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Incidence of diseases and selection of soybean cultivars (*Glycine max* l. Merril) in a water deficit environment

Incidência de doenças e seleção de cultivares de soja (Glycine max l. Merril) em ambiente de déficit hídrico

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ABSTRACT

This work aimed to verify if it is possible to select soybean genotypes tolerant to diseases and water stress. The experimental design was randomized blocks (RBD), with thirty soybean genotypes, in four replications, totaling 120 experimental units. Evaluations were performed based on crop yield components and disease incidence in thirty soybean cultivars in field conditions. Analysis of variance was performed at 5% probability using the F test. Variables that showed significance were compared using Scott-Knott's grouping of means at 5% probability. Pearson's linear correlation coefficients were calculated between pairs of variables, with significance imposed by the t test at 5% probability. The Euclidean distances were calculated and the UPGMA grouping was performed to construct the genetic dissimilarity dendrogram, after which the biplot principal components were used to identify the association trend between variables and cultivars. It was possible to select soybean genotypes for grain production and disease tolerance in an environment with water stress. Cultivars M 5947 IPRO, TEC 6702 IPRO, M 6410 IPRO showed the highest grain yield. The cultivar TEC 6702 IPRO showed the best agronomic performance for morphological and productive characteristics, associated with the lowest incidence of diseases.

KEYWORDS: water stress; selection of genotypes; yield grain.

RESUMO

Este trabalho teve como objetivo verificar se é possível selecionar genótipos de soja tolerantes a doenças e ao estresse hídrico. O delineamento experimental foi o de blocos casualizados (DBC), com trinta genótipos de soja, em quatro repetições, totalizando 120 unidades experimentais. As avaliações foram realizadas com base nos componentes de rendimento da cultura e na incidência de doenças em trinta cultivares de soja em ambiente de cultivo. A análise de variância foi realizada a 5% de probabilidade pelo teste F. As variáveis que apresentaram significância foram comparadas pelo agrupamento de médias de Scott-Knott a 5% de probabilidade. Os coeficientes de correlação linear de Pearson foram calculados entre pares de variáveis, com significância verificada pelo teste *t* a 5% de probabilidade. Foram calculadas as distâncias euclidianas e realizado o agrupamento UPGMA para a construção do dendrograma de dissimilaridade genética. Posteriormente, foram utilizados os componentes principais biplot para identificar a tendência de associação entre as variáveis e as cultivares. Foi possível selecionar genótipos de soja para produção de grãos e tolerância a doenças em ambiente com estresse hídrico. As cultivares M 5947 IPRO, TEC 6702 IPRO, M 6410 IPRO apresentaram as maiores produtividades de grãos. A cultivar TEC 6702 IPRO apresentou o melhor desempenho agronômico para características morfológicas e produtivas, associado à menor incidência de doenças.

PALAVRAS-CHAVE: estresse hídrico; seleção de genótipos; produtividade de grãos.

INTRODUCTION

Soybean (*Glycine max*) is an oilseed from the *Fabaceae* family, cultivated in practically all Brazilian states. The uses of soybean are diverse, ranging from human food to the manufacture of animal feed due to the high nutritional value of the grains (LORO et al. 2021). The versatility of soybean use and the great demand for grains promotes cultivation in large scale, with high investments being used to achieve high grain yields.

However, the grain yield of a crop is the result of the interaction between genotypes x environments (LORO et al. 2022). There are several environmental factors that limit the productive performance of the soybean crop, mainly the water deficit. This is the most limiting stress for crop plant development, preventing growth and development, resulting in reduced water and nutrient uptake by plants (HAMEED et al. 2014). In addition, it impairs the photosynthetic process, disordering enzymes and nutrient transport, which promotes nutritional and hormonal imbalance in plants (SEPAHVAND et al. 2021).

Abiotic stress usually occurs in conjunction with other stresses (PIMENTEL et al. 2021). For example, water stress and disease incidence can occur simultaneously. Thus, among the strategies that make it possible to minimize the effects of these stresses associated with sustainable agriculture is the use of tolerant genotypes, since the use of fungicides can be reduced and impacts on the environment minimized (PIMENTEL et al. 2021, ZIMMERMANN et al. 2022).

Therefore, identifying soybean genotypes with tolerance to water stress and major diseases can maximize crop efficiency. In addition, it is possible to reduce the use of inputs, reduce costs and promote sustainable cultivation. In this context, the objective of this work was to verify if it is possible to select soybean genotypes tolerant to diseases and water stress.

MATERIAL AND METHODS

The experiment was conducted in the 2022/2023 harvest, at Instituto Regional de Desenvolvimento Rural - IRDeR, located in the municipality of Augusto Pestana, belonging to the Regional University of Northwest of Rio Grande do Sul, whose coordinates are: latitude 28º26'20" South and longitude 54º00'22" West, altitude 300 meters. According to the Köeppen climate classification, the climate is characterized as subtropical Cfa (ALVARES et al. 2014). The soil is classified as Typical Distroferric Red Latosol (SANTOS et al. 2018). The experimental design used was randomized blocks (RBD) with 30 soybean genotypes (Table 1), in 4 replications, totaling 120 experimental units.

Soybean genotypes were sown on November 8th, 2022. The experimental units were composed of seven sowing rows, five meters long, spaced by 0.45 meters, totaling 15.75 m^2. The sowing density was 16 seeds per linear meter. Along with it, the fertilizer formulated based on N-P_2O_5-K_2O (02-20-20) was used at a dose of 200 kg ha^{-1}. Between the phenological stages V3 and V4, topdressing fertilization took place using 200 kg ha^{-1} of potassium chloride (KCL). The phytosanitary managements took place in a preventive way (insect pests and invasive plants) to minimize the biotic effects in the experiment.

Meteorological data of mean air temperature (°C), maximum air temperature (°C), minimum air temperature (°C), rainfall (mm), relative air humidity (%) and global solar radiation (MJ m^2 day^{-1}) were obtained from the Nasa Power website. The incidence of diseases was evaluated in the useful area of each experimental unit, which was composed of the three central lines. For disease evaluation, the incidence scale from 0 to 100% was used. Therefore, the incidence of the following diseases was evaluated: Charcoal rot (*Macrophomina phaseolina*), anthracnose (*Colletotrichum truncatum*) on leaves and cotyledons, powdery mildew (*Microsphaera diffusa*), cercosporiosis (*Cercospora kikuchii*), target spot (*Corynespora cassiicola*), Asian rust (*Phakopsora pachyrhizi*), frog eye spot (*Cercospora sojina*), septoria (*Septoria glycines*). The presence or absence of nitrogen-fixing microorganisms and the percentage of stem breakage were also evaluated.

Subsequently, five plants from the three central rows of each experimental unit were randomly collected to evaluate the following variables: plant height (PH, cm), insertion height of the first pod (IFP, cm), number of pods on the main stem (NPMS), number of pods on the branch (NPB), number of branches (NB), number of pods with one grain (NP1), number of pods with two grains (NP2), number of pods with three grains (NP3), number of grains per plant (NGP), grain weight per plant (GWP, g), thousand grain weight (TGW, g), grain yield (GY, kg ha^{-1}), cercosporiosis (*Cercospora kikuchii*) in grains (%) and green grains (%).

Table 1. Qualitative characteristics of the cultivars used in the experiment.

Cultivar	FC[1]	PC	SS	TC	HP	PuC	PuD	HC	PR	GH
M5892IPRO	Purple	Light gray	Spherical	Y	Present	Gray	Average	IB	Negative	Semi Determinate
M 5947 IPRO	Purple	Light gray	Spherical	Y	Present	Gray	Average	IB	Negative	Indeterminate
M 6410 IPRO	Purple	Light gray	Spherical	Y	Present	Gray	Average	IB	Negative	Indeterminate
M 5710 I2X	Purple	Light gray	Flattened sphecal	Y	Present	Gray	Average	IB	Negative	Indeterminate
M 5737 I2X	-	-	-	-	-	-	-	-	-	-
M 6130 I2X	-	-	-	-	-	-	-	-	-	-
M 6110 I2X	-	-	-	-	-	-	-	-	-	-
M 6100 XTD	-	-	-	-	-	-	-	-	-	-
TEC 6702 IPRO	Purple	Light gray	Flattened sphecal	Y	Present	Gray	Average	LB	Positive	Indeterminate
BS 2606 IPRO	Purple	Dark gray	Flattened sphecal	Y	Present	Gray	High	IB	Negative	Indeterminate
ST 490 I2X	Purple	Dark gray	Esférica	Y	Present	Gray	Average	IB	Positive	Indeterminate
ST 580 I2X	Purple	Light gray	Flattened sphecal	Y	Present	Gray	Average	IB	Negative	Indeterminate
ST 611 I2X	Purple	Light gray	Flattened sphecal	Y	Present	Gray	Average	IB	Negative	Indeterminate
ST 621 I2X	White	Light gray	Flattened sphecal	Y	Absent	Gray	Average	LB	Negative	Indeterminate
ST 631 I2X	-	-	-	-	-	-	-	-	-	-
BMX TROVÃO I2X	White	Dark gray	Flattened sphecal	Y	Absent	Gray	Average	LB	Negative	Indeterminate
BMX TORQUE I2X	Purple	Light gray	Flattened sphecal	Y	Present	Gray	Average	IB	Negative	Indeterminate
BMX VÊNUS CE	Purple	Light gray	Flattened sphecal	Y	Present	Gray	Average	IB	Negative	Indeterminate
BMX NEXUS I2X	Purple	Light gray	Spherical	Y	Present	Gray	Average	IB	Negative	Indeterminate
TMG 22X57 I2X	-	-	-	-	-	-	-	-	-	-
TMG 2757 IPRO	Purple	Light gray	Spherical	Y	Present	Gray	-	IB	Positive	Indeterminate
TMG 19870 IPRO	-	-	-	-	-	-	-	-	-	-
TMG 2360 IPRO	White	Light gray	Spherical	Y	Absent	Gray	Average	LB	Negative	Indeterminate
TMG 7362 IPRO	White	Dark gray	Spherical	Y	Absent	Gray	High	LB	Positive	Indeterminate
FTR 158 RR	White	Dark gray	Flattened sphecal	Y	Absent	Gray	Average	LB	Positive	Indeterminate
FTR 1060 I2X	White	Light gray	Flattened sphecal	Y	Absent	Gray	Average	LB	Positive	Indeterminate
FTR 4462 I2X	Purple	Medium brown	Flattened sphecal	Y	Present	Medium brown	Average	B	Positive	Indeterminate
FTR 4664 I2X	Purple	Medium brown	Flattened sphecal	Y	Present	Medium brown	Average	B	Positive	Indeterminate
BRS 2553 XTD	Purple	Light gray	Spherical	Y	Present	Gray	Average	IB	Positive	Indeterminate
BRS 2558 XTD	Purple	Medium brown	Spherical	Y	Present	Medium brown	High	B	Negative	Indeterminate

[1]flower color (FC); pod color (PC); seed shape (SS); tegument color (TC); hypocotyl pigmentation (HP); pubescence color (PuC); pubescence density (PuD); hilum color (HC); peroxidase reaction (PR) and growth habit (GH); imperfect black (IB); light brown (LB); black (B); yellow (Y). Source: Ministry of Agriculture, Livestock and Supply, 2023.

Analysis of variance was performed at 5% probability using the F test. Variables that showed significance were compared using the Scott-Knott mean grouping test at 5% probability. Pearson's linear correlation coefficients were calculated between pairs of variables, with significance verified by the t test at 5% probability. Biplot principal component analysis was used to identify the trend of association between variables and cultivars. Euclidean distances between genotypes were calculated and the UPGMA clustering algorithm was applied to construct the genetic dissimilarity dendrogram. All analyzes were performed using the R software (R CORE TEAM 2023).

RESULTS AND DISCUSSION

The air temperature during the vegetative stage of the soybean crop ranged from 10 °C to 37 °C (Figure 1). In the reproductive stage, variations in air temperatures were again observed, ranging from 9 °C to 38 °C. In the emergence and vegetative period, the ideal air temperature is around 30 ºC and, for the reproductive period, the ideal temperatures should be around 25 ºC. The accumulated precipitation volume during the entire soybean crop cycle was 362 millimeters. During the reproductive period, only 232 millimeters were recorded, with a daily average of 2.36 millimeters of rain per day. The period of greatest humidity was observed from 110 days after emergence, a period that coincides with the reproductive period of the soybean crop. Another important factor for the culture is the radiation rate, which in the experiment was 5.99 MJ m^2.

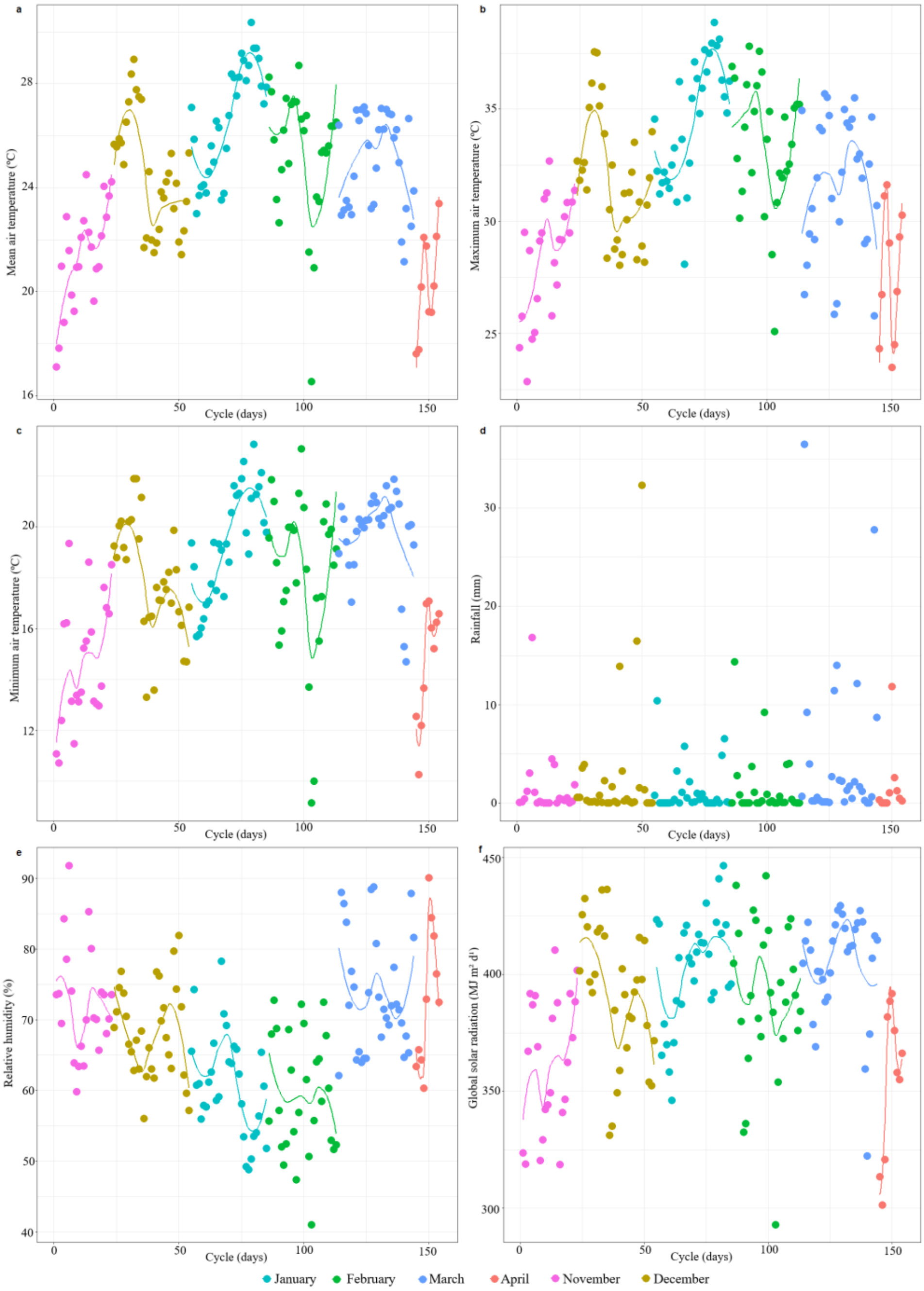

Figure 1. Climate element data of mean air temperature (a), maximum air temperature (b), minimum air temperature (c), rainfall (d) and relative humidity (e) and global solar radiation (f) during the soybean cycle, based on NASA Prediction of Worldwide Energy Resources (NASA POWER 2023).

According to the analysis of variance, significant effects of the soybean genotypes were observed for all variables (Table 2). The coefficient of variation ranged from 7.25% for the thousand grain weight to 35.03% for the grain yield. This reveals the high experimental precision and promotes reliability in the inferences made.

Table 2. Analysis of variance for 30 soybean cultivars under water stress.

FV	DF	PH[1]	IFP	NPMS	NPB	NB
Cultivars	29	94.053*	20.838*	51.950*	59.057*	1.605*
Block	3	156.061	18.621	84.354	58.256	1.960
Residue	87	19.121	8.841	12.512	26.962	0.429
Total	119	-	-	-	-	-
CV (%)	-	8.42	19.16	18.83	32.14	30.76
FV	DF	NP1	NP2	NP3	NGP	GWP
Cultivars	29	8.176*	29.829*	57.706*	124.364*	28.726*
Block	3	5.397	24.119	125.064	303.317	63.802
Residue	87	2.721	7.796	18.669	56.928	9.805
Total	119	-	-	-	-	-
CV (%)	-	26.20	28.02	31.82	27.70	29.93
FV	DF	TGW	GY	CK	GG	
Cultivars	29	2078.96*	5418573*	59.164*	568.04*	
Block	3	129.55	4042103	15.503	72.91	
Residue	87	148.38	960451	5.601	82.98	
Total	119	-	-	-	-	
CV (%)	-	7.25	35.03	30.14	32.46	

[1]PH: plant height, IFP: insertion height of the first pod, NPMS: number of pods on the main stem, NPB: number of pods on the branch, NB number of branches, NP1: number of pods with one grain, NP2: number of pods with two grains, NP3: number of pods with three grains, NGP: number of grains per plant and GWP: grain weight per plant, TGW: variable thousand grains weight, GY: grain yield, CK: *Cercospora kikuchi* on the grain and GG: green grain. *Significant at 5% probability by F test.

Cultivars that showed greater magnitude in the expression of agronomic variables were associated with reduced incidence of diseases and green grains. The TEC 6702 IPRO cultivar showed superior performance in relation to all agronomic variables analyzed, except for the number of pods containing three grains (Table 3 and 4). In addition, it exhibited the lowest values of incidence of *Cercospora kikuchi* on the grain and number of green grains. LORO et al. (2022) also revealed that it was possible to identify soybean genotypes with greater tolerance to *Cercospora kikuchi* on the grain. The authors also described that the incidence of this pathogen reduces the thousand grain weight of soybeans. BELLINASSO et al. (2021) observed that the percentage of green grains is determined by the genotype and the soil cover used.

Table 3. Mean results by Scott-Knott grouping for 30 soybean cultivars in a growing environment for the variables plant height (PH), insertion height of the first pod (IFP), number of pods on the main stem (NPMS), number of pods on the branch (NPB), number of branches (NB), number of pods with one grain (NP1) and number of pods with two grains (NP2).

Cultivars	PH	IFP	NPMS	NPB	NB	NP1	NP2
BMX NEXUS I2X	59.60a	21.40a	17.90b	10.20a	1.75a	4.45b	9.55c
BRS 2558 XTD	59.40a	16.00a	23.65a	10.00a	1.40d	2.55c	9.55c
M 6410 IPRO	57.25a	16.60a	18.75b	10.20a	2.30a	2.75c	9.70c
ST 611 I2X	56.85a	15.95a	17.05b	7.25b	1.35d	3.00c	870c
FT 1060 I2X	55.75a	15.80a	18.65b	8.60b	1.75a	6.20a	11.75b
TMG 7362 IPRO	55.50a	14.60a	20.80a	5.90b	1.50b	4.55b	11.50b
M 5947 IPRO	55.25a	17.05a	20.10b	14.60a	2.45a	2.00c	9.60c
M 6110 I2X	54.90a	13.55a	14.15b	12.95a	2.20a	2.80c	9.55c
BRS 2553 XTD	54.85a	16.20a	25.25a	2.10b	0.40e	2.20c	8.10c
M 6100 I2X	54.85a	14.60a	16.55b	13.85a	2.40a	4.25b	10.60c
BMX TROVÃO I2X	54.35a	16.50a	16.45b	7.65b	1.45b	2.85c	7.45c
TEC 6702 IPRO	54.30a	14.20a	22.70a	13.70a	1.90a	7.20a	15.80a
BS 2606 IPRO	53.40a	14.00a	25.10a	11.60a	1.75a	6.15a	13.70a
ST 621 I2X	53.30a	15.15a	21.45a	8.15b	1.70a	4.80b	11.15b
ST 580 I2X	52.95a	16.35a	18.35b	8.30b	1.30d	2.70c	9.45c
M 6130I2X	52.50a	15.05a	18.05b	5.45b	1.20d	2.65c	8.40c
BMX TORQUEI 2X	51.95a	15.00a	13.00b	10.35a	2.35a	2.95c	6.20c
TMG 2360 IPRO	51.50a	18.00a	16.45b	2.95b	0.60e	2.60c	6.15c
FT 4464 I2X	50.70b	14.05a	18.45b	6.80b	1.45d	3.55c	13.55a
FT 4462 I2X	49.95b	17.65a	18.35b	6.15b	1.70a	2.50c	13.85a
M 5710 I2X	49.95b	14.00a	18.15b	8.45b	1.90a	3.70c	9.60c
TMG 2757 IPRO	49.95b	18.60a	14.95b	3.20b	0.75e	2.20c	6.15c
TMG 19870 IPRO	49.35b	18.55a	12.75b	9.95a	2.55a	4.50b	10.00c
ST 631 I2X	48.40b	14.90a	25.75a	17.95a	2.90a	6.30a	16.50a
ST 490 I2X	48.30b	8.55a	24.80a	2.25b	0.50e	2.20c	5.65c

Cultivars	PH	IFP	NPMS	NPB	NB	NP1	NP2
BMX VENUS CE	48.00b	15.55a	17.35b	7.00b	1.85a	4.35b	9.30c
FT 158 RR	46.75c	15.55a	14.85b	8.25b	1.45c	3.80c	10.55c
M 5737 I2X	46.60d	14.75a	18.45b	3.80b	0.80e	2.80c	8.65c
TMG 22X57 I2X	46.25d	15.95a	15.30b	4.85b	0.90e	1.75c	6.95c
M 5892 IPRO	35.05e	11.45a	19.95b	8.25b	1.70a	2.80c	11.30b

Means followed by the same lowercase letter do not differ statistically by Scott Knott grouping at 5% probability.

Table 4. Mean results by the Scott-Knott grouping for 30 soybean cultivars in a growing environment for the variables number of pods with three grains (NP3), number of grains per plant (NGP), grain weight per plant (GWP), thousand grain weight (TGW), grain yield (GY), *Cercospora kikuchii* (CK) on the grain and green grain (GG).

Cultivars	NP3	NGP	GWP	TGW	GY	CK	GG
BMX NEXUS I2X	13.60b	28.10b	8.47b	140.25g	2852.74c	3.40e	11.50c
BRS 2558 XTD	21.45a	33.75a	13.32a	154.30f	2034.18c	6.80c	34.50a
M 6410 IPRO	16.50a	28.95b	12.36a	174.95c	5343.66a	4.40e	0.75c
ST 611 I2X	12.65b	24.40b	9.01b	168.40c	1594.55c	4.90c	9.25c
FT 1060 I2X	13.80b	31.55a	9.25b	141.10g	2756.07c	1.10f	2.25c
TMG 7362 IPRO	11.15b	27.20b	11.00b	189.00b	3649.98b	1.70f	13.95c
M 5947 IPRO	21.25a	33.05a	15.49a	188.20b	5718.13a	8.55c	2.60c
M 6110 I2X	14.25b	26.60b	10.10b	160.60d	3181.17c	1.95f	3.35c
BRS 2553 XTD	16.40a	27.30b	11.99a	168.95c	3192.97c	3.75e	15.15c
M 6100 I2X	16.20a	30.30a	12.85a	175.90c	2065.17c	3.65e	5.80c
BMX TROVÃO I2X	13.55b	24.35b	10.37b	182.05c	2329.22c	20.25a	42.45a
TEC 6702 IPRO	12.85b	36.80a	16.05a	215.80a	5556.07a	3.10f	2.85c
BS 2606 IPRO	16.60a	36.45a	15.33a	187.90b	3792.55b	1.40f	32.95a
ST 621 I2X	13.75b	29.65b	7.72b	136.35g	1717.17c	1.20f	4.20c
ST 580 I2X	14.15b	26.30b	12.87a	193.50b	2094.66c	2.90f	13.30c
M 6130I2X	12.35b	23.55b	11.65a	201.75a	3067.91c	3.85e	0.95c
BMX TORQUEI2X	13.70b	23.55b	9.89b	175.35c	2322.52c	3.10f	5.95c
TMG 2360 IPRO	10.50b	19.25b	7.99b	175.65c	2190.06c	3.65e	10.40c
FT 4464 I2X	8.15b	25.25b	8.27b	156.65f	2604.22c	1.95f	13.40c
FT 4462 I2X	8.30b	24.50b	7.93b	144.40g	2672.37c	0.35f	8.35c
M 5710 I2X	13.45b	26.90b	10.58b	169.60c	3308.73c	5.15c	4.90c
TMG 2757 IPRO	9.90b	18.15b	7.19b	165.30c	2232.16c	2.45f	8.40c
TMG 19870 IPRO	8.00b	22.70b	7.95b	160.65d	2298.84c	3.05f	5.65c
ST 631 I2X	21.50a	44.20a	13.65a	134.35g	2715.37c	0.85f	3.65c
ST 490I 2X	18.85a	26.90b	6.25b	109.15h	1560.00c	0.00f	41.20a
BMX VENUS CE	9.45b	23.65b	8.46b	158.75d	2414.13c	5.30c	24.05b
FT 158 RR	8.50b	23.10b	7.82b	158.05e	1818.33c	4.80d	16.25c
M 5737 I2X	10.85b	22.40b	9.60b	185.65b	896.14c	10.40b	26.10b
TMG 22X57 I2X	11.85b	20.60b	7.83b	173.10c	1894.28c	1.55f	11.00c
M 5892 IPRO	13.90b	28.05b	12.51a	194.95b	4048.52b	2.55f	2.05c

Means followed by the same lowercase letter do not differ statistically by Scott Knott grouping at 5% probability.

Therefore, the results indicate that the TEC 6702 IPRO cultivar has the potential to maximize productive performance, since it presents ideal characteristics for an agronomic ideotype and disease tolerance. The result corroborates the study conducted by PITOL (2015), who found that the TEC 6702 cultivar has high tolerance to environments with water deficit, a fact that occurred in this experiment. PIMENTEL et al. (2021) reports that the tolerance of a genotype to water stress is due to the reprogramming of gene expression, which allows development under adverse conditions.

Although the cultivars M 6410 IPRO and M 5947 IPRO showed inferiority for most of the traits of interest, they exhibited the highest grain yield, together with the cultivar TEC 6702 IPRO. This indicates that they may be promising cultivars to maximize grain yield. The cultivar BMX TROVÃO 12X, on the other hand, presented the highest mean incidence of *Cercospora kikuchi* and number of green grains. Furthermore, in most agronomic traits, this cultivar was grouped together with the lowest averages. The presence of green seeds may be related to meteorological conditions in the reproductive stage that result in the premature death of the plant (FRANÇA-NETO et al. 2012).

The grain weight (r = 0.67), number of grains per plant (r = 0.52), number of pods on the branch (r = 0.47) and number of branches (r = 0.46), in that order, present the highest magnitudes of positive correlation coefficient with grain yield (Table 5). Thus, it can be inferred that these variables determine grain yield. CARVALHO et al. (2018) showed that the greater the number of branches promotes the highest grain yield.

The number of grains showed the highest positive correlation with grain yield in a study carried out by MOURA et al. (2021) and ZIMMERMANN et al. (2022). *Macrophomina phaseolina* was the only disease that showed a negative correlation with grain yield. This indicates that this disease is decisive for reducing the productive performance of soybeans. The number of green grains was also negatively correlated with grain yield.

Table 5. Estimates of Pearson's linear correlation for 26 variables of agronomic interest measured in 30 soybean cultivars in a growing environment.

	GY	CE	LR	AN	PM	FS	SB	AC	NP4	TS	NPB	NB	NP1	NP2	PH	NPMS	NP3	NGP	GWP	IFP	NO	SE	BB	MP	CK	GG
TGW	0.41	0.27	0.20	0.40	0.29	0.25	0.16	-0.11	0.00	0.05	0.12	0.07	0.10	0.07	-0.04	-0.04	-0.01	0.05	0.48	-0.03	-0.05	0.08	0.10	0.12	0.30	-0.13
GY		0.38	0.26	0.36	0.25	0.38	-0.12	-0.05	-0.01	0.01	0.47	0.46	0.27	0.44	0.24	0.38	0.42	0.52	0.67	-0.09	-0.01	0.00	0.09	-0.31	-0.03	-0.23
CE			0.50	0.60	0.38	0.30	-0.03	-0.05	-0.14	0.20	0.08	-0.01	0.24	0.23	-0.13	0.30	0.09	0.22	0.26	-0.28	-0.29	-0.29	-0.20	-0.33	-0.17	-0.03
LR				0.75	0.74	0.67	-0.15	0.00	-0.02	0.01	0.02	0.03	-0.10	-0.08	-0.32	0.02	0.08	0.00	0.11	-0.10	0.14	-0.08	0.28	-0.19	-0.04	-0.14
AN					0.84	0.76	0.04	0.01	-0.05	-0.12	0.09	0.09	0.00	0.10	-0.30	0.10	0.10	0.10	0.27	-0.22	0.06	-0.32	-0.01	-0.13	-0.02	-0.29
PM						0.85	-0.16	-0.04	-0.09	-0.16	0.02	0.04	-0.14	0.04	-0.46	0.05	0.07	0.03	0.17	-0.19	0.23	-0.17	0.22	0.02	0.05	-0.17
FS							-0.15	0.05	-0.11	-0.23	0.14	0.14	-0.15	0.04	-0.28	0.07	0.19	0.10	0.24	-0.10	0.20	-0.24	0.25	-0.10	0.10	-0.19
SB								0.19	-0.10	-0.07	-0.10	0.00	0.06	0.00	0.21	-0.02	-0.03	-0.02	0.03	-0.02	-0.48	-0.20	-0.23	0.07	-0.11	-0.04
AC									-0.09	-0.33	0.10	0.01	0.06	0.03	-0.10	0.06	0.10	0.09	0.02	-0.13	-0.11	-0.01	0.03	-0.02	-0.09	0.01
NP4										0.13	0.02	-0.07	0.04	-0.06	0.05	0.13	0.15	0.09	0.12	-0.05	0.02	-0.06	-0.16	-0.01	0.08	0.02
TS											-0.30	-0.37	-0.04	-0.03	-0.09	0.14	-0.14	-0.11	-0.08	0.03	-0.18	0.30	0.11	-0.25	-0.33	0.08
NPB												0.85	0.62	0.66	0.27	0.35	0.66	0.83	0.75	-0.13	-0.01	-0.11	-0.02	-0.05	0.00	-0.15
NB													0.46	0.57	0.26	0.19	0.53	0.67	0.60	-0.09	0.12	-0.08	0.00	-0.10	-0.04	-0.26
NP1														0.67	0.15	0.39	0.25	0.65	0.47	-0.16	-0.17	-0.21	-0.24	-0.09	-0.12	-0.07
NP2															0.12	0.57	0.36	0.78	0.62	-0.23	-0.19	-0.27	-0.23	-0.10	-0.19	-0.13
PH																0.27	0.38	0.32	0.32	0.24	-0.10	0.00	-0.16	-0.13	0.01	0.00
NPMS																	0.72	0.78	0.65	-0.38	-0.33	-0.32	-0.33	-0.12	-0.15	0.21
NP3																		0.83	0.77	-0.32	-0.11	-0.14	-0.10	-0.04	-0.01	0.12
NGP																			0.85	-0.33	-0.18	-0.25	-0.22	-0.10	-0.10	0.00
GWP																				-0.27	-0.16	-0.17	-0.12	-0.03	0.08	-0.01
IFP																					0.17	0.17	0.18	-0.05	0.14	-0.16
NO																						0.24	0.28	0.01	0.27	-0.11
SE																							0.79	0.13	-0.05	-0.09
BB																								0.22	-0.08	-0.18
MP																									0.15	0.09
CK																										0.34

GG: green grain, CK: *Cercospora kikuchi* on the grain, MP: *Macrophomina phaseolina*, BB: bacterial blight, SE: septoria, NO: nodulation, IFP: insertion height of the first pod, GW: grain weight, NGP: number of grains per plant, NPMS: number of pods on the main stem, PH: plant height, NP1: number of pods with one seed, NP2: number of pods with two grains, NP3: number of pods with three grains, NP4: number of pods with four grains, NB: number of branches, NPB : number of pods on the branch, TS: target spot, AC: anthracnose on cotyledon, SB: stem breakage, FS: frogeye spot, PM: powdery mildew, AN: anthracnose, LR: leaf rust, CE: cercosporiosis and GY: grain yield. Correlation coefficients ≥ 0.18 and ≤ -0.18 are significant at 5% significance by Student's t test.

The first two principal components explained 38.64% of the total data variability (Figure 2). The main relationships observed between cultivars and variables were between the incidence of diseases. The cultivar M5892IPRO showed higher magnitudes of incidence of anthracnose (AN), frogeye spot (FS), powdery mildew (PM) and leaf rust (LR). This indicates the greater susceptibility of the cultivar for tolerance to the main soybean diseases. However, TMG22X57I2X showed the lowest magnitudes of incidence of these diseases, but with a high incidence of bacterial blight (BB), septoria (SE), brown spot (BS), target spot (TS) and *Cercospora kikuchii* (CK) on the grain. These results highlight the importance of proper selection of soybean cultivars based on the specific growing conditions and phytosanitary challenges present in the region.

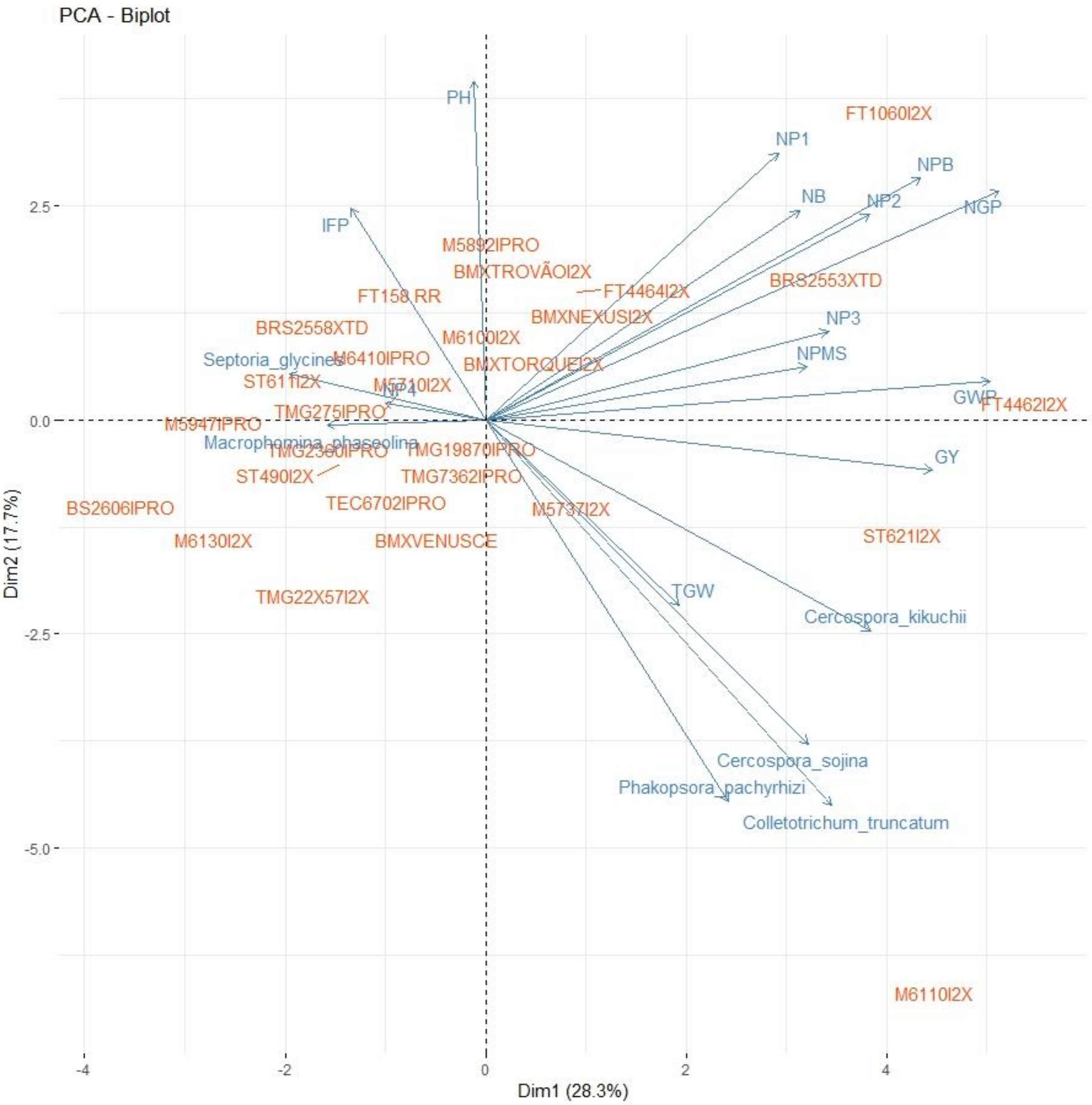

Figure 2. Biplot analysis showing the interactions of the 30 soybean cultivars with the analyzed variables. MP: *Macrophomina phaseolina*, BB: bacterial blight, SE: septoria, NO: nodulation, AC: anthracnose on cotyledon, SB: stem breakage, FS: frogeye spot, PM: powdery mildew, AN: anthracnose, LR: leaf rust , CE: cercosporiosis, PH: plant height, IFP: insertion height of first pod, NPMS: number of pods on the main stem, NPB: number of pods on the branch, NB number of branches, NP1: number of pods with one grain and NP2 : number of pods with two grains, NP3: number of pods with three grains, NGP: number of grains per plant, GWP: grains weight per plant, TGW: thousand grain weight, GY: grain yield, GG: green grain and CK: *Cercospora kikuchi* on the grain, for 30 soybean cultivars.

Studies performed by MOURA et al. (2021) indicate that the more distinct the genotype groups, the greater the degree of dissimilarity, which can be used in selections for hybridizations. In this case, the cultivars were grouped based on similarities of qualitative and quantitative traits (Figure 3). According to the results obtained in the dendrogram of genetic dissimilarity for the 30 soybean cultivars, the formation of two large distinct groups stood out.

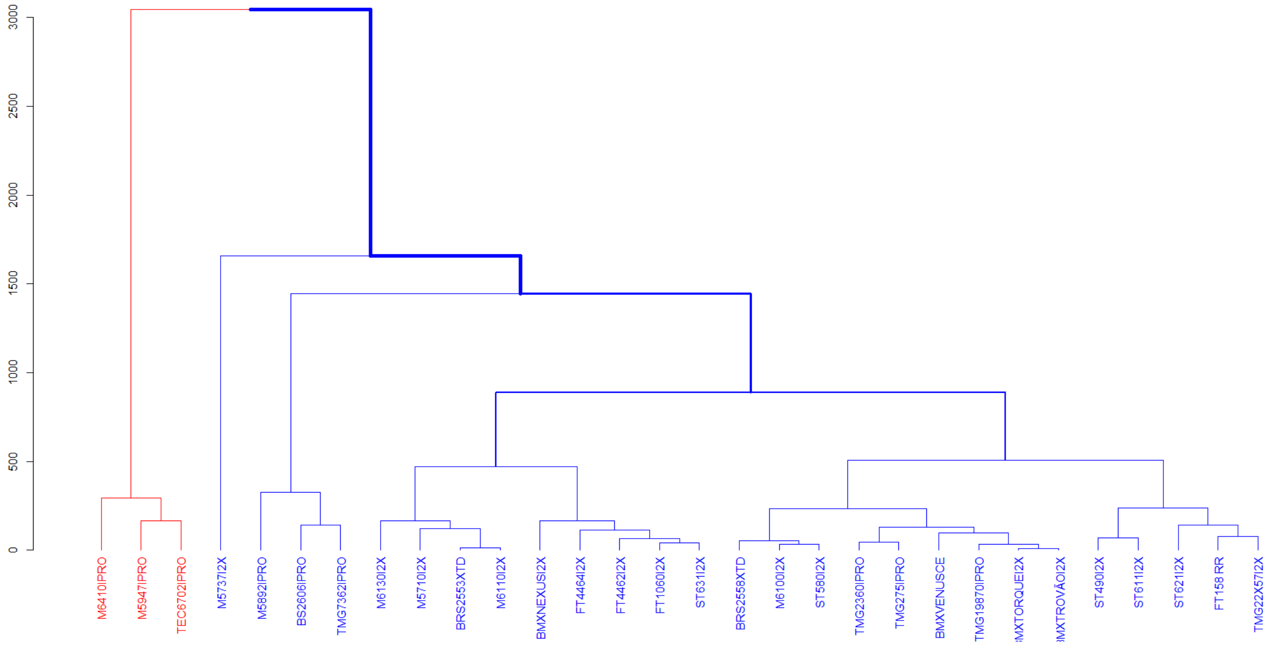

Figure 3. Cluster dendrogram, obtained by the hierarchical mean link between group method (UPGMA), using the Euclidean distance as a measure of dissimilarity for cultivars BMX NEXUS I2X, BRS 2558 XTD, M 6410 IPRO, ST 611 I2X, FT 1060 I2X, TMG 7362 IPRO, M5947 IPRO, M 6110 I2X, BRS 2553 XTD, M 6100 I2X, BMX TROVÃO I2X, TEC 6702 IPRO, BS 2606 IPRO, ST 621 I2X, ST 580 I2X, M 6130 I2X, BMX TORQUE I2X, TMG 2360 IPRO, FT 4464 I2X, FT 4462 I2X, M 5710 I2X, TMG 2757 IPRO, TMG 19870 IPRO, ST 631 I2X, ST 490 I2X, BMX VÊNUS CE, FT 158 RR, M 5737 I2X, TMG 22X57 I2X and M 5892 IPRO.

Large group I was formed by the cultivars M 6410 IPRO, M 5947 IPRO and TEC 6702 IPRO, which showed higher magnitudes of agronomic traits and lower incidence of diseases. They also showed similar qualitative characteristics such as purple flower, light gray pod, yellow tegument, present hypocotyl pigmentation, gray pubescence, average pubescence density and indeterminate growth habit. Within the large group II, nine distinct subgroups were formed, formed by the other evaluated cultivars.

Therefore, it can be inferred that there is genetic diversity among the cultivars evaluated for agronomic traits, qualitative traits and disease response. This indicates that the cultivars can be used as parents for the development and selection of superior soybean lines. Therefore, it was possible to identify cultivars with superior agronomic performance and positive response to disease tolerance. In addition, it was possible to identify characters that can be used for indirect selection of grain yield. On the other hand, *Macrophomina phaseolina* and the number of green grains reduce grain yield. Therefore, the results highlight the importance of environmental conditions, adequate selection of cultivars and disease management to obtain an ideal productive performance in the soybean crop. The genetic diversity among the evaluated cultivars also suggests the possibility of using them as parents for the development of superior soybean lines.

CONCLUSION

The TEC 6702 IPRO, M 5947 IPRO, M 6410 IPRO cultivars have greater productive potential in environments with water deficit.

Cultivar TEC 6702 IPRO expresses better agronomic performance for morphological characteristics and tolerance to diseases, such as *Cercospora kikuchii* in grains, anthracnose in cotyledons and powdery mildew.

There is genetic diversity among soybean cultivars for agronomic, qualitative and disease response traits.

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