

ORIGINAL RESEARCH PAPER

# Germination and vigor of two varieties of Jiló (*Solanum gilo* Raddi) under different substrates and pH conditions

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**Abstract:** *Jiló* (*Solanum gilo* Raddi) is a vegetable crop widely cultivated in Brazil, particularly by smallholder farmers, and plays an important economic and nutritional role in several regions of the country. However, information regarding the influence of different substrates and pH conditions on seed germination and seedling vigor remains limited. Therefore, this study aimed to evaluate the germination and vigor of two commercial *Jiló* varieties, light-green and dark-green, grown in substrates with different pH levels. The experiment was conducted in a completely randomized design using a 2 × 3 factorial arrangement (two varieties × three substrates), with four replications. The treatments consisted of washed sand (pH 7.0), commercial substrate (pH 6.5), and an organic substrate based on cattle manure (pH 5.5). The evaluated variables were seedling height, root length, number of leaves, fresh mass, and dry mass. Data were subjected to analysis of variance (ANOVA), and means were compared using *Tukey's* test at the 5% significance level. Substrate effects were significant for seedling height, number of leaves, and fresh mass, whereas varietal effects were observed only for the number of leaves. The commercial substrate (pH 6.5) promoted the highest number of leaves in the light-green variety, while the dark-green variety grown in washed sand exhibited the highest fresh mass. In contrast, the organic substrate at pH 5.5 yielded the lowest values for most traits evaluated, indicating a negative effect of higher acidity on early seedling development. It is concluded that substrates with pH values ranging from 6.5 to 7.0 provide more favorable conditions for germination and initial seedling vigor in *Jiló*, regardless of variety, thereby improving crop establishment.

**Keywords:** *Solanum gilo*; physiological quality; early development; agricultural substrates; seedling production; vegetable crops.

## 1. Introduction

*Solanum gilo* Raddi (jiló) belongs to the Solanaceae family and is one of the most widely cultivated tropical vegetables in Brazil, especially in the Southeast and Midwest regions. Native to West Africa, it was introduced into the country during the colonial period and has become an important component of Brazilian cuisine and family farming systems (Filgueira, 2008; Pereira, 1989). The crop has considerable socioeconomic importance, particularly for small-scale farmers supplying local markets.

Despite the increasing market demand, the production of jiló seedlings still faces challenges related to achieving uniform stands and successful crop establishment. Seed physiological quality is one of the main factors determining production success, since the germination process is influenced by environmental conditions and intrinsic species characteristics. Seeds of Solanaceae species are often highly sensitive to factors such as temperature, water availability, oxygen supply, and substrate physicochemical properties, which directly affect germination rate and percentage (Bewley et al., 2013; Brasil, 2009). Recent studies have

demonstrated that changes in germination conditions significantly influence seedling vigor and early development in Solanaceae species, directly affecting plant establishment and subsequent agronomic performance (Metwally et al., 2022).

Among environmental factors, the substrate plays a fundamental role in seedling establishment, serving as a physical support and a source of water, oxygen, and nutrients (Ferrarezi et al., 2024). The physical and chemical properties of substrates, including bulk density, porosity, water-holding capacity, and hydrogen potential (pH), directly influence seedling emergence and root growth (Marcos Filho, 2015). Substrate pH affects nutrient availability, microbial activity, and several metabolic processes involved in plant growth. Excessively acidic or alkaline conditions may impair germination and seedling development by affecting nutrient uptake and cellular physiological balance (Malavolta et al., 1997; Alvarez et al., 1999). Recent studies have shown that seed germination and early seedling growth respond significantly to pH variations, highlighting the importance of this factor for successful crop establishment (Follmer et al., 2021; Msimbira et al., 2022).

In Brazil, the three most commonly used substrates for vegetable seedling production are washed sand, commercial substrates, and manure-based organic composts. Each material presents distinct characteristics regarding pH, porosity, water retention, and nutrient availability, directly influencing seedling vigor (Sediyama et al., 2014; Nakagawa, 1999).

In the context of vegetable seedling production, different substrate materials are used, particularly washed sand, commercial growing media, and manure-based organic composts. These substrates differ in water retention, aeration, nutrient availability, and pH values, which may result in distinct responses regarding germination performance and seedling vigor (Nakagawa, 1999; Sediyama et al., 2014). Recent studies involving Solanaceae species have demonstrated that substrate composition and chemical properties significantly affect root growth, nutrient uptake, and seedling development, emphasizing the importance of selecting appropriate materials for seedling production (Trejo-Téllez et al., 2022; Villarreal-Sánchez et al., 2022).

Given this scenario, the present study aimed to evaluate the germination and vigor of two commercial jiló varieties, light-green and dark-green, grown in three substrates with different pH values to identify the most suitable conditions for producing vigorous seedlings. Specifically, the study sought to compare the performance of the two varieties regarding seedling

height, root length, number of leaves, and fresh biomass; evaluate the effect of substrate-associated pH on early seedling development; and provide practical information to support jiló seedling production management in Rio Verde, Goiás State, Brazil, and similar regions.

## 2. Material and Methods

### 2.1. Experimental site and period

The experiment was conducted at the greenhouse facilities of UniBRAS Rio Verde University Center, Rio Verde, Goiás State, Brazil (17°47'53" S and 50°55'41" W; 748 m above sea level), from September to November 2025. The region is characterized by a tropical savanna climate (Köppen classification: Aw), with a rainy summer and a dry winter.

### 2.2. Experimental design and treatments

The experiment was arranged in a completely randomized design (CRD) in a  $2 \times 3$  factorial scheme, consisting of two jiló (*S. gilo* Raddi) varieties (light-green and dark-green) and three substrate types (washed sand, commercial substrate, and cattle manure-based organic substrate), with four replications per treatment, totaling 24 experimental units.

Seeds of both varieties were sown directly into plastic pots containing the respective substrates. After seedling emergence, thinning was performed, leaving one uniform plant per pot. Throughout the experimental period, irrigation was carried out daily to maintain substrate moisture near field capacity.

The substrates presented distinct pH values: washed sand pH 7.0, commercial substrate pH 6.5, and organic substrate pH 5.5. Substrate pH was determined using a 1:2.5 substrate-to- $\text{CaCl}_2$  solution (0.01 mol L<sup>-1</sup>) ratio and measured with a bench pH meter, following the methodology proposed by Embrapa Solos (Teixeira et al., 2017).

### 2.3. Evaluated variables

Seedling growth and vigor were assessed at the end of the evaluation period using the following variables: Seedling height (SH): measured in centimeters from the collar region to the apex of the main stem using a graduated ruler; Root length (RL): measured in centimeters from the collar region to the tip of the primary root after carefully removing the substrate and washing the root system; Number of leaves (NL): determined by counting fully expanded and visually healthy leaves; Fresh mass (FM): obtained immediately after harvesting

using an analytical balance with 0.001 g precision and expressed in grams per plant, and Dry mass (DM): determined after drying the plant material in a forced-air circulation oven at 65 °C until constant weight (approximately 72 h), and subsequently weighed on an analytical balance, with results expressed in grams per plant.

#### 2.4. Statistical analysis

Data were subjected to analysis of variance (ANOVA) considering the effects of variety, substrate, and their interaction. When significant effects were detected by the *F*-test ( $p \leq 0.05$ ), treatment means were compared using Tukey's honestly significant difference (HSD) test at the 5% probability level.

Before the analyses, data were evaluated for normality of residuals and homogeneity of variances using the Shapiro-Wilk and Bartlett tests, respectively. All statistical analyses were performed using R software version 4.3.0 (R Core Team, 2025). The coefficient of variation (CV, %) was calculated as an indicator of experimental precision.

### 3. Results

#### 3.1. *Solanum gilo*

Factorial analysis of variance revealed a significant effect of substrate type (Factor B) on seedling height ( $p = 0.018$ ), number of leaves ( $p = 0.002$ ), and fresh mass ( $p = 0.007$ ). In contrast, the variety factor (Factor A) did not significantly affect any of the evaluated growth variables when analyzed independently.

A significant Variety  $\times$  Substrate interaction was observed for the number of leaves ( $p = 0.018$ ), indicating that the response of the two jiló varieties to substrate conditions differed for this trait. This result suggests that the effect of substrate characteristics on leaf development is dependent on the genotype evaluated.

The statistical results, including treatment means, standard deviations, and analysis of variance (ANOVA) parameters for the evaluated variables, are presented in (Table 1).

Seedling height was significantly affected by substrate type ( $F = 5.09$ ;  $p = 0.018$ ), whereas neither variety nor the interaction between variety and substrate showed significant effects (Table 1). Among the evaluated treatments, the commercial substrate pH 6.5 promoted the highest mean seedling height, reaching 5.50 cm for the light-green variety and 3.88 cm for the dark-green variety. In contrast, the organic substrate pH 5.5 resulted in the lowest growth values, with mean heights of 3.63 cm and 3.25 cm for the light-green and dark-green varieties,

respectively. These findings indicate that substrate conditions exerted a greater influence on early seedling growth than the genetic differences between the evaluated varieties.

Root length was not significantly affected by variety, substrate, or the interaction between these factors, as the analysis of variance detected no statistical differences ( $p > 0.05$ ) for this variable (Table 1). The lack of significance may be attributed to the high variability observed among replicates, as indicated by the elevated coefficients of variation, which reached 51.3% for the light-green variety grown in washed sand and 53.7% for the dark-green variety grown in the organic substrate. Although no significant differences were detected, numerical variation was observed among treatments. The highest mean root length was recorded for the light-green variety cultivated in washed sand, reaching 25.75 cm.

Leaf number was the variable most responsive to the evaluated factors, showing significant effects of both substrate ( $F = 8.58$ ;  $p = 0.002$ ) and the interaction between variety and substrate ( $F = 5.11$ ;  $p = 0.018$ ) (Table 1). These results indicate that the performance of the varieties regarding leaf production depended on the conditions provided by each substrate. The highest mean value was observed for the light-green variety grown in the commercial substrate pH 6.5, with 6.0 leaves per seedling, differing significantly from the organic substrate treatment for the same variety 3.25 leaves, the dark-green variety grown in the commercial substrate 4.0 leaves, and the dark-green variety grown in the organic substrate 3.25 leaves. In contrast, the lowest values were recorded in the organic substrate pH 5.5, regardless of variety, indicating reduced leaf development under this condition.

Fresh mass was significantly affected by substrate type ( $F = 6.68$ ;  $p = 0.007$ ), whereas the interaction between variety and substrate was not significant (Table 1). According to Tukey's test, the dark-green variety grown in washed sand pH 7.0 exhibited the highest mean fresh mass, reaching 2.25 g per seedling. This value differed significantly from those observed for the light-green variety grown in the organic substrate 0.26 g and the dark-green variety grown in the same substrate 0.24 g. In general, the lowest fresh mass values were recorded in the organic substrate pH 5.5, regardless of variety, indicating reduced biomass accumulation under these conditions.

A high level of variability was observed among replicates of the dark-green variety grown in washed sand, as reflected by the coefficient of variation of 85.9%. This behavior was mainly influenced by a single experimental unit that exhibited a fresh mass considerably higher than the remaining observations within the same treatment. Despite this variability, the overall trend of the results

indicates superior seedling performance in substrates with pH values closer to neutrality compared with the more acidic organic substrate.

Dry mass did not differ significantly among the evaluated treatments ( $p > 0.05$ ), indicating high variability among the experimental units (Table 1). Most of the observed values were extremely low, ranging from 0.0001 to 0.0004 g, which can be attributed to the early developmental stage of the seedlings at the time of evaluation. However, some treatments exhibited higher values than the others, particularly the light-green variety grown in washed sand and commercial substrate, as well

as the dark-green variety grown in washed sand.

The wide dispersion of the data for this variable contributed to increased experimental variability and, consequently, to the absence of statistically detectable differences among treatments. Nevertheless, the results suggest a tendency toward greater dry matter accumulation in seedlings grown in washed sand and commercial substrates compared with the organic substrate, although this response was not sufficient to demonstrate a significant effect under the conditions of the present study.

Table 1. Mean values ( $\pm$  standard deviation) of seedling vigor variables of light-green and dark-green *Solanum gilo* varieties cultivated in different substrates. Results of the two-factor analysis of variance (ANOVA) are presented for each evaluated variable ( $n = 4$ ). F-statistics and associated p-values refer to the effect of substrate within each variety.

| Variety / Substrate                                  | Height (cm)        | Root length (cm)    | N. Leaves          | Fresh mass (g)     | F (substrate) | p-value |
|------------------------------------------------------|--------------------|---------------------|--------------------|--------------------|---------------|---------|
| Light-Green variety                                  |                    |                     |                    |                    |               |         |
| Washed sand (pH 7.0)                                 | 5.18 $\pm$ 1.65 ab | 25.75 $\pm$ 13.20 a | 4.25 $\pm$ 0.50 b  | 1.48 $\pm$ 0.65 ab | -             | -       |
| Commercial (pH 6.5)                                  | 5.50 $\pm$ 1.78 a  | 12.63 $\pm$ 2.36 b  | 6.00 $\pm$ 0.82 a  | 1.56 $\pm$ 0.68 a  | 5.09**        | 0.02    |
| Organic (pH 5.5)                                     | 3.63 $\pm$ 0.48 b  | 14.63 $\pm$ 2.87 b  | 3.25 $\pm$ 0.50 c  | 0.26 $\pm$ 0.10 c  | 8.58***       | 0.00    |
| Dark-Green Variety                                   |                    |                     |                    |                    |               |         |
| Washed sand (pH 7.0)                                 | 5.25 $\pm$ 0.96 a  | 17.88 $\pm$ 8.70 a  | 5.00 $\pm$ 1.41 ab | 2.25 $\pm$ 1.93 a  | -             | -       |
| Commercial (pH 6.5)                                  | 3.88 $\pm$ 0.63 ab | 11.75 $\pm$ 1.56 b  | 4.00 $\pm$ 0.00 b  | 0.62 $\pm$ 0.12 b  | 6.68***       | 0.01    |
| Organic (pH 5.5)                                     | 3.25 $\pm$ 0.65 b  | 17.50 $\pm$ 9.39 a  | 3.25 $\pm$ 1.26 c  | 0.24 $\pm$ 0.16 b  | -             | -       |
| <b>Variety (F / p)</b>                               | 1.89 / 0.18        | 0.39 / 0.54         | 1.32 / 0.26        | 0.03 / 0.85        | -             | -       |
| <b>Variety <math>\times</math> Substrate (F / p)</b> | 1.19 / 0.33        | 1.01 / 0.38         | 5.11 / 0.02        | 1.88 / 0.18        | -             | -       |

Note: Means followed by the same lowercase letter within a column do not differ significantly according to *Tukey's* test ( $p > 0.05$ ), considering all six treatment combinations (3 substrates  $\times$  2 varieties). \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ . Source: Authors, 2026

#### 4. Discussion

The significant effect of substrate on seedling height demonstrates the importance of physicochemical conditions during the early establishment of *Solanum gilo*. The superior performance observed in the commercial substrate pH 6.5, particularly for the light-green variety, can be attributed to the greater balance between aeration, water retention, and nutrient availability. According to Marcos Filho (2015), seedling height is one of the most sensitive indicators of seedling vigor because it reflects the efficiency of nutrient uptake and biomass allocation during early growth. Similar results were reported by Trejo-Téllez et al. (2022), who observed that substrates with balanced physical and chemical characteristics significantly enhanced seedling growth in Solanaceae species. Furthermore, Follmer et al.

(2021) demonstrated that pH values close to neutrality favor enzymatic activity and nutrient availability, directly stimulating shoot elongation and seedling establishment.

The lower height values observed in the organic substrate pH 5.5 suggest that excessive acidity may have limited nutrient absorption and root metabolic activity. Acidic conditions can reduce the availability of essential macronutrients such as phosphorus, calcium, and magnesium while increasing the solubility of potentially toxic ions, negatively affecting plant development (Malavolta et al., 1997; Alvarez et al., 1999). Similar findings were reported by Msimbira et al. (2022), who observed reduced seedling growth of tomato under acidic conditions, reinforcing the sensitivity of Solanaceae species to unfavorable pH levels during germination and

early development.

Root length did not differ significantly among treatments, although considerable numerical variation was observed. The absence of statistical significance may be associated with the high experimental variability recorded for this trait. Root growth is strongly influenced by microenvironmental factors and often exhibits greater phenotypic plasticity than shoot growth during the seedling stage (Bewley et al., 2013). The highest mean root length recorded in the light-green variety grown in washed sand may be related to the lower mechanical resistance and greater aeration provided by this substrate. Similar responses were reported by Villarreal-Sánchez et al. (2022), who observed enhanced root exploration in substrates with higher porosity and lower bulk density.

Another possible explanation for the lack of significant differences in root length is the natural compensatory mechanism of seedlings exposed to environments with limited nutrient availability. Under such conditions, plants tend to prioritize root elongation in search of resources, resulting in substantial variability among individual seedlings (Lynch, 2019). This phenomenon may explain the relatively high root length values observed in washed sand despite its low nutrient content.

The number of leaves was the variable most responsive to the experimental treatments, showing significant effects of substrate and the interaction between substrate and variety. Leaf production is directly associated with photosynthetic capacity and is therefore considered a reliable indicator of seedling vigor and future growth potential (Taiz et al., 2017). The superior performance of the light-green variety in the commercial substrate indicates that this genotype may exhibit greater responsiveness to favorable environmental conditions during early development.

The higher leaf production observed under pH 6.5 conditions is consistent with studies demonstrating that nutrient uptake efficiency is optimized within a slightly acidic to neutral pH range. According to Follmer et al. (2021), pH directly affects nutrient solubility and availability, influencing leaf initiation and expansion. Similar results were reported by Metwally et al. (2022), who observed significant increases in leaf formation and seedling vigor in tomato when grown under optimized nutritional conditions. The reduction in leaf number under the organic substrate confirms that excessive acidity can impair photosynthetic structure formation, limiting seedling development.

Fresh mass was significantly influenced by substrate type, with the highest value recorded for the dark-green variety cultivated in washed sand. Fresh biomass accumulation reflects both tissue expansion and water content, being widely used as an indicator of seedling vigor (Nakagawa, 1999). Although washed sand is

nutritionally poor, its excellent aeration and drainage characteristics may have favored root respiration and water uptake, resulting in greater biomass accumulation in some seedlings.

The markedly lower fresh mass values observed in the organic substrate corroborate findings reported for several horticultural species grown under acidic conditions. Trejo-Téllez et al. (2022) demonstrated that substrate composition significantly affects biomass accumulation in Solanaceae seedlings due to differences in nutrient availability and root development. Similarly, Msimbira et al. (2022) found that suboptimal pH conditions reduce cell expansion and water uptake, leading to lower fresh biomass production.

The elevated coefficient of variation observed for fresh mass in the dark-green variety cultivated in washed sand suggests substantial biological variability among individual seedlings. Such variability is common in seedling experiments involving early growth stages, where slight differences in germination timing can result in considerable differences in biomass accumulation (Marcos Filho, 2015). Despite this variability, the overall trend clearly indicates superior performance in substrates with pH values closer to neutrality.

Dry mass exhibited no significant differences among treatments, primarily due to the extremely low values obtained and the high dispersion of the data. Dry matter accumulation generally becomes more evident during later developmental stages, when seedlings have already established a larger photosynthetic apparatus and a more developed root system (Taiz et al., 2017). Therefore, the absence of statistical significance may reflect the early evaluation period rather than the absence of treatment effects.

Although statistical differences were not detected, seedlings cultivated in washed sand and commercial substrate tended to accumulate greater dry biomass than those grown in the organic substrate. Similar trends have been reported for other Solanaceae crops, where favorable pH conditions promoted greater carbon assimilation and biomass accumulation over time (Metwally et al., 2022; Trejo-Téllez et al., 2022). Consequently, extending the evaluation period could potentially reveal more pronounced differences among treatments.

Overall, the results demonstrate that substrate characteristics exert a stronger influence on the initial vigor of *S. gilo* seedlings than varietal differences. The superior performance observed under pH values ranging from 6.5 to 7.0 agrees with previous studies showing that near-neutral substrates provide optimal conditions for nutrient availability, microbial activity, and root growth (Follmer et al., 2021; Msimbira et al., 2022). These findings reinforce the importance of selecting substrates with adequate physicochemical properties to improve seedling quality and ensure successful crop establishment.

## 5. Conclusion

The results of this study demonstrated that substrate characteristics, particularly pH, exert a greater influence on the initial growth and vigor of *Solanum gilo* seedlings than varietal differences under the evaluated conditions. The organic substrate pH 5.5 consistently resulted in lower values of seedling height, number of leaves, and fresh biomass, indicating that acidic substrates may negatively affect early seedling development when pH correction is not performed.

The commercial substrate pH 6.5 provided the most favorable conditions for seedling establishment, especially for the light-green variety, promoting greater leaf production and overall vegetative development. Although washed sand pH 7.0 contains limited nutrient availability, it supported satisfactory root growth and biomass accumulation, particularly in the dark-green variety.

No significant differences were observed between the two varieties for most evaluated variables, suggesting that substrate properties had a stronger effect on seedling performance than genetic variation during the initial growth stage. Therefore, the use of substrates with pH values near neutrality is recommended for producing vigorous jiló seedlings.

Future studies should include more replications and additional physiological parameters, such as germination speed index, chlorophyll content, and nutrient accumulation, to further elucidate jiló varieties' responses to substrate conditions and to optimize seedling production systems.

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## Author's Contributions

Selismar Martins de Souza: conceptualization,

methodology, investigation, data curation, formal analysis, writing – original draft preparation, and visualization. *Elisabete Nunes da Rocha*: supervision, validation, writing – review and editing, conceptualization, formal analysis, and project administration.

## **Ethics**

This study did not involve human participants, animals, or any procedures requiring ethical committee approval. Therefore, ethical approval and informed consent were not applicable.