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ORIGINAL ARTICLE

Screening of common bean accessions for use in genetic improvement

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Abstract – This study evaluated 21 bean genotypes from the Active Germplasm Bank of CEAFA to identify promising materials for genetic improvement. The plants were characterized in a greenhouse for leaf temperature, number of pods, total grain number and grain weight. Results showed significant variability among genotypes. Lower leaf temperatures were observed in accessions BAG06 and BAG27. For yield-related traits, BAG59 and BAG27 stood out with the highest values for total grain number and total grain weight. The adapted Mulamba and Mock index indicated BAG27 and BAG59 as the most promising genotypes considering all evaluated traits. The results confirm the genetic diversity within the CEAFA germplasm collection and reinforce the importance of these accessions for breeding programs aimed at higher productivity and environmental resilience.

Keywords: *Phaseolus vulgaris* L. Variability. Gene bank.

***Screening* de acessos de feijão-comum para o uso no melhoramento genético**

Resumo – O estudo avaliou 21 genótipos de feijão provenientes do Banco Ativo de Germoplasma do CEAFA, visando identificar materiais promissores para o melhoramento genético. As plantas foram caracterizadas em casa de vegetação quanto à temperatura foliar, número de legumes por planta, número de grãos por legume, número total de grãos e peso total de grãos. Os resultados mostraram variabilidade significativa entre os genótipos. Menores temperaturas foliares foram observadas nos acessos BAG06 e BAG27. Para caracteres produtivos, destacaram-se BAG59 e BAG27, que apresentaram maiores valores para número total e peso de grãos. A análise pelo índice adaptado de Mulamba and Mock indicou BAG27 e BAG59 como os genótipos mais promissores no conjunto de características avaliadas. Os resultados confirmam a diversidade genética do BAG/CEAFA e reforçam a importância desses acessos para programas de melhoramento voltados a maior produtividade e resiliência ambiental.

Palavras-chave: *Phaseolus vulgaris* L. Variabilidade. Banco de germoplasma.

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Introduction

Beans are one of the most important legumes worldwide. In Brazil, beans are of great economic and sociocultural importance, and the country is also considered the largest producer and consumer. Current data show that grain production in the 2023/2024 crop year was estimated at 297.54 million tons, including 3.1 million tons of beans (CONAB, 2024). Furthermore, beans hold sociocultural importance, as they are a daily staple in the diets of the majority of the Brazilian population. Beans are fundamental to the Brazilian diet (Silva; Pessenti, 2022), making them indispensable due to their high protein content, as well as being a significant source of complex carbohydrates, essential minerals, and B vitamins (Santos; Luzia; Farias, 2023).

To maintain or increase productivity levels and combine nutritional traits, new cultivars must be released from time to time. In this regard, breeders must have access to genotypic diversity, as maintaining genetic variability is crucial in genetic improvement programs. Thus, when initiating a breeding program or continuing an existing one, there is a need to establish a germplasm base collection or breeder's working collection containing divergent genotypes, from which it will be possible to identify promising individuals for use in breeding per se. This diversity has a significant influence directly into breeding programs, since these genotypes may show a high capacity to adapt to different regions and exhibit high tolerance to biotic and abiotic factors (Lioi *et al*., 2019). These collections are indispensable resources for researchers and breeders, serving as repositories for access to genetic material that addresses current and urgent challenges, including plant water use, tolerance to heat stress, nitrogen and phosphorus utilization, resistance to diseases and pests, as well as improvements in mineral content (Salgotra; Chauhan, 2023).

One of the main purposes of maintaining or preserving a germplasm collection/bank is to protect variability, preventing genetic erosion and thus making the material available to breeders (Bueno *et al*., 2006) and the local community, which includes students, staff, homemakers, farmers, teachers, researchers, among others (Priyanka *et al*., 2021). Furthermore, it is possible to maintain the genetic constitution of some species through germplasm collections, thereby preventing the loss of genotypes due to disuse or replacement by modern varieties. Advances in plant breeding programs have focused on the development of genotypes adapted to adverse conditions (Cerutti *et al*., 2023), such as resistance to pathogens, adaptation to environmental conditions, and increased yield (Lima *et al*., 2020), as well as tolerance to water stress (Liu *et al*., 2025).

One agronomically important trait is water stress. Water stress compromises essential physiological processes in plants, reducing growth, photosynthesis, and productivity, which reinforces the need to develop more tolerant cultivars (Liu *et al*., 2023; Sato *et al*., 2024). Plant breeding plays a fundamental role in adapting crops to water-deficit conditions, enabling the selection of genotypes that are more efficient in water use and more resilient to climatic variations (Silva *et al*., 2024). In this context, leaf temperature is an important indicator of water stress in plants, since stomatal closure reduces transpiration and evaporative cooling, increasing leaf temperature. This makes leaf temperature useful for the early detection of water deficit and irrigation management (García-Tejero *et al*., 2021).

This study aimed to evaluate bean accessions from the germplasm bank of the State Center for Diagnosis and Research in Family Farming (CEAFA) for agronomically important traits, including those related to environmental stress.

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Materials and Methods

The experiment was conducted at the State Center for Diagnosis and Research on Family Farming (CEAFA) in the municipality of Maquiné, Rio Grande do Sul, at latitude 29°54′ S, longitude 50°19′ W, an elevation of 38 m, a Cfa climate, and annual precipitation of 1,700 mm. The propagation and characterization of the accessions were carried out in a greenhouse, using 10-liter pots filled with Haplic Orthic Chernozem typical of the site.

Seeds from bean accessions (Table 1) of different commercial groups were used, sourced from the Bean Germplasm Bank of the Bean Genetic Improvement Program (BAG/CEAFA).

During the 2024/25 growing season, BAG/CEAFA accessions were sown in a greenhouse. Temperature and irrigation were controlled automatically, with irrigation provided via drip irrigation. Weed control was performed by manual removal. Ten-liter pots were used, with five seeds from each accession sown per pot. After emergence, thinning was performed by removing two seedlings per pot.

The experimental design used was a completely randomized design with three replicates. Each replication contained two pots with three plants, totaling 18 sample units. The data were subjected to a test for comparison of means (Tukey's test at a 5 % probability of error), Spearman's correlation, and the modified Mulamba and Mock correlation. The adaptation of the Mulamba and Mock test consisted of obtaining an overall mean of the sum of ranks and subsequently ranking the lowest means of the treatments relative to the overall mean. The statistical package used was SAS UNIVERSITY EDITION (SAS Institute, 2014).

The following traits were evaluated: leaf temperature (TEMP) in degrees Celsius, number of pods per plant (NPP), number of seeds per pod (NSP), total number of seeds (TNS), and total seed weight (TSW) in grams. Temperature measurements were taken between 12:00 and 2:00 p.m. using a digital thermometer ST-600 infrared model, manufactured by Incoterm®. Leaf temperature was measured by placing the thermometer close to random leaves, approximately six leaves from the plants in each pot. Three temperature measurements were taken on different days during flowering (stage R6).

Table 1. List of bean accessions from the Bean Germplasm Bank of the Bean Genetic Improvement Program (BAG/CEAFA) evaluated in the experiment.

Treatment	Genotype	Color
1	BAG06	Wine-colored
2	BAG07	Speckled
3	BAG21	Black
4	BAG27	Black
5	BAG32	Black
6	BAG33	Black
7	BAG34	Speckled
8	BAG35	Gray
9	BAG40	Dark mottled
10	BAG45	Brown
11	BAG47	Black
12	BAG50	Beige
13	BAG51	Black
14	BAG59	Pink
15	BAG65	Wine-colored
16	BAG89	Black
17	BAG100	Speckled
18	BAG102	Black
19	BAT477	Brown
20	JURITI*	Brown
21	NEGRO ARGEL**	Gray

* Drought-susceptible cultivar; (Bertoldo *et al.*, 2019); ** Drought-tolerant cultivar (Sousa and Lima, 2010)

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Results and Discussion

Based on the results, it was possible to analyze the genotypes for the evaluated traits (Table 2). It should be noted that for the leaf temperature (TEMP) trait, lower values are desired, as there is a negative correlation with water stress (Guimarães *et al*., 2015; Bertoldo *et al*., 2019; Pohlmann *et al*., 2022; Anorato *et al.*, 2025). Conversely, for the other traits, high values indicate greater productive potential. Thus, the evaluated traits can be analyzed according to Table 2.

Thus, for the leaf temperature trait, genotypes BAG06 and BAG27 recorded the lowest values, 20.61 and 20.79 degrees Celsius, respectively. In contrast, the Juriti genotype recorded the highest leaf temperature (22.47 degrees Celsius). In the literature, the Juriti cultivar is reported to be susceptible to water stress (Bertoldo *et al*., 2019), and the higher temperature observed may corroborate the findings of other authors. However, it would be ideal to subject these same genotypes to water and temperature stress conditions to confirm this trend.

Regarding the total number of pods (TNP) trait, the BAG59 and Negro Argel genotypes had the highest values (118 and 96, respectively). On the other hand, the BAG34 genotype had the lowest value, with 33 pods per plant. For the total number of grains (TNG) trait, genotypes BAG59 (564 grains) and BAG27 (486 grains) were superior, while genotypes BAG33, BAG40, BAG32, BAG35, BAG50, and BAG34 produced a lower number of grains per plant. Genotypes BAG06 (six seeds) and BAG27 (five seeds) are noteworthy, with the highest number of seeds per pod (NSP). As for the total seed weight (TSW) trait, the genotypes with superior or better performance were BAG59, with 130 g, and BAG27, with 125 g. Genotype BAG34, with 43.67 g, had the lowest mean for the total seed weight (TSW) trait.

With the exception of leaf temperature, all other traits evaluated are related to yield potential. Therefore, high values represent positive indices. According to Loro *et al*. (2024), a plant ideotype can be derived from phenological, morphological, and yield-related traits. Furthermore, associating these traits with temperature values can aid in selecting more promising materials regarding tolerance to environmental stresses, such as temperature. Leaf temperature is a function of the leaf's energy balance; the higher the temperature, the lower the energy loss (Guimarães *et al*., 2015). Under water-limited conditions, stomata close, reducing the leaves' evaporative cooling capacity, increasing thermal stress on the leaf, and ultimately leading to an increase in leaf temperature (Engineer *et al*., 2016; Figueiredo *et al*., 2019).

With this information, it is possible to select superior genotypes for use by plant breeders in directed crosses or for testing in trials to determine their cultivation and use value (VCU) for release as new varieties. However, the ideal genotype is the one that best combines traits of agronomic interest. Currently, it is very difficult to define a plant's ideotype in terms of its physio/logical response in environments without water limitations and in those subject to water stress (Ledesma-Ramírez *et al*., 2022). Therefore, the breeder must utilize all statistical, genetic, phenotypic, and other tools at their disposal to achieve this objective. For example, in the present study, the ideotype would be a genotype with lower leaf temperature and higher productivity traits. However, due to the complexity of genetic compositions and environmental effects, as well as their interactions, this is often not possible. In this case, it is important to evaluate each genotype across the full range of traits, thereby making it possible to predict its overall performance in order to obtain the best genetic combination.

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Table 2. Mean values for bean genotypes for the traits leaf temperature in degrees Celsius (TEMP), total number of pods (TNP), number of seeds per pod (NSP), total number of seeds (TNS), and total seed weight in grams (TWS).

Genotypes	TEMP		TNP		NSP		TNS		TSW	
NEGRO ARGEL	21.7	abc	**96**	**ab**	4.4	abcd	419	abcd	110.0	abc
JURITI	22.5	a	51	bcde	4.0	abcd	203	def	65.0	abc
BAT477	21.3	abc	68	bcde	4.0	abcd	243	cdef	68.3	abc
BAG06	**20.6**	**c**	43	cde	**6.0**	**a**	247	cdef	60.0	abc
BAG07	21.8	abc	68	bcde	2.7	bcd	169	ef	105.0	abc
BAG21	20.9	abc	89	abc	4.9	abcd	435	abc	110.0	abc
BAG27	**20.8**	**bc**	89	abc	**5.4**	**ab**	**486**	**ab**	**125.0**	**ab**
BAG32	21.3	abc	40	de	3.0	bcd	123	f	61.6	abc
BAG33	21.5	abc	58	bcde	2.7	bcd	143	f	86.6	abc
BAG34	21.6	abc	33	e	2.4	cd	76	f	43.6	c
BAG35	21.4	abc	46	cde	2.3	cd	107	f	48.3	c
BAG40	21.6	abc	43	cde	3.2	bcd	138	f	67.5	abc
BAG45	21.4	abc	68	bcde	2.9	bcd	203	def	80.0	abc
BAG47	21.3	abc	82	abcd	4.6	abcd	372	bcde	95.0	abc
BAG50	21.8	abc	47	cde	2.1	d	96	f	58.3	bc
BAG51	20.9	abc	80	abcd	4.9	abcd	386	abcde	108.3	abc
BAG59	21.2	abc	**118**	**a**	4.8	abcd	**564**	**a**	**130.0**	**a**
BAG65	21.5	abc	52	bcde	3.6	abcd	180	ef	76.6	abc
BAG89	21.9	abc	80	abcd	5.1	abc	409	abcd	106.6	abc
BAG100	22.4	ab	63	bcde	4.6	abcd	298	bcdef	91.6	abc
BAG102	21.3	abc	78	abcde	4.9	abcd	384	abcde	106.6	abc
Overall average	**21.5**		**66.3**		**3.9**		**272**		**86.2**	
CV (%)	**9.2**		**23.3**		**23.9**		**30.2**		**26.8**	

* Means with the same letter are not statistically different according to Tukey's test at a 5% significance level.

Table 3 shows the results obtained from the adapted test by Mulamba and Mock (1978). This test identifies the superior genotypes across the set of traits evaluated. To estimate the test results, the genotypes and their respective means for the evaluated traits are grouped. They are then classified according to the mean values (higher or lower depending on the trait of interest). The adaptation made by the authors to the original test was that, in the end, an overall mean of the sum of ranks was obtained; in this case, genotypes with a rank sum lower than the overall mean are classified as promising.

Based on this information, as shown in Table 3, genotype BAG27 received a rank of 2 for temperature (20.79 degrees Celsius), as it had the second-lowest mean of all genotypes for the temperature trait.

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Furthermore, the same genotype had a mean of 29.67 degrees Celsius for the pods per plant trait, which was the third-highest mean. Finally, by summing all the ranks, it obtained a value of 14 degrees Celsius for the sum of all traits. This value (14), in addition to being the lowest obtained, is below the overall average of the sum of the ranks (66 degrees Celsius). The use of selection indices enables the integration of information from multiple variables, allowing the breeder to assign weights according to the selection criteria of interest (Nascimento *et al*., 2025).

Table 3. Adapted test* by Mulamba and Mock (sum of ranks**) on bean genotypes, for the traits: leaf temperature in degrees Celsius (TEMP), total number of pods (TNP), number of seeds per pod (NSP), total number of seeds (TNS), and total seed weight in grams (TSW).

Genotypes	TEMP	*rank*	TNP	*rank*	NSP	*rank*	TNS	*Rank*	TSW	*Rank*	Sum
BAG27	20.79	2	89	3	5.40	2	486	2	125.00	2	14
BAG59	21.17	5	118	1	4.79	7	564	1	130.00	1	16
BAG21	20.88	3	89	4	4.96	4	435	3	110.00	3	21
BAG51	20.95	4	80	6	4.85	6	386	6	108.33	5	33
NEGRO ARGEL	21.65	16	96	2	4.36	10	419	4	110.00	4	38
BAG102	21.31	7	78	8	4.93	5	384	7	106.67	7	42
BAG47	21.32	9	82	5	4.62	8	372	8	95.00	9	44
BAG89	21.87	19	80	7	5.10	3	409	5	106.67	6	47
BAT477	21.27	6	68	9	4.03	11	243	11	68.33	14	60
BAG06	20.61	1	43	18	6.08	1	247	10	60.00	18	66
BAG45	21.42	10	68	10	2.98	16	203	13	80.00	12	71
BAG100	22.36	20	63	12	4.55	9	298	9	91.67	10	72
BAG07	21.84	17	68	11	2.65	17	169	15	105.00	8	79
BAG65	21.50	12	52	14	3.63	13	180	14	76.67	13	80
BAG33	21.54	13	58	13	2.65	18	143	16	86.67	11	84
JURITI	22.47	21	51	15	4.00	12	203	12	65.00	16	91
BAG40	21.55	14	43	19	3.17	14	138	17	67.50	15	98
BAG32	21.31	8	40	20	3.02	15	123	18	61.67	17	98
BAG35	21.42	11	46	17	2.34	20	107	19	48.33	20	104
BAG50	21.84	18	47	16	2.06	21	96	20	58.33	19	110
BAG34	21.61	15	33	21	2.40	19	76	21	43.67	21	118
Averages	**21.45**	**-**	**66.33**	**-**	**3.94**	**-**	**272.00**	**-**	**86.22**	**-**	**66**

*An overall average of the sums was calculated, and the best genotypes above the overall average were selected; **sum of the average scores for each trait, where a lower value indicates better performance.

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As shown in Table 4, the yield traits exhibit significant positive correlations with one another. Leaf temperature showed negative correlations with all yield traits, although statistical significance was observed only with total number of seeds (TNS). The results indicate that, although the genotypes were not subjected to a specific water stress situation, genotypes with lower leaf temperature may exhibit better values for traits related to yield.

Table 4. Spearman's correlations between the variables analyzed in bean genotypes for the traits leaf temperature in degrees Celsius (TEMP), total number of pods (TNP), number of seeds per pod (NSP), total number of seeds (TNS), and total seed weight in grams (TWS).

Characters	TNP	NSP	TNS	TWS
TEMP	-0.262	-0.295	-0.505*	-0.268
TNP		0.998***	0.574**	0.936***
NSP			0.589**	0.926***
TNS				0.629**
TWS				0.887***

N = 21 genotypes. Significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

It is important to note that, based on the results, it is possible to observe diversity among the genotypes evaluated. According to Bertoldo, Silva, and Favreto (2016), a broad genetic base is essential for the success of a breeding program, as this makes selection possible. Furthermore, according to Carvalho *et al.* (2021), genetic variability is essential for selecting individuals for pre-improvement and generational advancement. The results were significant, with ten genotypes outperforming the overall average and thus considered the most promising. Genotypes BAG27 and BAG59 stand out, with lower values in the sum of ranks. These genotypes also stood out in the results of the mean comparison test (Table 2). Furthermore, another relevant genotype, in addition to the other nine, is BAG102. This accession had already shown good results in another experiment, but when subjected to water stress due to drought (Bertoldo *et al*., 2019). In contrast, some genotypes were not considered promising for the evaluated traits, such as genotypes BAG35, BAG50, and BAG34. Of all the genotypes evaluated, BAG34 can be considered the worst across the set of traits. Furthermore, some genotypes were classified as intermediate and warrant further study. Based on these results, genotypes BAG27 and BAG102 will be evaluated in a new experiment, where they will be subjected, along with other genotypes, to water stress conditions involving drought and flooding.

Thus, the economic and sociocultural importance of beans can be emphasized, and it is essential to conduct in-depth studies of these crops to achieve genetic improvement, in order to meet the needs of the Brazilian population in the face of climate challenges. Therefore, it was concluded that there is variability

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among the genotypes evaluated. A lower leaf temperature may indicate better efficiency for traits related to productivity. The rank sum test can aid in selecting superior genotypes across the set of traits. Genotypes BAG27 and BAG59 achieved superior results across the set of traits.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any potential conflicts of interest.

Ethical Statements

The authors confirm that the ethical guidelines adopted by the journal were followed by this work, and all authors agree with the submission, content and transfer of the publication rights of the article to the journal. They also declare that the work has not been previously published nor is it being considered for publication in another journal.

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References

ANAMA/PGDR-UFRGS. **Diagnóstico socioeconômico e ambiental do Município de Maquiné-RS: perspectivas para um desenvolvimento rural sustentável**. Relatório de Pesquisa, Pró-Reitoria de Pesquisa da UFRGS: Porto Alegre, RS, 2000. 108 p.

ANORATO, L. R. e*t al*. Índice de Estresse Hídrico em Híbridos de Milho em Estádio Inicial de Crescimento sob Variação Hídrica. **International Seven Multidisciplinary Journal,** v.4, n.2, 2025 https://doi.org/10.56238/sevenVIImulti2025-009.

BERTOLDO, J. G.; SILVA, R. P.; FAVRETO, R. **Recursos vegetais e melhoramento genético: conceitos e aplicações**. Porto Alegre: Fepagro, 2016. 100 p. (Boletim Fepagro, n.26).

BERTOLDO, J. G. *et al*. **Sensibilidade de genótipos de feijão ao estresse hídrico**. Pesquisa Agropecuária Gaúcha, v. 25, n. 3, p. 36–50, 2019. https://doi.org/10.36812/pag.201925336-50.

BUENO, L. C. S.; MENDES, A. N. G.; CARVALHO, S. P. **Melhoramento Genético de Plantas**. 2. ed. Lavras: UFLA, 2006. 319p.

Received: 13 Mar, 2026. Accepted: 10 Jun., 2026.

CARVALHO, M. G. *et al*. Selection among segregating pepper progenies with ornamental potential using multivariate analyses. **Revista Caatinga**. v. 34, n. 3, p. 527–536, 2021. Available from: https://doi.org/10.1590/1983-21252021v34n304rc Accessed: 24 Oct. 2024.

CERUTTI, P. H. *et al.* Fenotipagem do caráter distribuição radicular de populações segregantes no melhoramento genético de feijão. **Delos: Desarrolos Local Sostenible**, v. 16, n. 47, p. 2814–2829. 2023. https://doi.org/10.55905/rdelosv16.n47-018.

CONAB - COMPANHIA NACIONAL DE ABASTECIMENTO. **Perspectivas para a agropecuária**. Brasília, DF, v. 9, safra 2021/22, Edição Grãos. 2024. Available from: https://www.conab.gov.br/perspectivas para-a-agropecuaria. Accessed: 27 Oct. 2024.

ENGINEER, C. *et al.* CO2 sensing and CO2 regulation of stomatal condutance: advances and open questions. **Trends in Plant Science**, v. 21, n. 1, p. 16-30, 2016. https://doi.org/10.1016/j.tplants.2015.08.014.

FIGUEIREDO, F. R. A., *et al.* Respostas fisiológicas de Mulungu submetida a estresse salino e aplicação de ácido salicílico. **Irriga**, v. 24, n. 3, p. 662-675, 2019. http://dx.doi.org/10.15809/irriga.2019v24n3p662-675.

GARCÍA-TEJERO, I. F. *et al*. Application of thermal imaging to irrigation management in horticultural crops. **Agricultural Water Management**, v. 245, p. 106-129, 2021. https://doi.org/10.1016/j.atech.2021.100021.

GUIMARÃES, C. M. *et al*. Physiological parameters to select upland rice genotypes for tolerance to water deficit. **Pesquisa Agropecuária Brasileira**, v. 50, n. 7, p. 534-540, 2015. https://doi.org/10.1590/S0100-204X2015000700003.

LEDESMA-RAMÍREZ, L. *et al.* Evaluación de genotipos desarrollados para resistencia a sequía en ambientes de riego normal y restringido**. Ciencia y Tecnología Agropecuaria de México**, v. 10, n. 2, p.102-110, 2022. Available from: https://www.somecta.org.mx/wp-content/uploads/2023/02/14EVALUACION-DE-GENOTIPOSRIEGO-NORMAL-Y-RESTRINGIDO.pdf. Accessed: 25 Oct. 2024.

LIMA, A. R. D. S. *et al*. Desempenho agronômico de linhagens e cultivares de feijão comum na região do ecótono Cerrado/Pantanal. **Research, Society and Development**, v. 9, n. 7, p. 1-19, 2020. https://doi.org/10.33448/rsd-v9i7.3666 .

LIOI, L. *et al.* Genotyping-by-Sequencing Reveals Molecular Genetic Diversity in Italian Common Bean Landraces. **Diversity**, v. 11, n. 9, p. 1-14, 2019. https://doi.org/10.3390/d11090154.

LIU, S.; WANG, H.; QIN, F. Genetic dissection of drought resistance for trait improvement in crops. **The Crop Journal**, v. 11, n. 4, p. 975-985, 2023. https://doi.org/10.1016/j.cj.2023.05.002

LIU Y, *et al*. Response mechanisms of crops to drought stress and strategies of molecular breeding for drought resistance. **Sheng Wu Gong Cheng Xue Bao**, v. 41, n. 11, p. 4419-4442, 2025. https://doi.org/10.13345/j.cjb.250448.

LORO, M. V. *et al*. Relações lineares entre variáveis

ISSN: 0104-9070. ISSN ONLINE: 2595-7686.
Received: 13 Mar, 2026. Accepted: 10 Jun., 2026.

meteorológicas e caracteres fenológicos, morfológicos e produtivos em bases genéticas de milho. **Revista Vivências**, v. 20, n. 41, p. 95-111, 2024. https://doi.org/10.31512/vivencias.v20i41.1042.

MULAMBA, N. N.; MOCK, J. J. Improvement of yield potential of the ETO blanco maize (Zea mays L.) population by breeding for plant traits [Mexico]. **Egypt Journal of Genetic and Cytology**, v. 7, n. 1 p. 40-51, 1978. Available from: https://www.cabidigitallibrary.org/doi/full/10.5555/19791677302. Accessed: 17 Oct. 2024.

NASCIMENTO, M. S. *et al*. Selection of early lima bean lines for grain yield. **Pesquisa Agropecuária Tropical**, v. 55, p. 19, 2025. https://doi.org/10.1590/1983-40632025v5582796.

PRIYANKA, V. *et al*. Germplasm Conservation: Instrumental in Agricultural Biodiversity-A Review. **Sustainability**. v. 5, n. 1, p. 6743, 2021. https://doi.org/10.3390/su13126743.

POHLMANN, V., *et al.* f. Foliar silicon in tolerance to water deficit in beans. **Ciência Agrícola**, v. 20, n. 1, p. 25-32, 2022. Available from: https://ufal.emnuvens.com.br/revistacienciaagricola/article/download/11241/9581. Accessed: 14 Sep. 2024.

SANTOS, G. N. DE L. M.; LUZIA, D. M. M.; FARIAS, V. L. DA S. Composição centesimal e atividade antioxidante de feijão (*Phaseolus vulgaris* L.). **Revista Interfaces**, v. 15, n. 10, 2023. Available from: https://publicacoes.uniesp.edu.br/index.php/1/article/view/75. Accessed: 13 Jul. 2024.

SAS INSTITUTE INC. 2014. SAS® University Edition: Installation Guide for Windows. Cary, NC: SAS Institute Inc.

SILVA, V. H. D.; PESSENTI, I. L. Translocação de fósforo em diferentes cultivares de feijão (*Phaseolus vulgaris*) na região dos campos gerais. **Journal of Biotechnology and Biodiversity**, v. 10, n. 4, p. 279–286, 2022. Available from: https://doi.org/10.20873/jbb.uft.cemaf.v10n4.silva.

SILVA, C. M., *et al*. Melhoramento genético de plantas para adaptabilidade às mudanças climáticas. **Revista De Gestão E Secretariado**, v. 15 n. 9, e4161. 2024. https://doi.org/10.7769/gesec.v15i9.4161.

SALGOTRA, R. K.; CHAUHAN, B. S. Genetic diversity, conservation, and utilization of plant genetic resources. **Genes**, v. 14, p. 174, 2023. Available from: https://doi.org/10.3390/genes14010174.

SOUSA, M. A.; LIMA, M. D. B. Influência da supressão da irrigação em estádios de desenvolvimento do feijoeiro cv. carioca comum. **Bioscience Journal**, v. 26, n. 4, p. 550-557, 2010. Available from: https://seer.ufu.br/index.php/biosciencejournal/article/view/7134/5129. Accessed: 13 Jul. 2024.

ISSN: 0104-9070. ISSN ONLINE: 2595-7686.
Received: 13 Mar, 2026. Accepted: 10 Jun., 2026.