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# Morphophysiological variation, vigor test, and influence of light and temperature on the germination of four cultivars of *Glycine max* (L.) Merrill

# Variação morfofisiológica, teste de vigor e influência de luz e temperatura na germinação de quatro cultivares de *Glycine max* (L.) Merrill

# Variación morfofisiológica, prueba de vigor e influencia de la luz y la temperatura en la germinación de cuatro cultivares de *Glycine max* (L.) Merrill

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**ABSTRACT**
Soybean (*Glycine max*. (L.) Merrill) is a crop whose productivity depends on the quality of the seeds used. In this context, the objective of this study was to characterize the seeds physically, evaluate viability using tetrazolium, identify physiological vigor through an electrical conductivity test, and determine the influence of temperature and photoperiod on the germination of four cultivars (Ultra, Olimpo, Extrema and Foco). 200 seeds were used, measuring size, weight of a thousand seeds, moisture content, and fresh mass. In tetrazolium (1%), 100 seeds were soaked for 4 h at 25°C. For electrical conductivity, 50 seeds were submerged on 75 mL of deionized water at 25°C for periods of 4, 8, 12, 16, 20 and 24 h. In the germination process, the treatments (four replications of 50 seeds) were incubated (B.O.D.) at temperatures of 25°C, 27°C, 30°C and 35°C, under photoperiods of 12 and 14 h. The experimental design adopted was completely randomized for all experiments, and the means were subjected to analysis of variance and Tukey's test at 5% probability. The Ultra cultivar presented perimeter (38.21±3.72 mm), length of 9.98±0.24 mm, and width of 7.94±0.27 mm. The cultivars presented viability above 90%. For electrical conductivity, the 12 h period was effective for identifying vigor. The Ultra cultivar (25°C and 12 h of photoperiod) achieved 77% germination, 10 germinated seeds per day, an average germination time of 4 days and 43 germinated seeds by the third day.

**Keywords:** Seeds, *Glycine max*, vigor, temperature and photoperiod.

**RESUMO**
A soja (*Glycine max*. (L.) Merrill) é uma cultura cuja produtividade depende da qualidade das sementes utilizadas. Neste contexto, o objetivo deste trabalho foi caracterizar fisicamente as sementes, avaliar a viabilidade usando tetrazólio, identificar o vigor fisiológico pelo teste de condutividade elétrica e determinar a influência da temperatura e o fotoperiodo na germinação de quatro cultivares (Ultra, Olimpo, Extrema e Foco). Utilizou-se 200 sementes, medindo tamanho, peso de mil sementes, teor de água e massa fresca. No tetrazólio (1%) 100 sementes foram embebidas por 4 h a 25°C. Para a condutividade elétrica 50 sementes foram submersas em 75 mL de água deionizada a 25°C por períodos de 4, 8, 12, 16, 20 e 24 h. No processo germinativo

os tratamentos (quatro repetições de 50 sementes) foram incubados (B.O.D.) a temperatura de 25°C, 27°C, 30°C e 35°C, sob fotoperiodo de 12 e 14 h. O delineamento experimental adotado foi inteiramente casualizado para todos os experimentos, as médias submetidas à análise de variância e ao teste de Tukey a 5% de probabilidade. A cultivar Ultra apresentou perímetro de 38,21±3,72 mm, comprimento de 9,98±0,24 mm e largura de 7,94±0,27 mm. As cultivares apresentaram viabilidade acima de 90%. Para a condutividade elétrica o período de 12 h foi eficaz para a identificação do vigor. A cultivar Ultra (25°C e 12 h de fotoperíodo) alcançou 77% de germinação, 10 sementes germinadas por dia, tempo médio de germinação de 4 dias e 43 sementes germinadas no terceiro dia.

**Palavras-chave:** sementes, *Glycine max*, vigor, temperatura e fotoperiodo.

**RESUMEN**
La soja (*Glycine max* (L.) Merrill) es un cultivo cuya productividad depende de la calidad de semillas utilizadas. En este contexto, el objetivo de este trabajo fue caracterizar físicamente las semillas, evaluar la viabilidad usando tetrazolio, identificar el vigor fisiológico por la prueba de conductividad eléctrica y determinar la influencia de temperatura y fotoperíodo en la germinación de cuatro cultivares (Ultra, Olimpo, Extrema y Foco). Se utilizaron 200 semillas, midiendo tamaño, peso de mil semillas, contenido de agua y masa fresca. En el tetrazolio (1%), 100 semillas fueron sumergidas durante 4 h a 25°C. Para la conductividad eléctrica, 50 semillas se sumergieron en 75 mL de agua desionizada a 25°C en períodos de 4, 8, 12, 16, 20 y 24 h. En el proceso germinativo, los tratamientos (cuatro repeticiones de 50 semillas) fueron incubados (B.O.D.) a temperaturas de 25°C, 27°C, 30°C y 35°C, y fotoperíodos de 12 y 14 h. El diseño experimental adoptado fue completamente aleatorizado para todos los experimentos, y las medias sometidas a análisis de varianza y a la prueba de Tukey con 5% de probabilidad. El cultivar Ultra presentó perímetro de 38,21±3,72 mm, longitud de 9,98±0,24 mm y ancho de 7,94±0,27 mm. Los cultivares mostraron viabilidad superior al 90%. Para la conductividad eléctrica, el período de 12 h fue eficaz para identificar el vigor. El cultivar Ultra (25°C y 12 h de fotoperíodo) alcanzó 77% de germinación, 10 semillas germinadas por día, tempo medio de germinación de 4 días y 43 semillas germinadas al tercer día.

**Palabras clave:** Semillas, *Glycine max*, vigor, temperatura y fotoperíodo.

## 1 INTRODUCTION

Soybean production has increased significantly in recent decades, driven both by the expansion of the planted area and by the adoption of management techniques that have increased productivity (Barbosa; Ferreira, 2017). Brazil has established itself as a major exporter of soybeans, with its areas cultivated with the grain and production of the crop for export growing considerably (Conab, 2023). According to Zakir and Freitas (2015), the crop is widely recognized for its nutritional components with significant health benefits.

High global consumption rates, economic, technological and environmental factors, the availability of arable land, investments in logistics infrastructure and the development of technologies adapted to the climatic conditions of the Amazon region have favored the expansion of soybeans, especially in the states of Tocantins, Pará, Rondônia, and more recently, in Acre (Chiacchio; Souza, 2024).

The use of high-quality seeds results in high-performance plants, with a higher growth rate, better production structure, deeper root system and a greater number of pods and seeds, which leads to higher productivity (Schmidt, 2020). Seed germination is one of the most critical steps for the successful establishment of seedlings, in addition to being essential for the efficient growth and development of plants (Mangena, 2021). For Vieira and de Carvalho (2023), the degree of moisture in the seeds after dispersal is a factor that influences their germination. For Bewley and Black (1994), the germination process involves the resumption of metabolic activities in the seeds, being predominantly affected by temperature, which influences the imbibition speed and biochemical reactions, thus altering the germination percentage and speed. Therefore, extremely high or low temperatures can inhibit the germination process. Therefore, it is essential to evaluate the combinations of light intensities and temperature to obtain accurate information about the biology of the species (Silva *et al*., 2020).

The tetrazolium test, when used to analyze seed viability, allows the maximum germination potential to be assessed without having to wait for the complete physiological event to occur (Silva *et al*., 2020). According to Krzyzanowski and Santos Dias (2022), this test is useful for categorizing the level of seed vigor and estimating batch performance.

Among the most important seed vigor tests according to the ISTA (International Seed Analysis Association) of 2014, electrical conductivity stands out due to its simplicity, repeatability, speed, easy interpretation of results and low cost (Silva *et al*., 2020). This test is based on measuring electrolyte leakage during seed soaking, with damaged seeds showing slower restoration of cell membranes (Ataíde *et al*., 2017). Thus, this work was designed with the purpose of verifying the biometric variation in seeds, evaluating the physiological quality through the electrical conductivity test, and determining the light, and temperature conditions suitable for the germination behavior of four cultivars of *Glycine max* (L.) Merrill, in order to enhance their germination.

## 2 MATERIAL AND METHODS

The experiment was conducted between October and November 2022, at the Bionorte Complex facilities belonging to the Federal University of Acre - Brazil, and at the Forest Seed Analysis Laboratory of the Acre Technology Foundation (FUNTAC) in Rio Branco, AC - Brazil. According to Köppen-Geiger (https://en.climate-data.org/), Rio Branco's climate is of the Am type - tropical monsoon, characterized by a rainy and a dry season, with temperatures varying between a maximum of 30.92°C and a minimum of 20.84°C, with annual precipitation ranging from 2,200 to 2,500 mm. Seeds from four Brasmax cultivars with indeterminate growth habit and without prior treatment were used, with the following technology: 75I77RSF IPRO (Ultra), 80I82RSF IPRO (Olimpo), 81I81RSF IPRO (Extrema) and 74I77RSF IPRO (Foco) produced in the 2022/2023 harvest, subjected to the following tests for each cultivar: 1) viability test, 2) morphological analysis, 3) moisture content, 4) weight of a thousand seeds, 5) determination of electrical conductivity and 6) germination test.

For the viability test, 100 seeds were randomly selected. The first step was to prepare a 1% tetrazolium solution, dissolving 10 g of 2,3,5 TTC – Triphenyl Tetrazolium (DicaLab brand) in 1000 mL of distilled water (Brasil, 2009). To facilitate penetration of the solution and expose the embryo, the seeds were pre-moistened for two hours (in a container with 75 mL of distilled water and kept at laboratory temperature (25±3ºC). After this period, each seed was sectioned (longitudinal cut) forming two halves and discarding one of them. Two replicates of 50 halves each were soaked in a 5 mL tetrazolium solution on a sheet of blotting paper and placed in a non-transparent polystyrene gerbox box (11 cm long, 11 cm wide, and 3.5 cm deep) without a wedge. The boxes were then incubated for four hours in a vertical B.O.D. (Biochemical Oxygen Demand) incubator from Lucadema, model Luca-161/02, at a temperature of 25±3 ºC without photoperiod (Brasil, 2009). Finally, the embryos of the viable seeds capable of producing normal seedlings, they color completely or partially, indicating that the seed is viable. Non-viable seeds are those that do not meet these requirements (Figure 1A). The result was expressed as a percentage.

For the morphological analysis of the seeds, the ImageJ® software version 1.46 (Ferreira; Rasband, 2012) was used, which allows digital editing and quantitative measurement of the seed shape. 200 seeds arranged in groups of 20, with adequate spacing between them, were photographed. The images were captured with a 26x lens and 14 megapixels, at a distance of 20 cm, on a white background and using a ruler as a reference. The following biometric parameters were measured: area (mm²); perimeter (mm); circularity (0-1); length (mm); width (mm) and roundness (0-1) of the seed (Figure 1B). Image processing involved capturing and converting the images to 8-bit format (256 tones) using a threshold mask to differentiate contrasts between image components. Finally, the seeds were biometrically analyzed, and the results were exported to an Excel spreadsheet (Microsoft®). The moisture content was determined using the forced circulation oven method (Nova Ética brand and model 410/3ND), where the seeds remained for 24 h at 105±3ºC as prescribed in the RAS (Seed Analysis Rules) (Brasil, 2009). Four samples of 4±0.5 g of seeds (approximately 25 units) were used, packaged in aluminum capsules measuring 60x40 mm (diameter and height, respectively) (Figure 1C). After the drying period, the samples were removed from the oven and quickly covered to be transferred to the desiccator containing blue silica gel (4 mm) for approximately 15 min. This procedure ensured that the capsules cooled to laboratory temperature (25±2ºC) and thus avoided excessive moisture gain during weighing. A precision analytical balance (0.0001 g), Marte Cientifica brand, model ATY224, was used to weigh the capsules.

Water content (WC) was calculated using the following equation (1):

$$WC\ (\%) = \frac{(P-p)}{(P-t)} \times 100 \quad (1)$$

Where:

P = initial weight (weight of the aluminum capsule and its lid plus the weight of the wet seed)
p = final weight (weight of the aluminum capsule and its lid plus the weight of the dry seed)
t = tare (weight of the empty aluminum capsule with its lid)

To determine the weight of a thousand seeds, a random manual count was performed, using eight replicates of 100 seeds each. The seeds were weighed on a precision scale (0.0001 g), brand Marte Cientifica, model ATY224 (Figure 1D), and the average weight obtained was then multiplied by 10. The weight of a thousand seeds and the number of seeds per kilogram were determined according to the recommendations of the Rules for Seed Analysis (Brasil, 2009) and expressed in grams.

The determination of electrical conductivity was performed according to the methodology proposed by the AOSA (Official Seed Analysis Association) Vigor Committee of 1983 and described by Vieira et al., 2004, using 4 replicates of 50 physically pure seeds for each treatment. The seeds were weighed on a precision scale (0.0001 g), Marte Cientifica model ATY224, and submerged in a beaker (100 mL) containing 75.0 mL of deionized water for 4, 8, 12, 16, 20 and 24 h and placed in a B.O.D. incubator at a temperature of 25± 2°C. After the soaking period, the solutions containing the seeds were gently stirred with a stick to homogenize the leachates. Then, the electrical conductivity of the solution in which the seeds were immersed was read (Figure 1E) using a benchtop digital conductivity meter, Aprolab model DDS-12DW. The value obtained was divided by the weight of the sample to obtain the result.

Electrical conductivity (EC) was calculated by equation (2):

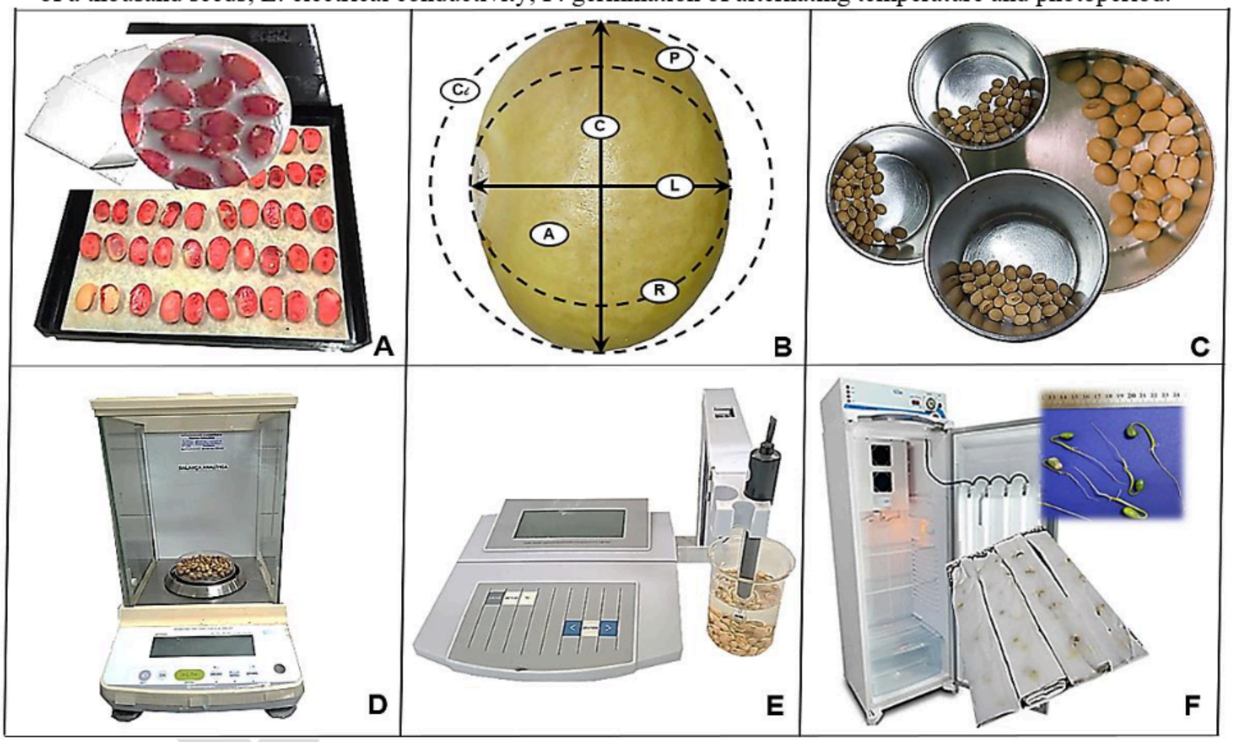
$$EC\ (\mu S.\,cm^{-1}.\,g^{-1}) = \frac{(VA - VP)}{PA} \quad (2)$$

Where:

VA = sample value
VP = standard value
PA = sample weight

For the germination test, a completely randomized experimental design arranged in a 4x6 factorial scheme (cultivars x temperature-photoperiod) was used, with four replicates of fifty seeds each. Seed germination of the four cultivars was conducted under six different temperature and photoperiod conditions (25°C-12 h, 30°C-12 h, 35°C-12 h, 25°C-14 h, 27°C-14 h and 30°C-10 h) throughout the germination period. Each cultivar was sown between sheets of Germitest® paper moistened with distilled water in a proportion of twice the weight of the dry paper. The seeds were placed on two sheets of Germitest® paper, loosely covered with a third sheet, and these were wrapped in a roll and placed in a transparent plastic bag (20 cm long, 30 cm wide and 0.033 microns thick) to prevent water loss through evaporation. The bags were properly identified and kept upright inside a SOLAB SL-225 B.O.D. incubator (Figure 1F), adjusted to the specified temperatures and photoperiods. Lighting was provided by four 20 W Phillips fluorescent lamps. The seeds remained in this condition for ten days.

Figure 1. Evaluations tested on *Glycine max* (L.) Merrill seeds, A: germination viability; B: biometric analysis of area (A), perimeter (P), width (L), length (C), circularity (C*i*) and roundness (R); C: moisture content; D: weight of a thousand seeds; E: electrical conductivity; F: germination of alternating temperature and photoperiod.




Source: UFAC itself, Rio Branco, AC, Brazil, 2024.

At the end of the test, the germinated seeds that showed primary root protrusion of at least 2 mm were evaluated. Finally, with the germination data obtained, the following variables were calculated, according to the equation proposed by Carvalho and Carvalho (2009):

Germination Percentage (G) is calculated by the following equation (3):

$$G\ (\%) = \frac{N}{A} \times 100 \quad (3)$$

Where:

N = number of germinated seeds

A = number of seeds in the sample (200.00)

Average Germination Time (AGT): calculated by the following equation (4):

$$\text{AGT (days)} = \frac{\sum niti}{\sum ni} \quad (4)$$

Where:

no = number of seeds germinated in time i
ti = incubation time

The Germination Speed Index (GSI) is calculated by equation (5):

$$\text{GSI (seed/day)} = \sum \frac{ni}{ti} \quad (5)$$

Where:

no = number of seeds germinated at time i
ti = time after test installation

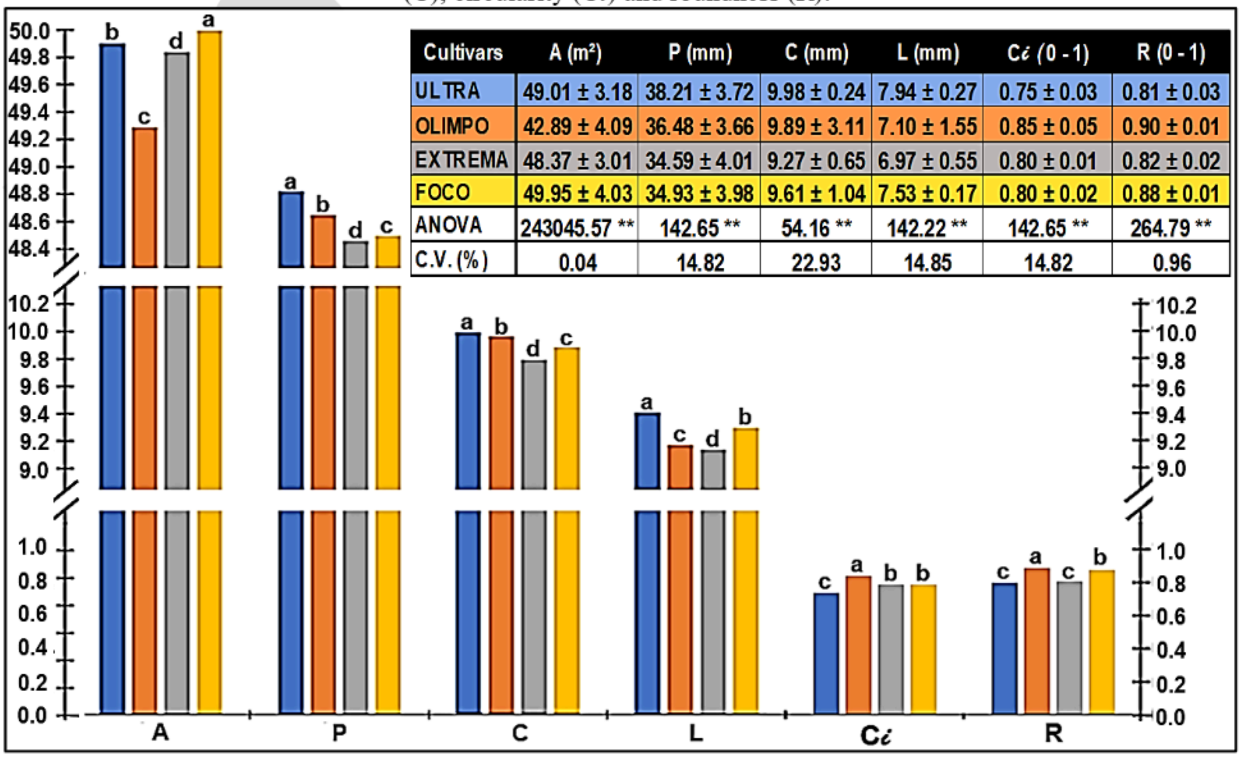
For statistical analysis, the mean germination percentage result was transformed into arcsine of the square root of the proportion; however, the values presented are the original ones.

The data were submitted based on the assumptions of analysis of variance. Initially, discrepant data were verified using the Grubbs (1969) test, the normality of the residuals was assessed at 5% significance using the Shapiro and Wilk (1965) test, and the homoscedasticity of the variances was checked at 5% significance using the Bartlett (1937) test. After these checks, an analysis of variance (ANOVA) was performed. When they were compared using the Tukey (1949) post-hoc test, also at 5% significance. All statistical processing was done with the RStudio program, version 4.4.1.

## 3 RESULTS AND DISCUSSIONS

According to the averages presented in Figure 2, the Ultra cultivar presented the highest values of perimeter (38.21±3.72 mm), length (9.98±0.24 mm), and width (7.94±0.27 mm), compared to the other cultivars. On the other hand, the Olimpo cultivar stood out with the greatest circularity (0.85±0.05) and roundness (0.90±0.01), among the cultivars analyzed. For Fontana (2017), the Verde (Edamame) genotype obtained a length of 8.34 mm and a width of 7.34 mm for the BRSMG 800A genotype, both genotypes with suitability for human consumption, of smaller size when compared to the findings in this work.

Figure 2. Biometric variables (mean ± standard error) of seeds from four cultivars (Ultra, Olimpo, Extrema and Foco) of *Glycine max* (L.) Merrill. Different letters indicate that there was a statistically significant difference (**) between the means by the Tukey test at the 1% probability level; area (A), perimeter (P), width (L), length (C), circularity (C*i*) and roundness (R).




| Cultivars | A (m²) | P (mm) | C (mm) | L (mm) | Cἰ (0 - 1) | R (0 - 1) |
|---|---|---|---|---|---|---|
| ULTRA | 49.01 ± 3.18 | 38.21 ± 3.72 | 9.98 ± 0.24 | 7.94 ± 0.27 | 0.75 ± 0.03 | 0.81 ± 0.03 |
| OLIMPO | 42.89 ± 4.09 | 36.48 ± 3.66 | 9.89 ± 3.11 | 7.10 ± 1.55 | 0.85 ± 0.05 | 0.90 ± 0.01 |
| EXTREMA | 48.37 ± 3.01 | 34.59 ± 4.01 | 9.27 ± 0.65 | 6.97 ± 0.55 | 0.80 ± 0.01 | 0.82 ± 0.02 |
| FOCO | 49.95 ± 4.03 | 34.93 ± 3.98 | 9.61 ± 1.04 | 7.53 ± 0.17 | 0.80 ± 0.02 | 0.88 ± 0.01 |
| ANOVA | 243045.57 ** | 142.65 ** | 54.16 ** | 142.22 ** | 142.65 ** | 264.79 ** |
| C.V. (%) | 0.04 | 14.82 | 22.93 | 14.85 | 14.82 | 0.96 |

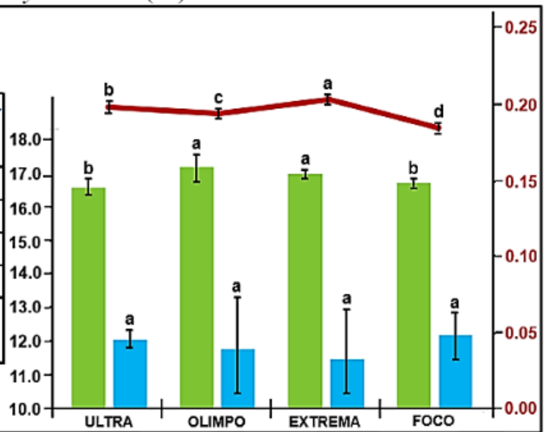
Source: UFAC itself, Rio Branco, AC, Brazil, 2024. Different letters indicate that there was a statistically significant difference (**) between the means by the Tukey test at the 1% probability level; C.V.: coefficient of variation; ANOVA: analysis of variance.

The Extrema cultivar showed the highest values of viability (98%) and mass (0.21±0.02 g). Regarding seed moisture content, the four cultivars exhibited similar values, ranging from 12.04±0.01%; 11.97±0.06%; 11.90±0.05%; and 12.06±0.03%; for Ultra, Olimpo, Extrema, and

Foco cultivars respectively (Figure 3). Zolini *et al*. (2022) tested moisture content by the standard method in soybean grains at two powers of 560 W and 700 W, resulting in an average value of 9.69% for both powers. In the work of Prado *et al*. (2020) the moisture content of commercial soybean seeds of the NS 7780 IPRO cultivar that were subjected to storage five times (0 day, 90 days, 180 days, 270 days, and 360 days) and two conditions: with control (RH of 70%) and without control (exposed to the closed environment and without acclimatization), found an average result at zero day of 9.23%. Therefore, the results of both authors mentioned were lower when compared to our water content on a wet basis.

Figure 3. Parameters (mean ± standard error) of the morphological variables of the seeds of four cultivars (Ultra, Olimpo, Extrema and Foco) of *Glycine max* (L.) Merrill.

| Cultivars | Weight of a thousand seeds (g) | Water Content (%) | Mass (g) | Viability (%) |
|---|---|---|---|---|
| ULTRA | 16.71 ± 0.06 | 12.04 ± 0.01 | 0.20 ± 0.05 | 97.00 |
| OLIMPO | 17.33 ± 0.12 | 11.97 ± 0.06 | 0.19 ± 0.01 | 95.00 |
| EXTREMA | 17.11 ± 0.01 | 11.90 ± 0.05 | 0.21 ± 0.02 | 98.00 |
| FOCO | 16.85 ± 0.02 | 12.06 ± 0.03 | 0.17 ± 0.03 | 95.00 |
| ANOVA | 17.26 ** | 0.04 ns | 326.88 ** | |
| C.V. (%) | 1.10 | 6.47 | 1.20 | |




Source: UFAC itself, Rio Branco, AC, Brazil, 2024. Different letters indicate that there was a statistically significant difference (**) and the same letters indicate non-significant (ns) between the means by the Tukey test at the 1% probability level; C.V.: coefficient of variation; ANOVA: analysis of variance.

Analyzing the results of the electrical conductivity test (Table 1), it can be observed that there was a tendency for the amount of electrolytes released by the Foco cultivar (132.14±1.29 $\mu S.cm^{-1}.g^{-1}$) to increase over the soaking time. The Ultra cultivar presented lower average electrical conductivity values (32.15±0.80 $\mu S.cm^{-1}.g^{-1}$), indicating greater vigor. However, these increases in leachates over time are proportional for each of the four cultivars. Therefore, the similarity in the ordering of the four cultivars in the 12-h soaking period indicates that it is possible to perform the test in less time and, consequently, obtain faster results.

Research on physiological quality carried out by Gaban *et al.* (2024) using six commercial cultivars of RSF IPRO technology produced in the 2020/2021 harvest, compared six lots for each cultivar, concluding that lot 3 of the DM Foco 74I77 RSF IPRO cultivar obtained 112 μS.cm⁻¹.g⁻¹, corroborating the highest percentage of greenish seeds and consequently lower vigor. Therefore, their results presented a lower average electrical conductivity value than the Foco cultivar of this research.

Table 1. Mean values (± standard error) of electrical conductivity ($\mu S.cm^{-1}.g^{-1}$) as a function of the imbibition periods (4, 8, 12, 16, 20 and 24 h) of four cultivars (Ultra, Olimpo, Extrema, and Foco) of *Glycine max* (L.) Merrill.

| The imbibition Periods | Cultivars | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ULTRA | | OLIMPO | | EXTREMA | | FOCO | |
| 4 h | 32.15 ± 0.80 | Fb | 36.04 ± 0.53 | Eb | 43.71 ± 0.70 | Ea | 48.25 ± 1.25 | Da |
| 8 h | 53.09 ± 2.32 | Ea | 42.00 ± 0.92 | Eb | 47.90 ± 0.96 | Eab | 52.32 ± 0.35 | Da |
| 12 h | 60.86 ± 0.65 | Dc | 67.39 ± 1.04 | Dbc | 74.19 ± 1.06 | Dab | 76.44 ± 0.69 | Ca |
| 16 h | 89.52 ± 1.14 | Cbc | 97.37 ± 1.50 | Ca | 85.35 ± 2.47 | Cc | 93.85 ± 0.53 | Bab |
| 20 h | 101.14 ± 0.62 | Bc | 106.62 ± 2.88 | Bc | 114.26 ± 4.37 | Bb | 124.58 ± 3.68 | Aa |
| 24 h | 109.84 ± 1.25 | Ac | 120.17 ± 1.46 | Ab | 124.43 ± 3.65 | Ab | 132.14 ± 1.29 | Aa |
| Mean values | 74.43 | d | 78.26 | c | 81.64 | b | 87.93 | a |
| ANOVA | 8.60 ** | | | | | | | |
| C.V. | 4.62 | | | | | | | |

Source: UFAC, Rio Branco, AC, Brazil, 2024. Lowercase letters in the row (cultivars) and uppercase letters in the column (soaking periods), do not differ by Tukey's test. **: significant at the 1% probability level ($p < 0.01$); C.V.: coefficient of variation; ANOVA: analysis of variance.

In Table 2, it can be seen that the treatments with temperature and photoperiod of 25ºC-12 h light and 27ºC-14 h light were the seeds that expressed the maximum germination potential, being classified as statistically similar, noting that the maximum germination percentage is influenced by temperature.

The highest average value of germination percentage achieved seven days after the implementation of the test was for the Ultra cultivar in the treatment of 27ºC-14 h light (80±1.63%) and followed by the treatment of 25ºC-12 h light (77±1.91%), both being statistically equal.

For Ciscon *et al*. (2021), the Monsoy IPRO cultivars produced in the 2018/2019 harvest had a percentage of 63% for 5917 IPRO and 90% for 6410 IPRO and both tests were installed in a BOD-type incubator, at a temperature of 25ºC and a photoperiod of 12 h. Compared with our percentage average in the Ultra cultivar, the values were higher than cultivar 5917 IPRO and lower than cultivar 6410 IPRO.

Table 2. Mean values (± standard error) of germination percentage (%) as a function of temperature/photoperiod alternation of four cultivars (Ultra, Olimpo, Extrema, and Foco) of *Glycine max* (L.) Merrill.

| Temperature photoperiod | Cultivars | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ULTRA | | OLIMPO | | EXTREMA | | FOCO | |
| 25°C-12 h luz | 77.00 ± 1.91 | Aa | 71.00 ± 4.43 | Aab | 64.00 ± 2.83 | Aab | 61.00 ± 2.52 | Ab |
| 30°C-12 h luz | 51.00 ± 4.12 | Ba | 53.00 ± 4.73 | BCa | 44.00 ± 4.32 | Ba | 45.50 ± 7.72 | Aa |
| 35°C-12 h luz | 39.00 ± 1.00 | Ba | 44.00 ± 4.00 | Ca | 36.00 ± 1.63 | Ba | 48.00 ± 5.66 | Aa |
| 25°C-14 h luz | 69.00 ± 1.91 | Aa | 63.00 ± 3.42 | Aba | 71.00 ± 3.41 | Aa | 61.00 ± 5.97 | Aa |
| 27°C-14 h luz | 80.00 ± 1.63 | Aa | 75.00 ± 1.91 | Aab | 71.00 ± 4.43 | Aab | 61.00 ± 2.52 | Ab |
| 30°C-10 h luz | 49.00 ± 1.90 | Ba | 53.00 ± 5.26 | BCa | 43.00 ± 5.25 | Ba | 46.00 ± 5.29 | Aa |
| Mean values | 60.83 | a | 59.83 | ab | 54.83 | ab | 53.75 | b |
| ANOVA | 10.41 ** | | | | | | | |
| C.V. | 14.05 | | | | | | | |

Source: UFAC, Rio Branco, AC, Brazil, 2024. Lowercase letters in the row (cultivars) and uppercase letters in the column (temperature/photoperiod alternation) do not differ according to Tukey's test. **: significant at the 1% probability level ($p < 0.01$); C.V.: coefficient of variation; ANOVA: analysis of variance.

The seeds of the Ultra cultivar 25ºC-12 h light and 27ºC-14 h light resulted in an average germination speed index of 10.00±1.91 seeds/day and 9.99±0.31 seeds/day respectively (Table 3) sown on paper.

Table 3 shows that temperature affects the germination speed, with cultivars subjected to 30ºC and 35ºC leading to a reduction in their speed.

In the study by Werner *et al.* (2020), the values obtained in soybean seeds of the MS8644 IPRO cultivar, incubated in BOD and subjected to different micronutrients (zinc, boron, cobalt, molybdenum, and control) were on average 15 seeds/day. These values are higher than those found in this research.

Table 3. Mean values (± standard error) of germination speed index (seeds/day) as a function of alternating temperatures/photoperiod of four cultivars (Ultra, Olimpo, Extrema and Foco) of *Glycine max* (L.) Merrill.

| Temperature photoperiod | Cultivars | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ULTRA | | OLIMPO | | EXTREMA | | FOCO | |
| 25°C-12 h luz | 10.00 ± 1.91 | Aa | 9.36 ± 0.50 | Aa | 6.66 ± 0.33 | BCb | 8.25 ± 0.44 | Aab |
| 30°C-12 h luz | 7.04 ± 0.51 | BCa | 7.06 ± 0.52 | BCa | 5.31 ± 0.83 | Cdab | 4.75 ± 0.72 | Bb |
| 35°C-12 h luz | 3.93 ± 1.00 | Da | 4.40 ± 0.28 | Da | 3.41 ± 0.09 | Da | 4.48 ± 0.58 | Ba |
| 25°C-14 h luz | 8.65 ± 0.31 | ABa | 7.93 ± 0.32 | ABa | 8.66 ± 0.37 | Aa | 7.56 ± 0.97 | Aa |
| 27°C-14 h luz | 9.99 ± 0.31 | Aa | 9.38 ± 0.19 | Aab | 8.56 ± 0.70 | Abab | 7.76 ± 0.25 | Ab |
| 30°C-10 h luz | 6.23 ± 0.16 | Ca | 5.11 ± 0.43 | CDab | 4.16 ± 0.40 | Da | 4.35 ± 0.48 | Bb |
| Mean values | 7.66 | a | 7.21 | a | 6.13 | b | 6.19 | b |
| ANOVA | 19.40 ** | | | | | | | |
| C.V. | 14.13 | | | | | | | |

Source: UFAC, Rio Branco, AC, Brazil, 2024. Lowercase letters in the row (cultivars) and uppercase letters in the column (temperature/photoperiod alternation) do not differ according to Tukey's test. **: significant at the 1% probability level ($p < 0.01$); C.V.: coefficient of variation; ANOVA: analysis of variance.

The average germination time was fast for all treatments (Table 4), however, the longest average time occurred in the Foco cultivar with 5.55±0.08 days (35ºC-12 h light) and 5.57±0.20 days (30ºC-10 h light). However, the Ultra cultivar had no statistical difference for 25ºC-12 h light (4.00±0.02 days) and 27ºC-14 h light (4.23±0.09 days), however, the shortest time was reached in 30ºC-12 h light (3.79±0.05 days).

Table 4. Mean values (± standard error) of mean germination time (day) as a function of temperature/photoperiod alternation of four cultivars (Ultra, Olimpo, Extrema and Foco) of *Glycine max*. (L.) Merrill.

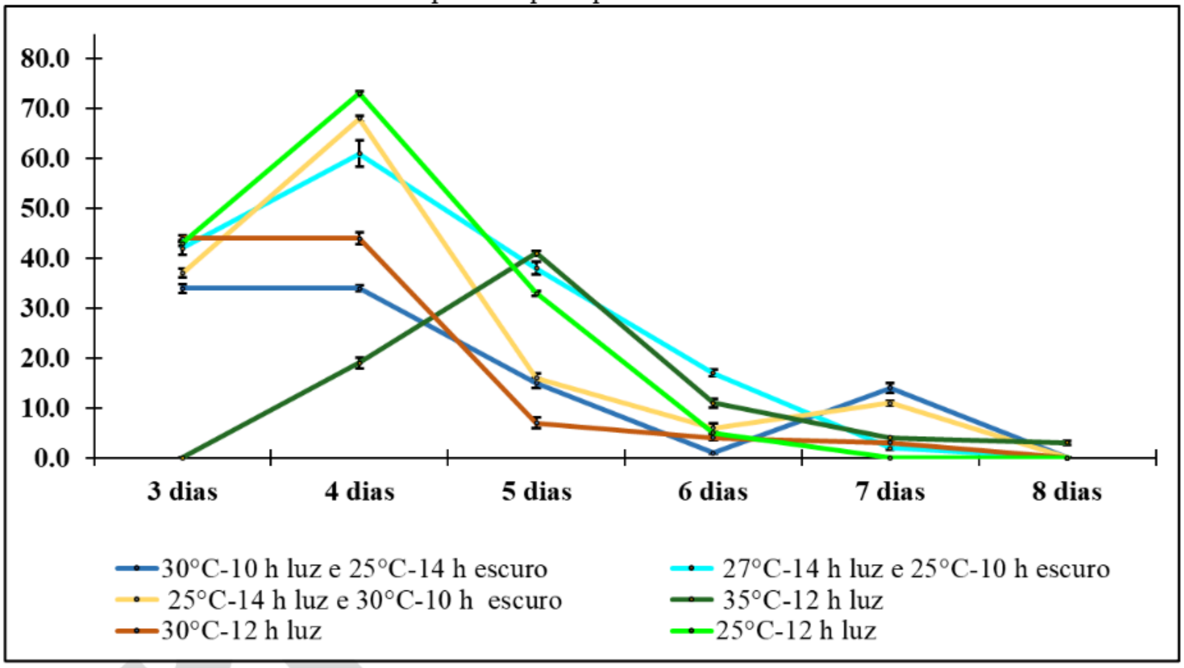
| Temperature photoperiod | Cultivars | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ULTRA | | OLIMPO | | EXTREMA | | FOCO | |
| 25°C-12 h luz | 4.00 ± 0.02 | Ba | 3.98 ± 0.08 | Bb | 4.99 ± 0.33 | Aa | 3.90 ± 0.06 | Db |
| 30°C-12 h luz | 3.79 ± 0.05 | Bb | 3.95 ± 0.08 | Bb | 3.85 ± 0.83 | Cb | 4.94 ± 0.05 | Ba |
| 35°C-12 h luz | 5.12 ± 0.16 | Ab | 5.13 ± 0.11 | Ab | 5.42 ± 0.09 | Aab | 5.55 ± 0.08 | Aa |
| 25°C-14 h luz | 4.25 ± 0.09 | Ba | 4.25 ± 0.10 | Ba | 4.38 ± 0.37 | Ba | 4.41 ± 0.22 | Ca |
| 27°C-14 h luz | 4.23 ± 0.09 | Ba | 4.22 ± 0.10 | Ba | 4.41 ± 0.70 | Ba | 4.14 ± 0.07 | CDa |
| 30°C-10 h luz | 4.24 ± 0.13 | Bb | 5.43 ± 0.15 | Aa | 5.42 ± 0.40 | Aa | 5.57 ± 0.20 | Aa |
| Mean values | 4.26 | c | 4.49 | b | 4.74 | a | 4.75 | a |
| ANOVA | 30.37 ** | | | | | | | |
| C.V. | 4.86 | | | | | | | |

Source: UFAC, Rio Branco, Brazil, AC, 2024. Lowercase letters in the row (cultivars) and uppercase letters in the column (temperature/photoperiod alternation) do not differ according to Tukey's test. **: significant at the 1% probability level ($p < 0.01$); C.V.: coefficient of variation; ANOVA: analysis of variance.

The Ultra cultivar shows the best average values for the three germination variables (G = 77±1.91%), germination speed index (IVG = 10±1.91 seeds/day), and average germination time (TMG = 4±0.02 days).

It can be seen in Figure 4 that at 25ºC-12 h light the cultivar surpasses in germinated seeds per day (3 days = 43 seeds) ending its germination potential on the sixth day (6 seeds), while the other three cultivars prolonged their germination process and compared to the 27ºC-14 h light treatment with fewer germinated seeds on the third day (42 seeds).

Figure 4. Seeds of *Glycine max* (L.) Merrill of the Ultra cultivar, germinated per day depending on the temperature-photoperiod alternation.




Source: UFAC itself, Rio Branco, AC, Brazil, 2024.

## 4 CONCLUSIONS

Through the viability test using the tetrazolium test on *Glycine max* (L.) Merrill seeds, it was observed that each cultivar presented good quality, with viability rates above 90%. The use of the bulk electrical conductivity test allows the identification of different levels of vigor of *Glycine max* (L.) Merrill seeds, and shorter periods (12 h) can be used to identify more pronounced differences between cultivars. Considering all the parameters evaluated, the effect of temperature and photoperiod on the germination of *Glycine max* (L.) Merrill seeds varied significantly among the different cultivars.

For the Ultra cultivar (75I77RSF IPRO), the treatment of 25ºC with 12 h of photoperiod provided, on average, the best biometric characteristics of the seeds, with perimeter = 38.21 mm, length = 9.98 mm and width = 7.94 mm. Furthermore, in this treatment, the highest number of germinated seeds (43) was observed on the third day, with a germination percentage of 77%, a germination speed index of 10 seeds/day and an average germination time of 4 days.

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