vegetable oil and carbohydrate, the latter as a source of ethanol (Siqueira, 2007), in addition to protein, which has been used for human feed and animal feed, and seeds with higher fiber content, which result in greater resistance to the attack of microorganisms, better control in the absorption and loss of water by grain (Huth, 2015), studies and these characteristics have gained importance in breeding programs.

However, there are still few studies of genetic divergence of soybean cultivars regarding the chemical composition of grains in different environments, aiming at the identification of cultivars, which could be used in future breeding programs, as well as the relative contribution of traits in genetic divergence, to which the present study was proposed.

MATERIALS AND METHODS

Eight competition trials of cultivars were carried out, four in the 2014/15 crop and four in the 2015/16 crop. In each harvest, two trials were conducted in the municipality of Porto Nacional – TO (Local 1 – Farm Serra Azul, 234 m altitude, 10°422273 S and 48°242513W) and two in Santa Rosa - TO (Local 2 - Farm Mariana, 288m altitude, 11°26'31''S and 48°7'2''W).

The sowings were carried out in two seasons, the first season being on November 3 in Porto Nacional and November 15 in Santa Rosa. On the other hand, the second season occurred 15 days after the first planting, being November 18 in Porto Nacional and November 30 in Santa Rosa, respecting the planting window of the two sites.

The experimental design used in each assay (environment) was randomized blocks with three replicates and eight treatments. The treatments consisted of eight cultivates, which are: 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.

Soil chemical characteristics were presented by soil analysis (Table 1).

Rainfall temperature and precipitation data recorded in the agricultural year 2014/2015 and 2015/2016 were obtained through monthly data collection at the test site (Table 2).

The grains from each cultivar in each crop, place and season, were harvested with 13% moisture, identified, crushed and stored in the form of soybean meal in cold chamber, at the Federal University of Tocantins - Gurupi Campus, under temperature and controlled humidity, aiming at maintaining the chemical quality of the grain.

Table 1. Result of the chemical analysis of the soil in the layer of 0 - 20 cm, in the conduction sites of the tests preceding planting.

Chemical Attributes	Local	
	Porto Nacional	Santa Rosa
pH (H_2O)	5.75	5.53
pH ($CaCl_2$)	5.11	4.85
P (mg. dm^3)	2.84	3.04
Ca+Mg (cmol.dm^3)	3.12	1.92
H+Al (cmol.dm^3)	4.71	3.97
K (cmol.dm^3)	0.16	0.18
CTC eft. (cmol.dm^3)	3.27	2.1
CTC (cmol.dm^3)	7.98	6.07
V (%)	40.98	34.62
Organic matter (g.dm^3)	31.05	16.12

Later, in the laboratory of industrial raw material of the Federal University of Tocantins - Palmas Campus, these samples were submitted to physico-chemical analyses to determine the grain compositions of each cultivar in relation to the oil contents (method of Bligh-Dyer), protein content (method of Kjeldhal), carbohydrate content (carbohydrate reagent method Fehling) and fiber content (gravimetric enzimic method for calculating hemicellulose and cellulose values) and lignin contents were quantified by the method of Klason.

After obtaining the data, variance analysis of each crop, each site, each sowing season and a general analysis involving the years, locations and seasons were performed. With the results of each variance analysis, the dissimilarity measurements were obtained, which allowed the obtaining of the dissimilarity matrix, residual covariance matrix and cultivar means, and the grouping method of Tocher, proposed by Rao, using the generalized Mahalanobis distance as a measure of dissimilarity.

The criterion of Singh to quantify the relative contribution of these characteristics to genetic divergence. A correlation was also performed Pearson between the harvests and/or Local and/or epoch and/or general, using the shortest average distance of Mahalanobis of each cultivar, using the test "t" at the level of 5% significance.

The analyses were performed using the Computational Genes program, 2007 (Cruz, 2007).

RESULTS AND DISCUSSION

The results of the grouping of cultivars, for each

Table 2. Monthly temperature and precipitation data in two agricultural years (Crops) 2014/15 (year 01) and 2015/16 (year 02) in the municipalities of Porto Nacional and Santa Rosa

Period	Average Temperature (°C)				Accumulated precipitation (mm)			
	Crop2014/2015		Crop2015/2016		Crop2014/2015		Crop2015/2016	
	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
Epoch1	—	—	—	—	189	166	165	240
Epoch2	—	—	—	—	199	175	174	249
Crop Average	27.2	26.7	28.2	26.7	204.7	184.0	167.8	237.0
Total crop	—	—	—	—	1.228	1.104	1.007	1.422

crop, place, year and general, originating from the method of optimization of Tocherare shown in Table 3.

When the harvests (years), the sites and sowing times were compared, variations were observed in the number of groups formed and, in their composition, probably due to the occurrence of the interaction cultivars x environments. In this case, the environmental factor can be attributed to climatic variations resulting from rain and precipitation that occurred in the harvests, places, and sowing times (Table 2), influencing the behavior of cultivars and the chemical composition of the grains.

In the 2015/16 Harvest, there was greater diversity among the cultivars, contributing to the formation of the largest number of groups (five groups). On the other hand, a lower divergence was observed between the cultivars for the 2014/15 crop, resulting in the formation of a smaller number of groups (Table 3).

When the sowing times were compared, there was no coincidence as to the number and composition of the groups formed. The differences between the seasons were due to the occurrence of higher temperatures and, mainly, the differences in precipitation, where there was a better distribution of rainfall in season 1 – Harvest 2015/16, during February, coinciding with the grain filling phase of the crop.

For the sites, there was similarity in the number of groups and the greater similarity, among all the comparations, in relation to the composition of the groups, where cultivars 3, 6 and 7 were always located in the same group and cultivar 8 in an isolated group. Among the sites, the results of soil analyses were very similar (Table 1), as well as small fluctuations in temperatures and regular rainfall distribution during plant development (Table 2).

When cultivated in different environments, represented by location, sowing season and crop

Table 3. Grouping by Tocher method, based on the generalized Mahalanobis distance, in trials, carried out in Porto Nacional and Santa Rosa - TO, with two sowing seasons and with eight soybean cultivars, in the 2014/15 and 2015/16 harvests.

Group	Crop2014/15	Crop2015/16	Porto Nacional	Santa Rosa	Epoch 1	Epoch 2	General
I	1; 2; 6; 3; 4 and 7	5 and 6	3; 6; 4 and 7	6; 7; 2; 3 and 5	5; 7 and 2	2; 3 and 1	2; 4; 6; 3 and 7
II	5 and 8	1 and 7	1; 5 and 2	1 and 4	1 and 8	4; 6 and 5	1 and 5
III	—	2 and 4	8	8	3 and6	7 and 8	8
IV	—	3	—	—	4	—	—
V	—	8	—	—	—	—	—

1=8473 RSF RR;2=8576 RSF RR; 3=8579RSF IPRO; 4=ST 820 RR; 5=TMG 132 RR; 6=9086RSF IPRO; 7=M8644 IPRO; 8=M9144 RR.Epoch1= Planting03/11 in Porto Nacional and 15/11 in Santa Rosa; Epoch2= Planting18/11 in Porto Nacional and 30/11 in Santa Rosa.

(year), soybean cultivars tend to present variations in the chemical composition of the grain (Hackenhaar *et al*., 2019).

The differential behavior among soybean cultivars, as a function of different years, local and even sowing times, were also observed for the levels of oil, protein (Hackenhaar, 2019; Faria *et al*., 2019; Daronch *et al*., 2018; Dourado *et al*., 2018; Santos *et al*., 2018; Naoe *et al*., 2017; Barbosa *et al*., 2011); of carbohydrates (Faria *et al*., 2018; Toller *et al*., 2018) and fibers in the grains (Huth, 2015).

The cultivar M9144 RR (8) presented a lower similarity in relation to the others, where, three times (crop 2015/16, Porto Nacional and Santa Rosa),was present alone in a single group and, twice, was present in a group with only one other cultivar (crop 2014/15 andepoch 2).

The general grouping, that is, involving all environments at the same time, revealed the formation of three groups, where again the cultivar M9144 RR was isolated in one group.

Groups formed by only one cultivar indicate that it is more divergent in relation to the other cultivars, and can be used as a parent in a future breeding program (Santos *et al.,* 2018). Like this M9144RR could be used as a parent in breeding programmers for the chemical composition of grains.

The correlations of low magnitude and non-significant, for the vast majority of combinations (except for the 2 x General season combination, which demonstrated high magnitude and significance), confirm that the harvests, seasons and places can promote changes in the number and composition of the groups (Table 4).

The relative contribution of each characteristic to genetic dissimilarity, according to Singh's method, varied according to the harvest, place and sowing time, demonstrating that the expression of each characteristic of this characteristic is dependent on the environment where the culture develops (Table 5).

The characteristics that, in general, contributed most to the genetic divergence of the cultivars were the oil and cellulose contents. On the other hand, carbohydrate and lignin contents, with the exception of 2014/15, hemicellulose, with the exception of season 1, and protein, contributed little to the genetic divergence of cultivars (Table 4).

Thus, the oil and cellulose contents in soybean grains could be used in breeding programs aimed at

Table 4. Correlations of distances between pairs of environments, represented by two sowing seasons, two distinct sites (Porto Nacional and Santa Rosa - TO), and two 2014/15 and 2015/16 harvests, in trials carried out with eight soybean cultivars.

	Crop2014/15	Crop2015/16	Porto Nacional	Santa Rosa	Epoch 1	Epoch 2	General
Crop2014/15	1	-0.24	-0.12	0.31	-0.13	-0.09	0.58
Crop2015/16		1	0.67	-0.64	0.15	0.09	-0.55
Epoch1			1	-0.88	-0.47	0.05	-0.68
Epoch2				1	0.45	-0.05	0.77 *
Porto Nacional					1	0.15	0.23
Santa Rosa						1	0.18
General							1

Epoch 1= Planting03/11 in Porto Nacional and 15/11 in Santa Rosa; Epoch2= Planting18/11 in Porto Nacional and 30/11 in Santa Rosa.

Table 5. The relative contribution of the characters for the genetic dissimilarity of 08 soybean cultivars, in trials, carried out in Porto Nacional and Santa Rosa - TO, with two sowing seasons, in the 2014/15 and 2015/16 harvests.

Features	Crop 2014/15	crop 2015/16	Porto Nacional	Santa Rosa	epoch 1	epoch 2	General
Oil	25.0	27.0	54.0	10.3	38.3	19.6	27.6
Protein	0.0	14.0	0.0	17.5	0.0	16.7	17.6
Carbohydrate	35.0	0.0	5.0	9.6	0.0	15.2	5.5
Hemicellulose	6.5	19.7	7.8	2.7	22.7	4.8	11.0
Cellulose	8.2	24.1	17.4	42.1	19.9	22.1	23.5
Lignin	21.8	8.1	9.0	2.4	11.3	15.9	12.7

the selection of cultivars. Second Coelho *et al*., 2019; Santos *et al*., 2018; Santos *et al*., 2019; Silva *et al*., 2019a; Silva *et al*., 2019b, in cultivar selection programs, the selection efficiency can be increased when only the characteristics that most contributed to discriminating cultivars are used.

Conflict of Interest

There is no conflict of interest between the authors. all authors contributed equally to the article.

CONCLUSION

The harvest, place and sowing season promoted the grouping of soybean cultivars.

The cultivar M9144 RR was the most divergent, being potentially promising for use in breeding programs aiming at the chemical composition of grains.

The characteristics of oil and cellulose content were the ones that most contributed to the genetic divergence of the cultivars.

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