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Interaction cultivar environment in soybean for protein yield with different fertilization and sowing dates

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***Abstract*— This study aimed at evaluating the interaction cultivar × environments for the oil and protein yield of the grains, in soybeans grown under different levels of potassium fertilization, in two sowing times, in the state of Tocantins. In the agricultural year of 2013/14, were performed twelve soybean cultivars competition trials in Palmas/TO. In each season, each test represented a distinct environment and consisted of a level of potassium fertilization (0, 40, 80, 120, 160, or 200 Kg K_2O ha^{-1}). The experimental design used in each test was a randomized block with 10 cultivars and three replications. Analyzes of stability and adaptability, stratification and environmental dissimilarity were performed. Potassium levels and sowing times resulted in differential performance of soybean cultivars. The BRS 333RR cultivar was presented as potentially promising for oil yield and BRS 9090RR for protein. The evaluation tests of soybean cultivars can be performed using low levels of potassium fertilization, providing reduced costs and less contamination of the water table.*

I. INTRODUCTION

Amazon soils, especially savannah soils as reference, usually present high acidity and low natural fertility. In this case it is necessary the use of great amount of agricultural inputs to increase productivity of crops. However, the use of agricultural inputs causes water table contamination and soils acidification that result in global warming.

One of these agricultural inputs required by soybean crop is potassium. According to Guareschi et al. [1], potassium is very important in mineral nutrition of soybean and it is the most absorbed and exported macronutrients by crop.

Chemical composition of soybean can present variations when it is cropped in different environments [2] and it can occur interaction between cultivar and environment (C x E) [3], [4] and [5].

Genetical enhancement programs of soybean aimed at the development of more productive cultivars [3]. On biometrical sense, two approaches are considered: 1) studies of stability and adaptability of different cultivars in which particular responses are taken for each cultivar under environmental variations. These studies aim at identifying wide or specific adaptability and predictable behavior; and 2) and other related to stratification methods and environmental dissimilarity by interaction cultivar x environment interaction (C x E).

This work aimed at study interaction cultivar x environment about yield of grains of soybean cropped under different levels of potassium fertilizing and seeding periods in Tocantins State, Brazil.

II. MATERIAL AND METHODS

In agricultural year of 2013/2014 twelve competition tests were carried out of cultivars of soybean at Agrotechnological Center of Federal University of Tocantins, Palmas Campus (10º45' S; 47º14' W; e 220 m of altitude), six of them installed in 5th December, 2013 (first seeding period) and six in 23rd January, 2014 (second seeding period – late seeding). Distinct environments were represented in each test in both periods for potassium fertilizing level (0, 40, 80, 120, or 200 kg of K_2O ha^{-1}). This fertilizer was applied half on planting groove and half 35 days after plants emergence using potassium chloride as source of K_2O.

On the experimental area were collected 20 samples of soil in depth of 0-20 cm that were homogenized and 1 kg of this sample was sent to laboratory for chemical and physical analyses of soil. Obtained contents were pH: 4.1; K: 14.0 mg dm^{-3}; P (Melich): 1.5 mg dm^{-3}; Ca: 0.7 cmol dm^{-3}; Mg: 0.5 cmol dm^{-3}; Organic Material.: 12.0 g dm^{-3}; Cation Exchange Capacity: 4.6 cmol dm^{-3} and Base Saturation: 26.7%. These analyses were carried out according to Embrapa's Method of soil analyses [6].

Rainfall and average temperature data during tests were obtained from Meteorology and Climatology Laboratory of Federal University of Tocantins – UFT and presented in Figure 1.

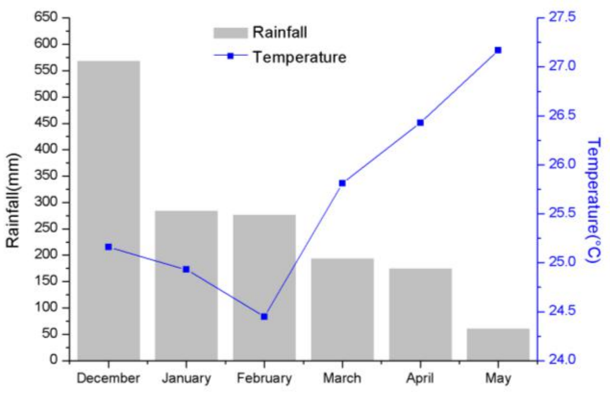

Fig.1: Rainfall (mm) and average temperature (ºC) occurred during tests from December, 2013 to May, 2014 on Palmas-TO, Brazil.

Experimental design was randomized blocks with 10 treatments and tree repetitions. Utilized cultivars on treatments were BRS 325RR, M 9144RR, BRS 33871RR, TMG 1288RR, BRS 333RR, P 98Y70RR, TMG 1180RR, BRS 9090RR, M 8766RR, and BRS 8990RR.

In each test, experimental plots were of four runs of 5.0 m of length with spaces of 0.45 m. On harvesting were neglected 0.45 m from border of central runs. Useful area was represented of two central runs of 3.6 m^2.

After chemical and physical analyses of soil, liming took place using two tons of dolomitic limestone Filler by hectare. Plowing, harrowing and grooving were made after 30 days of soil correction. Seeding fertilization was made by hand with 750 kg ha^{-1} of simple superphosphate that it about 150 kg of P_2O_5 ha^{-1}.

At the moment of seeding, fungicides were used to treat seeds then they were inoculated with strains of *Bradyrhizobium japonicum*. Seeding density was carried out to achieve from 10 to 14 plants by linear meter. After 15 days of seeding it was carried out paring. Pest control, diseases and weed was made when necessary.

Plants of each experimental portion were harvested a week after 95% of mature green beans at maturation stage R8 of Fehr et al. [7] scale. According to useful area of portion was determinates grain yield (weight in kg ha-1 after moisture correction of 12%). Then three samples were separated with 100 grams of each portion that were sent to laboratory of Soybean Embrapa in Londrina-PR, Brazil to determinate protein content (%) by Near Infrared Reflectance (NIR) according to Heil [8].

Protein yield (kg ha^{-1}) was obtained by multiplying protein content (%) for grain yield (kg ha^{-1}). To study cultivars behavior in each sowing date, yield data of protein were submitted to individual variance and then to joint analyses in which lesser residual medium square were not different more than seven times from larger medium square [9]. After that, analyses of adaptability, stability, environmental stratification and dissimilarity were made.

Adaptability and stability methods were carried out from Eberhart & Russel [10] and Lin & Binns [11] modified by Cruz et al. [9]. Environmental stratification and dissimilarity were made according to environmental grouping based on the Lin's algorithm [12]. Simple fraction and complex interaction cultivar x environment were estimated according to Cruz & Castoldi [13] method and then Pearson correlation among pairs of evaluated environments.

Averages of cultivars were compared by Scott-Knott test to 5% of significance using GENES Program [14].

III. RESULTS AND DISCUSSION

Individual variance analyses of protein yield (Table 1) presented significant effect from cultivars in all levels of potassium fertilization at two sowing dates. Variation coefficients (VC) ranged from 4.7% to 10.6%, respectively, in 40 and 120 kg ha^{-1} at second sowing date (01/23).

Table 1. Protein yield (kg ha^{-1}); cultivars variance (AS_{Treat}); residual variance (AS_R) and variation coefficient (VC) of six competition tests of soybean cultivars in each sowing dates, agricultural year of 2013/2014 at Palmas-TO, Brazil.

Dates	Tests (Kg of K_20 ha^{-1})	Average (Kg ha^{-1})	AS_{Trat}	AS_R	VC (%)
Date 05/12/13	0	1017	218985.6*	5569.8	7.3
	40	1453	124484. 1*	11346.2	7.3
	80	1609	35772.4*	16684.4	8.0
	120	1702	81266.5*	12205.8	6.5
	160	1750	83098.6*	17479.8	7.5
	200	1813	121756.1*	13379.3	6.4
	Average	1557			
Date 23/01/14	0	360	28088.7*	437.8	5.8
	40	422	44457.0*	389.2	4.7
	80	454	41993.5*	2002.9	9.8
	120	469	23656.4*	2464.6	10.6
	160	467	29768.2*	1755.8	8.9
	200	498	34367.5*	1337.4	7.3
	Average	445			

$^{ns\ *}$ = non-significant and significant, respectively to 5% of probability by F test

At second sowing date (01/23) for all levels of potassium fertilization there was a lesser protein yield comparing to first date (12/05), indicating date is unfavorable to soybean crop. This occurrence was expected because of rainfall falling-off on cultivars grain filling (Figure 1). According to Marques et al. [15] rainfall falling-off causes grain productivity fall and then protein yield fall.

Obtained data on this study are similar to Carvalho et al. [5] that verified effect of sowing dates on behavior of soybean in Tocantins State for grain yield.

Joint variance analyses for protein yield in each sowing dates showed significant effects to cultivar, environments and for interaction between them (Table 2).

Table 2. Summary of joint variance analyses for protein yield (kg ha^{-1}) in ten cultivars of soybean submitted to six levels of K_2O in two sowing dates on agricultural dates of 2013/2014 at Palmas-TO, North Region of Brazil.

Variation source	Liberty degrees	Average square	
		1st Date (1)	2nd Date (2)
Cultivar	9	387792.76*	160273.81*
Environment	5	2574409.34*	69783.05*
Cultivar×Environment	45	55514.14*	8411.53*
Block/Environment	12	31102.88	2326.76
Residue	108	12777.58	1397.95

VC (%)	7.2	8.4
General average	1557.0	445.2

VC: variation coefficient; (1) Sowing at 05/12/2013; (2) sowing at 23/01/2014; * significant at 5% of probability to F test.

The significant effect of cultivar suggests diversity among the cultivars that can be attributed to the genetic variability, and the effect of environments evidences the importance of the realization of the tests from different levels of potassium fertilization.

Interaction cultivars x environment significant effects indicate changes on fulfillment of soybean cultivars at different levels of potassium fertilization. Analyses of stability, adaptability and environmental stratification justify the importance of protein yield studies.

Variation coefficient (VC) in first and second date ranged from 7.2 to 8.4%, that indicates good experimental accuracy.

Table 3 shows averages and adaptability, stability parameters of cultivars using methods of Eberhart & Russell [10] and Lin & Binns [11] modified by Cruz et al. [9].

Table 3. Parameters of adaptability (β_1) and stability (σ^2d) for protein yield of soybean cultivar (kg ha^{-1}) obtained from Eberhart & Russell Method [10] - β_1 and σ^2d; and Lin & Binns [11] modified by Cruz et al. [9] - π, π_{Fav} e π_{Desf}, on agricultural year of 2013/2014 in Palmas-TO, North Region of Brazil.

Cultivar	Average	Yield of protein				
		Eberhart & Russell [10]		Lin & Binns [11]		
		β_1	$(\sigma^2_d)^3$	π	π_{Fav}	π_{Desf}
			First Date(2)			
BRS 325RR	1644.4b	1.01^{ns}	11.18*	34727.1	6718.7	90743.8
M 9144RR	1478.7c	1.01^{ns}	3.76^{ns}	78554.2	39178.5	157305.6
BRS 33871RR	1638.8b	0.40$^{(1)}$	21.01*	30225.0	44099.6	2475.9
TMG 1288RR	1444.3c	1.00^{ns}	5.42^{ns}	90533.1	60376.6	150846.0
BRS 333RR	1764.7a	0.80$^{(1)}$	11.08*	13271.3	543.2	38727.6
P 98Y70RR	1397.4d	1.37$^{(1)}$	3.92^{ns}	118564.1	57483.7	240724.9
TMG 1180RR	1513.7c	1.28$^{(1)}$	10.28*	67505.4	36920.3	128675.5
BRS 9090RR	1720.6a	1.04^{ns}	5.01^{ns}	12288.7	6034.2	24797.7
M 8766RR	1650.9b	1.06^{ns}	10.71*	26728.0	11889.8	56404.4
BRS 8990RR	1323.2e	1.03^{ns}	15.50*	149806.2	114397.2	220624.2
Average	1557.70					
			Second Date(3)			
BRS 325RR	273.2d	1.27^{ns}	0.45^{ns}	52537.1	50480.6	56650.2
M 9144RR	533.3a	0.27$^{(1)}$	3.85*	5093.6	7569.7	141.3
BRS 33871RR	519.3a	2.71$^{(1)}$	2.52*	6213.4	632.9	17374.5
TMG 1288RR	573.3a	1.01^{ns}	0.53^{ns}	633.4	933.1	33.9
BRS 333RR	478.2b	1.05^{ns}	0.16^{ns}	7822.0	7539.9	8386.3
P 98Y70RR	384.9c	1.17^{ns}	0.84*	22834.7	21967.5	24569.1
TMG 1180RR	481.2b	1.24^{ns}	0.24^{ns}	7093.7	6604.6	8071.9
BRS 9090RR	460.1b	-0.40$^{(1)}$	0.18*	12289.1	17504.0	1859.2
M 8766RR	423.1b	0.76^{ns}	0.42^{ns}	15524.5	17553.2	11467.3

BRS 8990RR	326.2d	0.91 ns	0.33ns	37052.3	37450.0	36256.8
Average	445.28					

Average followed by same lower case in columns belongs to same group, according to grouping criterion of Scott-Knott on 5% of significance. (1) Significant to 5% by t test, ns Non-significant. * and ** significant to 5 and 1 %, respectively by F test; (2) Sowing at 05/12/2013; (3) Sowing at 23/01/2014.

On first date (05/12), considerate the most favorable in this study, five groups of average were made (Table 3). Group of larger average was made only by cultivars BRS 333RR and BRS 9090RR. Cultivar BRS 8990RR presented lesser protein yield.

According methodology of Eberhart & Russell [10] and Lin & Binns [11] modified by Cruz et al. [9] environments classified as favorable were 80, 120, 160, and 200 kg ha $^{-1}$ of K_2O (Table 1). According to Lopes [16] recommended level for this soil based on chemical analyses would be 120 kg ha^{-1}. After soil analysis better environments are near of recommended potassium levels or superiors.

By Eberhart & Russell Methodology [10], cultivars M 9144RR, TMG 1288RR, P 98Y70RR, and BRS 9090RR presented regression deviations non-significant ($\sigma^2 d=0$) indicating predictability (stability) of behavior.

Cultivars BRS 333RR and BRS 33871RR presented average yield of protein above of general average and regression coefficient smaller than one ($\beta_1<1$) indicating adaptability to unfavorable environments.

Cultivars P 98Y70RR e TMG 1180RR presented $\beta_1>1$ and production average low so they were classified as poorly adapted to favorable environments.

M 9144RR, TMG 1288RR, BRS 8990RR, BRS 325RR, BRS 9090RR, and M 8766RR cultivars presented $\beta_1=1$ so they were classified as high adaptability. Among all of them only last three presented average above general average.

According to Eberhart & Russell Methodology [10] only BRS 9090RR cultivar was considered as ideal because presented average superior to general average, regression coefficient equal to unit and regression deviation non-significant.

By Lin & Binns method [11] modified by Cruz et al. [9] cultivars BRS9090RR, BRS333RR, M8766RR, and BRS33871RR presented general π smaller so they were classified of high stability and wide adaptability. First of them was considered highly adaptable by Eberhart & Russell Method [10].

Cultivars BRS333RR, BRS9090RR, BRS325RR, and BRS325RR presented stability/adaptability to unfavorable environments. Enhance that BRS3371RR also presented adaptability to unfavorable environments according to Eberhart & Russell Methodology [10].

Averages and parameters of adaptability and stability from cultivars for yield protein in second date of sowing (23/01) for Eberhart & Russell [10] and Lin & Binns [11], modified by Cruz et al. [9] are in Table 3.

Cultivars M9144RR, BRS3371RR and TMG1288RR belong to group with greater averages and in group with lesser averages are P98Y70RR and BRS325RR.

For this date tests of 80, 120, 160, and 200 kg ha^{-1} were classified as favorable environments like in first date of sowing (Table 1). These levels are near or superior to recommended level after soil analyses.

According to Eberhart & Russell method [10] cultivars BRS325RR, TMG1288RR, BRS333RR, TMG1180RR, M8766RR, and BRS8990RR presented regression deviation non-significant ($\sigma^2 d=0$) indicating predictability (stability) of behavior.

M9144RR and BRS9090RR cultivars presented regression coefficient lesser than unit and average above general average classified as adapted to unfavorable environments.

BRS33871RR cultivar presented $\beta_1>1$ and average above general average so it was classified as adapted to favorable environments.

BRS 325RR, TMG 1288RR, BRS 333RR, P 98Y70RR, TMG 1180RR, M 8766RR, and BRS 8990RR cultivars presented $\beta_1=1$ then they were classified with adaptability to wide environments conditions. Among them only TMG 1288RR, BRS333RR, TMG1180RR, and BRS9090RR presented average above general average.

TMG 1288RR, BRS 333RR and BRS 9090RR can be considered as ideal because they presented high average, regression coefficient equal to unit and non-significant deviation regression.

In Lin & Binns method (1988) [11] modified by Cruz et al. [9] cultivars TMG 1288RR, M 9144RR, BRS 33871RR, and TMG 1180RR were classified as high stability/adaptability. Enhance that TMG1288RR and TMG1180RR also presented general adaptability by Eberhart & Russell methodology [10].

BRS 33871RR, TMG 1288RR, TMG 1180RR, and BRS 333RR are stable or adapted to favorable environments, only BRS33871RR were classified as adapted to favorable environments by Eberhart & Russell [10].

Environmental stratification analysis using Lin's method [12] for the first sowing date (05/12) formed only one group with four environments: 5, 6 and 4 environments (Table 4).

For second sowing date three groups were formed distributed like that: group I with 4 and 5 environments; group II with 1 and 2 environments and group III with 5 and 6 environments.

Table 4. Grouping of twelve evaluation environments in 10 cultivars of soybean, based to protein yield, in agricultural year of 2013/2014, Palmas-TO, North Region of Brazil using Lin's method [12].

Groups	Environments*	Protein Yield Error MS¹ (x10³)	F_{cal} ²	Ft_{ab} ³
		First date(4)		
I	5, 6 and 4	4.18	0.98	1.83
		Second date(5)		
I	4 and 5	0.75	1.61	2.08
II	1 and 2	0.76	1.63	2.08
III	5 and 6	0.94	2.01	2.08

[1]Error Average Square, [2] F Calculated, [3] F Tabled to 5% of significance, (4) Sowing at 5/12/2013, (5) Sowing at 23/01/2014; Environments 1 (0 kg of K_2O ha^{-1}), 2 (40 kg of K_2O ha^{-1}), 3 (80 kg of K_2O ha^{-1}), 4 (120 kg of K_2O ha^{-1}), 5 (160 kg of K_2O ha^{-1}), 6 (200 kg of K_2O ha^{-1}).

Concomitant use of Cruz & Castoldi [13] method and Pearson correlation among environments (Table 5) in each group from Lin's method [12] (Table 4) revealed high percentage of interaction CxE attributed to simple fraction (FS>70%) and high Pearson correlation that confirms groups composition in each date.

IV. CONCLUSION

Potassium levels and sowing dates resulted in different behavior of soybean cultivars.

Stability and adaptability methodologies and environmental stratification and dissimilarity were concordant with each other.

BRS9090RR cultivar presented as potentially promising to protein yield in adequate date.

TMG1288RR cultivar presented as potentially promising to protein yield in late date.

Evaluation tests of soybean cultivars can be realized using low levels of potassium fertilization with cost reduction and less water table contamination.

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