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Proposal for soybean genotype selection based on the agronomic and environmental resilience index

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Abstract – The objective of this work was to propose a selection index based on the agronomic and environmental resilience of soybean. The experiment was carried out at the research farm of Universidade Regional do Noroeste do Estado do Rio Grande do Sul. The user experimental design was that of augmented blocks with interspersed controls, arranged in three replicates. The regular treatments corresponded to 89 F_8 lineages (99.218% homozygosity), and the common treatments were represented by four commercial controls (BRS 284, BMX Valente 6968 RSF RR, BMX Raio 50I52 RSF IPRO, and M 5710 I2X45). The following agronomic variables were measured based on five plants per experimental unit: number of seeds per plant and seed weight per plant. The agronomic and environmental resilience index (GSIRΔ) was proposed in order to combine the attributes of seed number and weight with meteorological data. Selection based on the GSIRΔ allows selecting 13 lineages (122F_8, 176F_8, 165F_8, 232F_8, 109F_8, 99F_8, 166F_8, 93F_8, 154F_8, 85F_8, 121F_8, 152F_8 and 169F_8) with a high agronomic potential for productivity and resilience to abiotic stresses, such as high temperatures and low precipitation volumes.

Index terms: genetic breeding, meteorological factors, progeny testing, selection index.

Proposta de seleção de genótipos de soja baseada no índice de resiliência agronômica e ambiental

Resumo – O objetivo deste trabalho foi propor um índice de seleção baseado na resiliência agronômica e ambiental da soja. O experimento foi realizado na Escola Fazenda da Universidade Regional do Noroeste do Estado do Rio Grande do Sul. O delineamento utilizado foi o de blocos aumentados com testemunhas intercaladas, dispostas em três repetições. Os tratamentos regulares corresponderam a 89 linhagens F_8 (99,218% de homozigose), e os tratamentos comuns foram representados por quatro testemunhas comerciais (BRS 284, BMX Valente 6968 RSF RR, BMX Raio 50I52 RSF IPRO e M 5710 I2X45). As seguintes variáveis agronômicas foram mensuradas com base em cinco plantas por unidade experimental: número de sementes por planta e peso de sementes por planta. O índice de resiliência agronômica e ambiental (GSIRΔ) foi proposto com o objetivo de combinar os atributos de número e peso de sementes com dados meteorológicos. A seleção baseada no GSIRΔ permite selecionar 13 linhagens (122F_8, 176F_8, 165F_8, 232F_8, 109F_8, 99F_8, 166F_8, 93F_8, 154F_8, 85F_8, 121F_8, 152F_8 e 169F_8) com alto potencial agronômico

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para produtividade e resiliência a estresses abióticos, como altas temperaturas e baixos volumes de precipitação.

Termos para indexação: melhoramento genético, fatores meteorológicos, testes de progênie, índice de seleção.

Introduction

Soybean [*Glycine max* (L.) Merr.] is considered one of the main agricultural commodities because it is the most widely cultivated oilseed in the world, being an important part of people's diet and a raw material for the industry (Ferreira et al., 2021). Ferreira et al. (2022) highlighted that the crop has grown in the last three decades, projecting a favorable scenario for producers and investors. The increase of productive potential of soybean genotypes is challenging. One of those challenges is a result of the impact of climate change, with temperature change in some farming areas and water restrictions due to the lack of rain in specific periods (Wang et al., 2023; Thomasz et al., 2024).

Considering this scenario, genetic breeding programs face the challenge of developing genotypes with high production potential, high resilience, and capable of broad adaptation to the environmental changes (Pradebon et al., 2023). Carvalho et al. (2021) stated that selecting superior and promising genotypes is an arduous process since important characteristics, such as number of seeds per plant and seed weight per plant, have low heritability. Low heritability happens because these characteristics are controlled by many genes that are greatly affected by the environment.

In the search for promising genotypes, different methodologies are used, such as genetic parameter analyses, genetic and phenotypic correlations, selection gains, and the use of selection indices (Vasconcelos et al., 2012). The latter is an alternative that allows grouping independent variables that, together, improve selection strategies (Cruz et al., 2020). According to Bizari et al. (2017), due to their speed and efficiency, the selection indices are more successful in selecting genotypes.

Several indices assist in selecting genotypes for stress conditions, such as the strategies proposed by Ghazvini et al. (2024) for selection of barley progenies, or the indices mentioned by Alves et al. (2021) and Farias et al. (2024) to determine the sensitivity of soybeans to water deficit. However, most of these indices depend on a large number of covariates, do not completely associate agronomic characteristics with meteorological variables, and do not consider meteorological variables.

The objective of this work was to propose a selection index based on the agronomic and environmental resilience of soybean.

Materials and Methods

The study was carried out at the research farm of Universidade Regional do Noroeste do Estado do Rio Grande do Sul, located in the municipality of Augusto Pestana, in the state of Rio Grande do Sul, Brazil (28°26'25"S, 54°00'07"W). The soil was classified as a Latossolo Vermelho distroférrico típico, according to the Brazilian Soil Classification System (Santos et al., 2018), i.e., Oxisol. The climate is characterized as Cfa according to Köppen's classification.

The experimental design used was augmented blocks with interspersed controls, with three replicates, totaling 101 experimental units. The regular treatments corresponded to 89 F_8 lineages (99.218% homozygosity), and the common treatments were represented by four commercial controls (BRS 284, BMX Valente 6968 RSF RR, BMX Raio 50I52 RSF IPRO, and M 5710 I2X).

The experimental units consisted of two sowing rows, each one 5.0 m long, spaced 0.45 m apart, representing a total area of 4.5 m^2. Sowing was performed in the first half of December 2021, with a density of 14 seeds per linear meter. Base fertilization consisted of 300 kg ha^{-1} of organic mineral fertilizer with the NPK 05-20-20 formulation. In order to minimize biotic effects on the results of the experiment, phytosanitary management was carried out preventively.

Agronomic data were collected by harvesting all plants in each experimental unit. In order to determine the number of seeds per plant (NSP), plants were collected individually, and the number of seeds was counted. In order to determine the seed weight per plant (SWP, g), the seeds of a plant were crushed, weighed on a digital scale, and the moisture content was corrected to 13%.

The meteorological station at the research farm of Universidade Regional do Noroeste do Estado do Rio Grande do Sul provided data related to air temperature and precipitation (Prec, in mm). Air temperature data were mean temperature (Tmean, in °C), minimum temperature (Tmin, in °C), and maximum temperature (Tmax, in °C). The optimal meteorological conditions for each phenological stage of soybean development were obtained in previous studies (Cunha & Bergamaschi, 1992; Carvalho et al., 2013; Silva et al., 2013; Tecnologias…, 2013; Ferrari et al., 2015; Neumaier et al., 2020; Cunha et al., 2021). The estimated optimal air temperatures were 22ºC, with upper basal of 40ºC and lower basal of 10ºC. The estimated optimal precipitation was 1.0 mm per day^{-1} from germination (G) to first expanded leaflet (V1), 5.0 mm per day along the vegetative period, and up to 8.0 mm per day in the reproductive period.

The assumptions of homoscedasticity, normality of errors, and independence of errors were checked by using Breusch-Pagan, Shapiro Wilk, and Bartlett's tests, respectively. All assumptions were met. NSP and SWP data were subjected to deviance analysis at 5% probability by using chi-square (χ^2). Restricted maximum likelihood (REML) was used to estimate the variance components and genetic parameters: genotypic variance (σ^2G), residual variance (σ^2E), phenotypic variance (σ^2P), and broad-sense heritability (H^2g). These parameters were used to estimate the best linear unbiased predictors (BLUPs), allowing the tested genotypes to be ranked.

The genetic selection index for resilience (GSIRΔ) is based on the estimated BLUPs of each genotype and daily meteorological data. The index is expressed mathematically as follows (Equation 1):

$$\mathrm{GSIR\Delta}\left[\left(\frac{\mathrm{NSC-NSL}}{\mathrm{SNS}}\right)\mathrm{X}\left(\frac{\mathrm{SWC-SWL}}{\mathrm{SSW}}\right)\mathrm{X}\left(\frac{\mathrm{PREC-RPREC}}{\mathrm{SPREC}}\right)\mathrm{X}\left(\frac{\mathrm{TEMP-RTEMP}}{\mathrm{STMED}}\right)\right] \quad (1)$$

where: GSIRΔ is the agronomic and environmental resilience index; NSC is the prediction of the number of seeds from commercial controls, NSL is the prediction of the number of seeds of each lineage, SNS is the sample standard deviation of the prediction for the variable number of seeds per plant, SWC is the prediction of seed weight of commercial controls, SWL is the prediction of seed weight for each lineage, SSW is the sample standard deviation of the prediction for the variable seed weight per plant, PREC is the ideal precipitation for the crop, equivalent to 650 mm (Carvalho et al., 2013), RPREC is the real precipitation occurred during the lineage cycle, SPREC is the sample standard deviation of real precipitation, TEMP is the ideal mean air temperature for crops, equivalent to 25ºC (Neumaier et al., 2020), RTEMP is the real mean air temperature occurred during the lineage cycle, and STMED is the sample standard deviation of the variable mean air temperature.

Each variable in Equation 1 was weighted by the respective standard deviation in order to turn the variable into a dimensionless parameter. The desired value of the parameter was deducted from the value of the control of the respective agronomic characteristics or, in the case of meteorological data, from values previously cited in other studies. The soybean cycle was used as a covariate to determine the requirements for total precipitation and mean air temperature of each genotype. In years when water restriction was overly pronounced, total precipitation and mean air temperature were used. However, it is suggested that in case of few occurrences of water restriction, only the values from the stress period should be used to calculate the index. The stratified precipitation at each phenological stage was measured by the meteorological station (Figure 1 A), the water requirement of the crop was obtained in literature (Figure 1 B), and the water deficit during the soybean cycle was estimated (Figure 1 C).

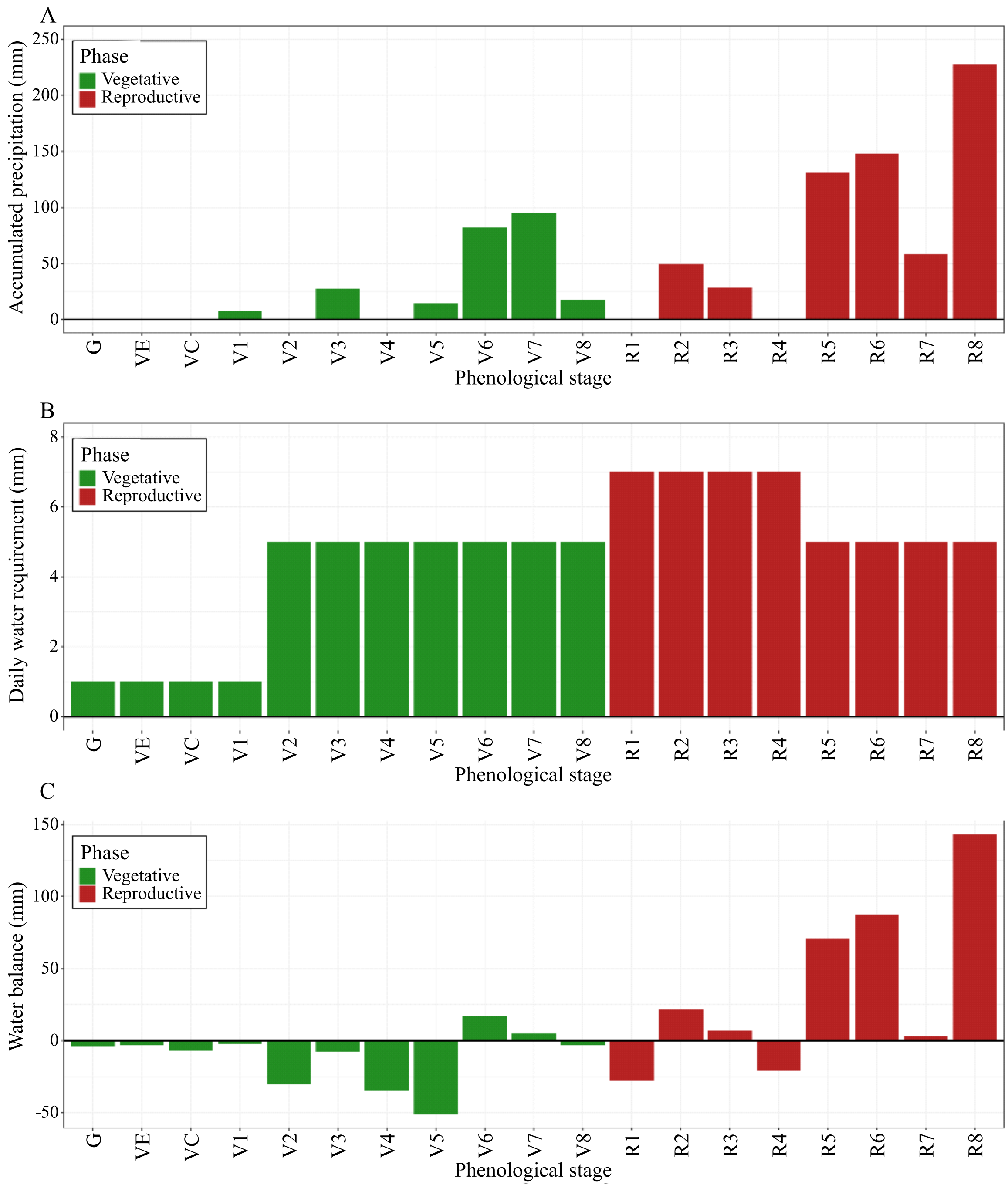

Figure 1. Data of (A) precipitation in the experimental area; (B) ideal daily water requirements[(1)] of soybean; and (C) estimated water balance (A-B), stratified by phenological stages[(2)] of the soybean life cycle. [(1)]Source: Cunha & Bergamaschi (1992), Carvalho et al. (2013), and Cunha et al. (2021). [(2)]G, germination; VE, emergence; VC, vegetative cotyledon; Vx, vegetative stage x; and Ry, reproductive stage y.

The R software (R Core Team, 2023) was used in all statistical analyzes. The packages ExpDes.pt (Ferreira et al., 2021), metan (Olivoto & Lúcio, 2020), and ggplot2 (Wickham, 2016) were installed.

Results and Discussion

In order to use GSIRΔ, it is necessary to know the water requirements, optimal temperature, and basal temperature of soybean.

The estimated demand of water for the complete cycle of soybean is 450 to 800 mm (Tecnologias…, 2013). In the present study, the accumulated water was 884 mm. Given this criterion, there was enough water for full development of the crop. However, the frequency, the distribution, and the phenological stages of soybeans must be considered.

During the vegetative phase, the water requirements (Figure 1 B) of 1.0 mm per day of water are expected in the stages of germination (G), emergence (VE), vegetative cotyledon (VC), and one expanded leaflet (V1). In subsequent stages, water requirement increases to 5.0 mm per day, as the soybean expands its leaf area and plant structure. Observing Figure 1 A, there was an absence of precipitation in stages V2 and V4, while in V5, V6, and V7, precipitation was close to the expected amount needed for full development of the crop. There was water deficit from G to V5, and in V8 (Figure 1 C). A lack of water harms plant growth, as it minimizes photosynthetic activity due to stomatal closure, consequently decreasing CO_2 assimilation (Bianchi et al., 2016). According to Carmello (2011), initial establishment depends directly on a satisfactory water supply.

During the reproductive phase, there is an increase in water requirements, mainly due to the differentiation of meristems and production of flowers. Maximum requirements are from R4 to R6, when the formation of the legume and grains takes place, and there is an increase in grain weight. The daily water requirement increases to 8.0 mm per day until physiological maturity, after which the water requirement decreases (Ferrari et al., 2015). No precipitation occurred in stages R1 and R4 (Figure 1 A), which resulted in severe stress on plants in the field (Figure 1 C). Water deficit causes physiological changes in the plant, including premature abscission of leaves and flowers (Barbosa et al., 2020). This set of actions culminates in the loss of soybean's productive potential. Regularity of the water supply due to precipitation was observed in stages R2, R3, R5, R6, and R8 (Figure 1 A). In these stages, precipitation was accumulated above the optimal amount for the crop (Figure 1C), a fact that was beneficial for the study results.

For soybean, the upper base temperature is 40°C, and the ideal maximum temperature is 30°C (Neumaier et al., 2020). During the vegetative period, soybean was submitted to temperatures between 30 and 40ºC, causing thermal stress in the plant (Figure 2). On the other hand, during the reproductive period, soybean was exposed to maximum temperature below 30°C, which is beneficial for phenological events and differentiations. This was a consequence of precipitation in the period, which improved the growing environment conditions.

For soybean, the lower base temperature is 10°C, and ideal minimum temperature is 20°C (Neumaier et al., 2020). In the present study, temperatures below 10°C were not observed. However, for some lineages with cycles longer than 125 days, a decrease in the minimum temperature was observed during the period of physiological maturity and field maturation, at the end of the crop cycle (Figure 2). When considering the mean temperature, more than 80% of the soybean cycle was in the range of 20 to 30ºC, a suitable condition for the crop.

Table 1 shows the estimates of variance components and genetic parameters. The estimates and ratios of genotypic variance (σ^2G) and phenotypic variance (σ^2P) provided an understanding of the magnitude of genetic variability. Broad sense heritability (H^2g) estimated for NSP and WSP were 0.25 and 0.24, respectively. These values express a low genetic variability for the attributes measured, which is expected due to the segregating generation of soybean lineages. This parameter is crucial for future predictions.

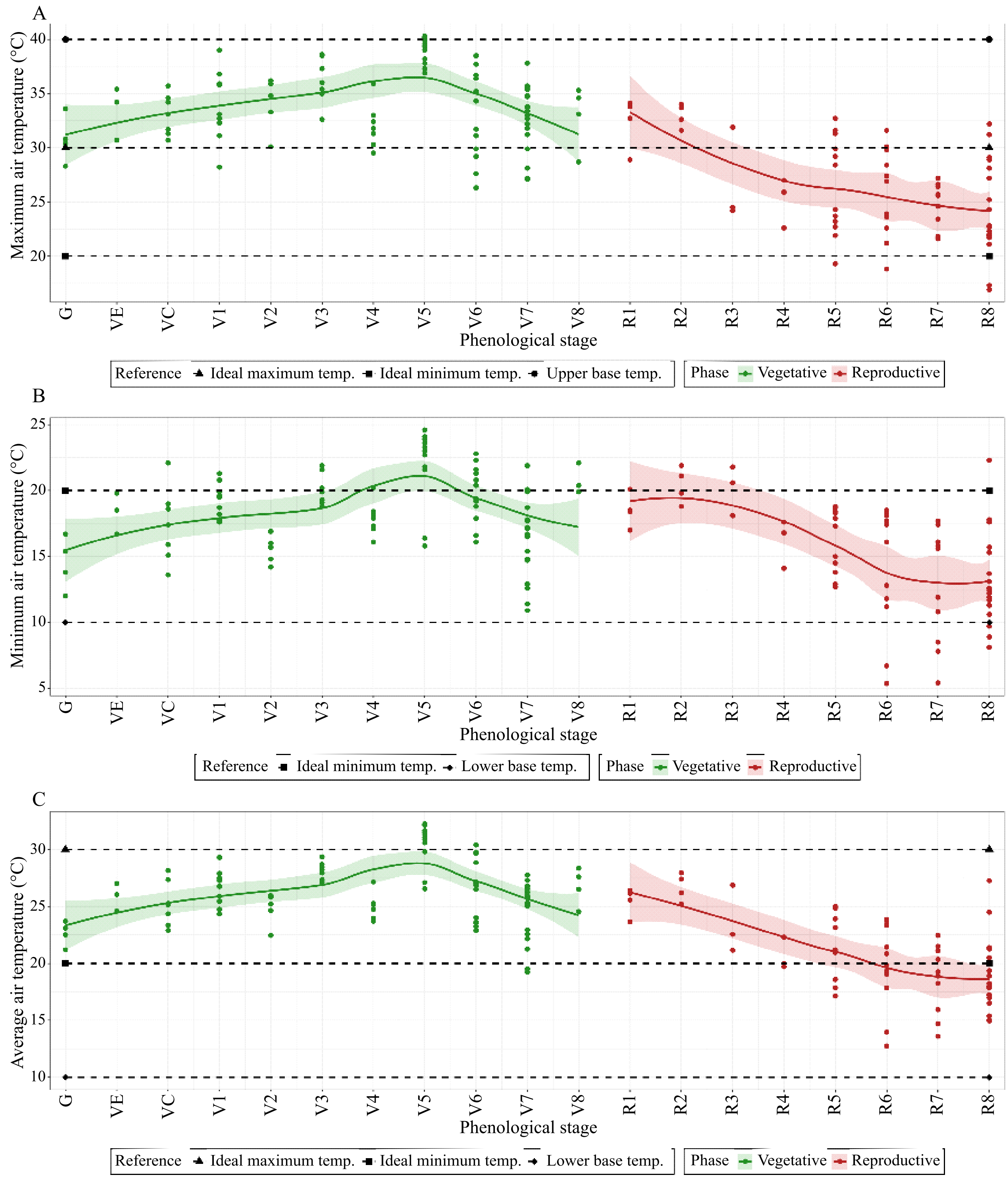

Figure 2. Data of the meteorological station of (A) maximum temperature; (B) minimum temperature; and (C) mean temperature of the air, during the soybean life cycle[(1)] in the experimental site. [(1)]G, germination; VE, emergence; VC, vegetative cotyledon; Vx, vegetative stage x; and Ry, reproductive stage y.

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Entringer et al. (2014) stated that selection success is directly proportional to the magnitude of heritability, but closely related to the target generation, number of lineages, and control of residual variability. By using several models for estimating genetic parameters, Carvalho et al. (2023) found a restricted-sense heritability for SWP of 0.16, revealing difficulty in obtaining genetic variability and an additive effect for this variable.

The estimated mean of the BLUP components for NSP is shown in Table 2. The results reveal that 33 of the lineages obtained a pure genetic gain (g) superior to that of the controls M 5710 I2X, BMX Raio 50I52 RSF IPRO, BMX Valente 6968 RSF RR, and BRS 284 (Table 2). High genetic gains can be obtained by selecting the $122F_8$, resulting in a gain of 91.046 seeds per plant, allowing the next generation to obtain plants with an average of 155.2 seeds. Borges et al. (2010) state that the use of BLUP predictions allows understanding and selecting promising genotypes through information that reveals the true genetic value, and minimizes distortions in estimates due to environmental effects.

The estimated mean of the BLUP components for SWP is presented in Table 3. The results show that 34 of the lineages expressed a pure genetic gain (g) higher than that of the commercial controls, meaning that there is a possibility of selecting genotypes with high productive potential. The best lineage was $122F_8$, which showed an increase of 12.999 g in SWP, resulting in a genotype with a potential yield of 24.887 g per plant in the next generation. The "new mean" predicted by BLUP will be close to the magnitude that the trait will obtain in the next cultivation. However, if the estimate of pure genetic + additive genetic gain (g + u) is close to the "new mean", there is a high probability that this prediction will be consistent (Borges et al., 2010). The predictions of total gains (g + u) were close to the "new mean", which characterizes them as correct and reliable.

The GSIRΔ index was developed with the aim of supporting the selection of resilient genotypes. It was developed through the prediction of the NSP and SWP characters, relating them to ideal climatic factors (precipitation and temperature) for soybeans. The lower the GSIRΔ index, the more resilient the genotypes. Subtracting the predicted values from the constants in the equation causes the values to tend towards zero. On the other hand, a high GSIRΔ index indicates that the environment is highly demanding for full genotypic expression. Cruz et al. (2014) created a similar index in their study, in order to find superior genotypes and environments that are favorable or unfavorable to the character of interest.

Table 4 shows the lineages and their respective values obtained by using GSIRΔ. The estimated mean value to be reached was 0.09, calculated from the individual mean values of all lineages in the study. The selected lineages were $122F_8$, $176F_8$, $165F_8$, $232F_8$, $109F_8$, $99F_8$, $166F_8$, $93F_8$, $154F_8$, $85F_8$, $121F_8$, $152F_8$ and $169F_8$. These genotypes showed high productive potential even in unsuitable climatic conditions. For the traits NSP and SWP, the $122F_8$ genotype stands out, but it requires a highly controlled environment to express its potential, since it presented the highest GSIRΔ.

The estimated heritability for the studied characters was $H^2 = 0.25$ and $H^2 = 0.24$ for NSP and SWP, respectively, meaningt they have a complex inheritance, in addition to being highly influenced by the environment. Among 89 lineages, 37.08% were better than commercial controls for NSP, and 38.20% for SWP. When GSIRΔ was used as a selection tool of lineages focusing on resilience, only 14.61% of them were selected.

Table 1. Estimates of variance components and broad-sense heritability for number of seeds per plant (NSP) and seed weight per plant (SWP) for F_8 soybean (*Glycine max*) lineages.

Estimates	NSP	SWP (g)	Estimates	NSP	SWP (g)
Genotypic variance (σ^2G)	690.15	19.95	Phenotypic variance (σ^2P)	2,811.29	84.92
Residual variance (σ^2E)	1,453.34	44.46	Heritability (H^2g)	0.25	0.24

Table 2. Results of BLUP as pure genetic gain (g), pure genetic gain and additive genetic merit (g + u), expected genetic gain after selection (gain), and expected population mean after selection (new mean) for the trait number of seeds per plant (NSP) in F_8 soybean (*Glycine max*) lineages, classified in decreasing order of "new mean".

Lineage[1]	g	g + u	Gain	New mean	Lineage	g	g + u	Gain	New mean
122F_8	91.046	155.197	91.046	155.197	135F_8	-3.283	60.868	10.649	74.799
176F_8	48.768	112.919	69.907	134.057	116F_8	-3.942	60.208	10.354	74.502
165F_8	47.278	111.429	62.364	126.515	158F_8	-4.159	59.991	10.061	74.212
232F_8	39.392	103.542	56.621	120.772	124F_8	-4.773	59.378	9.771	73.921
109F_8	30.145	94.295	51.326	115.476	130F_8	-5.035	59.115	9.486	73.636
166F_8	23.531	87.682	46.693	110.844	170F_8	-5.298	58.852	9.207	73.357
99F_8	23.135	87.285	43.328	107.478	118F_8	-5.695	58.456	8.931	73.081
93F_8	22.097	86.247	40.674	104.825	136F_8	-5.824	58.326	8.663	72.813
169F_8	19.062	83.213	38.273	102.423	81F_8	-6.470	57.680	8.392	72.543
121F_8	17.702	81.852	36.216	100.366	111F_8	-6.746	57.404	8.127	72.277
154F_8	17.222	81.373	34.489	98.639	164F_8	-6.876	57.275	7.868	72.018
85F_8	15.963	80.113	32.945	97.096	231F_8	-7.401	56.749	7.609	71.760
152F_8	14.506	78.656	31.527	95.677	153F_8	-8.015	56.136	7.349	71.499
159F_8	14.067	78.218	30.279	94.43	147F_8	-8.102	56.048	7.097	71.246
97F_8	11.318	75.469	29.015	93.166	146F_8	-8.19	55.961	6.849	70.999
134F_8	11.088	75.239	27.895	92.046	107F_8	-8.324	55.827	6.608	70.759
233F_8	10.387	74.538	26.865	91.016	105F_8	-9.025	55.126	6.364	70.514
77F_8	10.092	74.242	25.933	90.084	98F_8	-9.463	54.688	6.120	70.271
79F_8	8.689	72.84	25.026	89.176	125F_8	-9.679	54.471	5.881	70.032
127F_8	8.635	72.785	24.206	88.357	123F_8	-10.293	53.857	5.639	69.790
226F_8	7.495	71.646	23.410	87.561	172F_8	-10.819	53.332	5.397	69.548
110F_8	6.047	70.198	22.621	86.772	140F_8	-10.907	53.244	5.161	69.312
92F_8	5.535	69.685	21.878	86.029	148F_8	-10.994	53.156	4.931	69.081
157F_8	5.217	69.368	21.184	85.335	106F_8	-11.04	53.110	4.706	68.856
143F_8	4.867	69.017	20.531	84.682	86F_8	-11.64	52.510	4.478	68.629
76F_8	4.221	68.371	19.904	84.055	133F_8	-11.695	52.455	4.257	68.408
94F_8	3.169	67.319	19.284	83.435	139F_8	-11.87	52.280	4.039	68.189
91F_8	2.994	67.144	18.702	82.853	171F_8	-12.046	52.105	3.825	67.975
234F_8	2.588	66.739	18.147	82.297	744F_8	-12.778	51.372	3.606	67.757
228F_8	2.062	66.213	17.611	81.761	82F_8	-12.867	51.284	3.392	67.543
227F_8	1.799	65.95	17.101	81.251	83F_8	-13.042	51.108	3.184	67.332
80F_8	0.540	64.691	16.583	80.734	744F_8	-13.064	51.086	2.976	67.126
104F_8	0.176	64.327	16.086	80.236	112F_8	-13.844	50.306	2.766	66.916
M5710I2X	0	64.151	15.613	79.763	236F_8	-14.587	49.564	2.551	66.702
RAIO	0	64.151	15.167	79.317	142F_8	-14.762	49.388	2.340	66.491
VALENTE	0	64.151	14.745	78.896	137F_8	-14.85	49.301	2.133	66.284
BRS 284	0	64.151	14.347	78.497	141F_8	-14.937	49.213	1.930	66.080
238F_8	-0.041	64.109	13.968	78.119	175F_8	-15.814	48.337	1.721	65.872
88F_8	-0.336	63.814	13.601	77.752	101F_8	-16.035	48.116	1.515	65.665
113F_8	-0.525	63.623	13.248	77.399	103F_8	-16.123	48.028	1.312	65.463
151F_8	-1.268	62.883	12.894	77.045	119F_8	-17.086	47.064	1.103	65.253
117F_8	-1.401	62.749	12.554	76.704	95F_8	-17.774	46.377	0.891	65.041
145F_8	-1.969	62.182	12.216	76.367	100F_8	-18.489	45.662	0.676	64.826
163F_8	-2.319	61.832	11.886	76.036	89F_8	-19.527	44.624	0.454	64.604
129F_8	-2.757	61.393	11.560	75.711	131F_8	-19.757	44.394	0.234	64.384
87F_8	-2.789	61.361	11.248	75.399	149F_8	-21.51	42.641	0	64.151
115F_8	-2.978	61.172	10.946	75.096					

[1] RAIO, BMX Raio 50I52 RSF IPRO; VALENTE, BMX Valente 6968 RSF RR.

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Table 3. Results of BLUP as pure genetic gain (g), pure genetic gain and additive genetic merit (g + u), expected genetic gain after selection (gain), and expected population mean after selection (new mean) for the trait seed weight per plant (SWP) in F_8 soybean (*Glycine max*) lineages, classified in decreasing order of "new mean".

Lineage(1)	g	g + u	Gain	New mean	Lineage	g	g + u	Gain	New mean
122F_8	12.999	24.887	12.999	24.887	115F_8	-0.749	11.243	1.725	13.612
176F_8	10.093	21.981	11.546	23.434	107F_8	-0.890	10.997	1.671	13.559
165F_8	9.305	21.193	10.799	22.687	145F_8	-0.899	10.989	1.620	13.507
232F_8	7.690	19.577	10.022	21.909	105F_8	-0.907	10.981	1.570	13.458
109F_8	5.379	17.267	9.093	20.981	111F_8	-1.014	10.873	1.521	13.408
99F_8	4.769	16.657	8.373	20.260	170F_8	-1.0823	10.805	1.471	13.359
154F_8	3.676	15.563	7.702	19.589	125F_8	-1.087	10.801	1.424	13.312
93F_8	3.429	15.317	7.168	19.055	135F_8	-1.093	10.795	1.378	13.266
166F_8	3.059	14.947	6.711	18.599	106F_8	-1.097	10.790	1.334	13.222
85F_8	2.971	14.859	6.337	18.225	130F_8	-1.100	10.788	1.291	13.179
77F_8	2.522	14.409	5.990	17.878	129F_8	-1.105	10.783	1.25	13.138
121F_8	2.144	14.032	5.669	17.557	81F_8	-1.107	10.781	1.21	13.098
76F_8	1.861	13.748	5.377	17.264	153F_8	-1.187	10.701	1.170	13.058
152F_8	1.617	13.505	5.108	16.996	147F_8	-1.217	10.671	1.131	13.019
143F_8	1.548	13.436	4.871	16.758	123F_8	-1.218	10.669	1.093	12.981
159F_8	1.511	13.399	4.661	16.548	158F_8	-1.225	10.663	1.056	12.944
227F_8	1.488	13.376	4.474	16.362	231F_8	-1.314	10.573	1.019	12.907
169F_8	1.422	13.309	4.305	16.192	744F_8	-1.355	10.532	0.983	12.870
127F_8	1.316	13.204	4.147	16.035	164F_8	-1.388	10.5	0.947	12.835
94F_8	1.090	12.978	3.994	15.882	112F_8	-1.535	10.353	0.910	12.797
226F_8	0.921	12.809	3.848	15.736	136F_8	-1.563	10.325	0.873	12.761
92F_8	0.884	12.772	3.713	15.601	172F_8	-1.569	10.318	0.838	12.726
110F_8	0.829	12.717	3.588	15.476	118F_8	-1.626	10.262	0.803	12.691
104F_8	0.764	12.652	3.470	15.358	744F_8	-1.683	10.205	0.768	12.655
234F_8	0.651	12.539	3.358	15.245	86F_8	-1.742	10.146	0.733	12.621
79F_8	0.510	12.398	3.248	15.136	98F_8	-1.862	10.026	0.697	12.585
134F_8	0.469	12.357	3.145	15.033	139F_8	-1.900	9.987	0.662	12.550
97F_8	0.413	12.301	3.048	14.935	146F_8	-1.961	9.927	0.627	12.515
233F_8	0.307	12.195	2.953	14.841	171F_8	-2.005	9.883	0.593	12.480
113F_8	0.279	12.167	2.864	14.752	140F_8	-2.059	9.829	0.558	12.446
236F_8	0.203	12.091	2.778	14.666	133F_8	-2.207	9.681	0.523	12.411
91F_8	0.118	12.006	2.695	14.583	83F_8	-2.214	9.674	0.488	12.376
117F_8	0.003	11.891	2.613	14.501	82F_8	-2.249	9.639	0.454	12.342
116F_8	0.003	11.891	2.537	14.424	148F_8	-2.250	9.637	0.421	12.308
BRS284	0	11.888	2.464	14.352	141F_8	-2.255	9.633	0.388	12.276
RAIO	0	11.888	2.396	14.283	137F_8	-2.502	9.385	0.353	12.241
M5710I2	0	11.888	2.331	14.219	119F_8	-2.505	9.382	0.319	12.207
VALENTE	0	11.888	2.270	14.157	175F_8	-2.616	9.272	0.285	12.172
157F_8	-0.021	11.867	2.211	14.099	101F_8	-2.649	9.239	0.250	12.138
80F_8	-0.039	11.848	2.155	14.042	142F_8	-2.769	9.119	0.216	12.103
124F_8	-0.075	11.813	2.100	13.988	100F_8	-2.785	9.103	0.182	12.069
238F_8	-0.154	11.734	2.047	13.934	103F_8	-2.789	9.098	0.148	12.036
87F_8	-0.352	11.536	1.991	13.879	89F_8	-3.141	8.746	0.112	11.999
228F_8	-0.460	11.536	1.935	13.823	131F_8	-3.232	8.656	0.075	11.963
151F_8	-0.485	11.428	1.881	13.769	149F_8	-3.359	8.528	0.038	11.925
163F_8	-0.491	11.403	1.830	13.717	95F_8	-3.460	8.427	0	11.888
88F_8	-0.645	11.397	1.777	13.665					

(1) RAIO, BMX Raio 50I52 RSF IPRO; VALENTE, BMX Valente 6968 RSF RR.

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Table 4. Results of the genetic selection index for resilience (GSIRΔ), classified in decreasing order.

Lineage	GSIRΔ	Lineage	GSIRΔ	Lineage	GSIRΔ	Lineage	GSIRΔ
122F_8	1.69	119F_8	0.06	226F_8	0.03	111F_8	0.01
176F_8	1.05	175F_8	0.06	123F_8	0.02	170F_8	0.01
165F_8	0.83	142F_8	0.06	106F_8	0.02	227F_8	0.01
232F_8	0.67	137F_8	0.05	134F_8	0.02	135F_8	0.01
109F_8	0.51	141F_8	0.05	164F_8	0.02	129F_8	0.01
99F_8	0.36	82F_8	0.05	231F_8	0.02	234F_8	0.01
166F_8	0.29	83F_8	0.05	147F_8	0.02	115F_8	0.01
93F_8	0.26	171F_8	0.04	97F_8	0.02	145F_8	0
154F_8	0.22	133F_8	0.04	118F_8	0.02	163F_8	0
85F_8	0.15	148F_8	0.04	136F_8	0.02	87F_8	0
121F_8	0.15	139F_8	0.04	110F_8	0.02	124F_8	0
152F_8	0.09	744F_8	0.04	92F_8	0.02	104F_8	0
169F_8	0.09	112F_8	0.04	153F_8	0.02	91F_8	0
77F_8	0.08	140F_8	0.04	79F_8	0.02	151F_8	0
159F_8	0.07	86F_8	0.04	125F_8	0.02	88F_8	0
149F_8	0.07	744F_8	0.03	81F_8	0.02	238F_8	0
131F_8	0.07	127F_8	0.03	94F_8	0.01	80F_8	0
95F_8	0.07	76F_8	0.03	233F_8	0.01	117F_8	0
89F_8	0.07	98F_8	0.03	105F_8	0.01	116F_8	0
100F_8	0.07	172F_8	0.03	158F_8	0.01	113F_8	0
103F_8	0.06	146F_8	0.03	130F_8	0.01	157F_8	0
101F_8	0.06	143F_8	0.03	107F_8	0.01	228F_8	0
						236F_8	-0.01

Conclusions

1. Soybean (*Glycine max*) lineages 122F_8 and 176F_8 are superior in terms of productivity components.
2. The best linear unbiased predictors allows for selection of 33 lineages for number of seeds per plant and 34 lineages for seed weight per plant.
3. The proposed agronomic and environmental resilience index allows for selection of 13 lineages for high agronomic potential and resilience to abiotic stress.

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