Vol. 15, No. 3 (2026): 1254-1263 http://dx.doi.org/10.23960/jtepl.v15i3.1254-1263

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)

Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Effect of Shade Intensity and Soil Types on the Vegetative Growth and Chlorophyll Content of Javanese Pepper (*Piper retrofractum* Vahl.) Seedlings

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Article History:

Received : 09 Desember 2025
Revised : 24 May 2026
Accepted : 29 May 2026

Keywords:

Chlorophyll content,
Javanese pepper,
Shading intensity,
Soil type,
Vegetatif growth.

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ABSTRACT

Javanese pepper is an indigenous Indonesian spice with high economic value and widely utilized as a traditional medicinal plant. Efforts to increase Javanese pepper production require cultivation optimization, particularly during the nursery stage, which is a key factor in the success of on-farm cultivation. This study aimed to determine the optimal nursery conditions for Javanese pepper in terms of shading intensity and soil type. The study employed a two-factor factorial Randomized Complete Block Design (RCBD). The first factor was shading intensity: N1 = 0%, N2 = 50%, N3 = 70%, and N4 = 90%. The second factor was soil type: T1 = Vertisol, T2 = Regosol, and T3 = Latosol. There were 12 treatment combinations replicated three times, resulting in 36 experimental units. Each unit consisted of five plants, totaling 180 polybags. The selection of soil types was based on the dominant soil distribution in the Special Region of Yogyakarta. Observation data were analyzed using Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at the 5% significance level when significant effects were observed. The results showed that the best growth of Javanese pepper seedlings was obtained in Regosol soil under 50–90% shading intensity.

1. INTRODUCTION

Javanese pepper (*Piper retrofractum* Vahl.) is an indigenous Indonesian spice with high economic value and is widely utilized as a traditional medicine. Both domestic and international market demand continues to increase, thereby granting it significant potential as an export commodity (Hasan & Ihsannudin, 2022; Taufik & Soleha, 2020; Boga, 2025). Javanese pepper is used as a raw material in the herbal medicine and pharmaceutical industry, accounting for 9.5% of the total crude herbal drugs (simplisia) in Indonesia (Faramayuda *et al*., 2021). The main compound of Javanese pepper is piperine, which exhibits antiproliferative, antitumor, antioxidant, anti-diabetic, antiobesity, anti-inflammatory, neuroprotective, immunomodulatory, antihypertensive, antipyretic activities, and has the potential to inhibit SARS-CoV-2 (Hikmawanti *et al*., 2021; Tripathi, 2022; Mulyani, 2023; Sabina *et al*., 2013; Umarudin *et al*., 2024). In addition to piperine, this pepper contains alkaloids, flavonoids, tannins, saponins, steroids, triterpenoids, and essential oils that support various bioactivities of the plant (Rivai *et al*., 2020).

Although Javanese pepper has promising economic prospects, its cultivation still faces various constraints. The farming of Javanese pepper has not yet achieved allocative and economic efficiency, thereby necessitating productivity improvements through cultivation optimization (Hasan & Ihsannudin, 2022; Rabbi *et al*., 2019). Farmers' knowledge on pepper cultivation is generally based on traditional practices passed down through generations, whereas technological innovations in cultivation continue to develop (Savitri *et al*., 2023). The nursery stage is a critical factor as it determines the success of plant growth in the field. However, information regarding the optimal environmental conditions for Javanese pepper nursery remains limited.

The growing medium, particularly soil type, plays an important role in supporting the growth of Javanese pepper seedlings. This plant requires soil conditions with good drainage and aeration, as excessively compacted or waterlogged soil can lead to root rot. Different soil types possess distinct physical and chemical characteristics, which are presumed to affect seedling growth. Therefore, Vertisol, Regosol, and Latosol soils were selected as growing media for Javanese pepper seedlings based on their predominance in the Special Region of Yogyakarta.

Another environmental factor influencing the nursery of Javanese pepper is light intensity. Javanese pepper is classified as a plant that is adaptive to shade, yet it still requires an optimal range of solar radiation to support growth and production (Sulistyowati, 2010). Appropriate shading can protect the plant from excessive light exposure and high temperatures, particularly in urban yard cultivation systems. Conversely, excessive shading can reduce photosynthetic processes and plant growth. Therefore, regulating shade intensity is an important factor in the nursery of this plant.

Over the past decade, research on Javanese pepper has largely focused on aspects of bioactivity, phytochemical content, health, socio-economics, and farm development (Setiani, 2024; Anisah & Hayati, 2017; Muzaki *et al*., 2018). However, studies on nursery techniques for Javanese pepper, particularly the interaction between shade intensity and soil type on seedling growth, remain very limited. Information regarding optimum nursery conditions based on local soil types and appropriate shade levels for urban farming systems has also not been extensively reported (Bahruddin *et al*., 2021).

This study aims to determine the optimal nursery conditions for Javanese pepper (*Piper retrofractum* Vahl.) based on the combination of shade intensity and soil type. The novelty of this research lies in the simultaneous testing of four shade intensity levels and three dominant soil types in the Special Region of Yogyakarta to support the cultivation of Javanese pepper in urban yard systems. The hypothesis of this study is that differences in shade intensity and soil type affect the growth of Javanese pepper seedlings, and that there is a specific treatment combination capable of producing the best seedling growth.

2. MATERIALS AND METHODS

2.1. Materials

The research was conducted from April 2025 to November 2025 in Sedayu, Bantul, Special Region of Yogyakarta, at an altitude of 110 meters above sea level. The materials used in this study included Javanese pepper seedlings derived from climbing stem cuttings aged approximately two months, with a cutting length of 25–30 cm and 3–4 nodes. The shading materials used were paranets with different densities to achieve shade intensities of 0%, 50%, 70%, and 90%. The growing media consisted of three soil types, namely Vertisol, Regosol, and Latosol, collected from the Special Region of Yogyakarta.

2.2. Methods

The research was conducted using a Randomized Complete Block Design (RCBD) with a 2-factor factorial pattern, where blocking was based on differences in light intensity conditions at the nursery location. The first factor was shade intensity, consisting of N1 = 0% (no shade), N2 = 50%, N3 = 70%, and N4 = 90%. These shade levels were determined based on the density of the paranet used as shading material and its ability to reduce incoming sunlight, where 50% paranet blocks approximately 50% of sunlight, 70% paranet blocks approximately 70% of sunlight, and 90% paranet blocks approximately 90% of sunlight. The second factor was soil type, consisting of T1 = Vertisol, T2 = Regosol, and T3 = Latosol. The study comprised 12 treatment combinations, each replicated three times, resulting in 36 experimental units. Each experimental unit contained five plants, giving a total of 180 polybags. The research was carried out during the nursery stage of Javanese pepper using climbing stem cuttings (which do not yet require trellising). The nursery medium used polybags measuring 20 × 25 cm, each filled with approximately 5 kg of soil according to the treatment (Figure 1).

2.2.1. Measurement Variables

Variables observed during the experiment were grouped into above and below ground parameters, and chlorophyll content. The above ground involved the increase in length of vines or tendrils, number of vines, number of leaves, stem diameter, fresh and dry weight of plant. All parameters were measured weekly for three months. Length of vines was measured from the base of the stem to the farthermost point of growth using a ruler. Stem diameter was measured

Figure 1. Unit experiment on shade intensity 0%, 50%, 70% and 90%

measured using Vernier calipers at marked positions on the stem. Dry weight of the plants was obtained by first measuring the fresh weight, then drying the samples in an oven at 80°C for 24 hours, after which the dry weight was recorded.

Below ground parameters included root length and root volume. Root volume was measured by immersing the roots of Javanese pepper plants into a graduated cylinder containing a known volume of water and recording the increase in water volume, which corresponded to the root volume.

Chlorophyll analysis was performed on leaf samples using a Shimadzu 1280 UV-Vis spectrophoto-meter to obtain chlorophyll A, chlorophyll B, and total chlorophyll. the analysis was conducted using an extraction method with 80% acetone as the solvent. Specifically, 0.1 g of fresh leaves was crushed and extracted until a homogeneous solution was obtained. The solution was then filtered, and the volume was adjusted to 10 mL. The absorbance of the extracted solution was measured at wavelengths of 663 nm for chlorophyll A and 645 nm for chlorophyll B. Chlorophyll content was calculated using the Arnon formula in Equation (1) – (3), and was expressed as mg/g fresh leaf.

$$\text{Chlorophyll A} = (12.7 \times A663) - (2.69 \times A645) \quad (1)$$

$$\text{Chlorophyll B} = (22.9 \times A645) - (4.68 \times A663) \quad (2)$$

$$\text{Total chlorophyll} = (20.2 \times A645) + (8.02 \times A663) \quad (3)$$

2.2.2. Data Analysis

The observational data were analyzed using Analysis of Variance (ANOVA) for a two-factor factorial experiment arranged in a Randomized Complete Block Design (RCBD). The analysis was conducted to determine the effects of each treatment factor, namely shade intensity and soil type, as well as the interaction effect between the two factors on the growth of Javanese pepper seedlings. When the analysis indicated a significant effect of the treatments or their interaction, a post-hoc test using Duncan's Multiple Range Test (DMRT) was performed at the 5% significance level to identify detailed differences among treatment means.

3. RESULTS AND DISCUSSION

The study on the effect of shade intensity and soil type on the growth of Javanese pepper seedlings were conducted in two stages. The first stage involved the analysis of the physicochemical properties of the soils used as growing media, while the subsequent stage consisted of the nursery process to determine plant growth conditions under various treatments.

3.1. Analysis of Chemical and Physical Properties of Soils as Growing Media

The growing media used in this study were collected from several locations in the Special Region of Yogyakarta, corresponding to the characteristics of each soil type. Vertisol soil was collected from the Bantul region (7°48'31.0"S 110°16'07.8"E), Regosol soil from the Sleman region (7°40'21.3"S 110°18'41.2"E), and Latosol soil from the Gunung Kidul region (7°51'23.7"S 110°30'01.5"E). The results of the chemical and physical analysis of the soil were presented in Table 1 and Table 2, respectively.

Table 1. Chemical properties of soil used in the experiment

Soil Type	N (%)	P (%)	K (%)	Organic Matter (%)	PH
Latosol	0.10	0.04	0.05	0.25	6.18
Regosol	0.29	0.60	0.31	7.91	6.43
Vertisol	0.13	0.17	0.17	3.22	6.90

Table 2. Physical properties of soil used in the experiment

Soil Type	Vertisol	Latosol	Regosol
Soil moisture ø 2 mm	10.23 %	7.06 %	6.06 %
Soil moisture content of a soil clod	11.47 %	6.29 %	5.13 %
Bulk Density (BD)	1.4682 g/cc	1.3131 g/cc	1.0692 g/cc
Particle Density (PD)	1.9988 g/cc	2.6166 g/cc	2.1309 g/cc
Calcium Carbonate Equivalent (CCE)	0.8113 %	0.5312 %	0.6156 %
Silt content	13.13 %	10.63 %	18.49 %
Clay content	43.26 %	52.31 %	7.16 %
Sand content	43.61 %	37.06 %	74.35 %

Based on the analysis results, the highest N, P, and K contents were exhibited by the Regosol soil type, followed by Vertisol and Latosol. Phosphorus plays an important role in root system formation and development (Huang *et al*., 2024), nitrogen supports vegetative growth and leaf formation (Shi *et al*., 2015), while potassium is involved in osmotic regulation, enzyme activity, and plant resistance to environmental stress (Hasanuzzaman *et al*., 2018). In line with previous research on maize (Rahim & Setyawati, 2022), where Regosol soil combined with compost resulted the best for plant height, stem diameter, number of flowers, and number of fruits.

Regosol soil had the highest organic matter content at 7.91%. The high organic matter content in Regosol plays a role in enhancing nutrient availability, improving soil structure, and increasing the soil's water-holding capacity as well as supporting soil microbial activity. These conditions facilitate more optimal nutrient uptake by Javanese pepper seedlings during the nursery phase. Adequate nutrient availability is an important factor in supporting vegetative plant growth, as optimal growth is strongly influenced by the sufficiency of nutrients in the growing medium (Ranesa & Tejowulan, 2024).

In addition to high nutrient and organic matter content, the Regosol soil in this study also had a near-neutral pH (6.43), which further supports the availability of macronutrients for plants compared to soils that are too acidic or too alkaline. This relatively optimal pH condition enhances the efficiency of nitrogen, phosphorus, and potassium uptake by plant roots (Cerozi & Fitzsimmons, 2016). The combination of higher nutrient content, favorable organic matter, and suitable pH conditions is presumed to be the primary factor causing Regosol soil to yield the best growth response of Javanese pepper seedlings during the nursery phase.

Based on the analysis of soil physical properties, the results showed that Regosol soil had the highest sand content at 74.35%, whereas Vertisol soil was dominated by a relatively balanced composition of sand and clay fractions. In Latosol soil, the highest fraction was found in the clay content at 52.31%. These differences in textural composition affect soil physical properties, particularly aeration, porosity, water-holding capacity, and root development. The sandy texture of Regosol supports root development during the nursery phase. During germination and early vegetative growth, plant roots can grow more rapidly in sandy-textured soils due to low mechanical resistance and good aeration (Parwata *et al*., 2017).

The bulk density of Regosol soil was also lower than that of Vertisol, resulting in a looser growing medium that facilitates young root penetration. The more porous soil structure of Regosol allows for more optimal oxygen diffusion in the root zone and reduces the risk of waterlogging, which can inhibit root respiration (Neira *et al*., 2015). These conditions are very important during the nursery phase because early plant growth is strongly influenced by the root's ability to absorb water and nutrients. Conversely, the high clay content in Latosol soil has the potential to increase soil density and reduce aeration, thereby slowing root development. In Vertisol soil, the high clay content can also cause the soil to become compact when wet and hard when dry, making it less optimal for seedling root growth. Thus, the dominance of the sand fraction in Regosol soil is presumed to be one of the main factors supporting better growth of Javanese pepper seedlings compared to other soil types.

3.2. Effect of Soil Type and Shade Intensity on Plant Growth

The growth of Javanese pepper plants was observed through the variables of increase in vine length, number of vines, increase in leaf number, increase in stem diameter, plant fresh weight, plant dry weight, root volume, and root length. Additionally, to examine the effect of shade intensity, chlorophyll a, chlorophyll b, and total chlorophyll were also measured. The increase in vine length was observed on the main vine of Javanese pepper seedlings by calculating the difference between the vine length after 12 weeks of planting and the initial vine length at the time of transplanting (Table 3).

Table 3. Effect of treatments on the increase in vine length (cm) of Javanese pepper

Soil Type	Shade Intensity				Average
	0%	50%	70%	90%	
Latosol	5.25 ± 1.52	7.50 ± 0.50	8.42 ± 3.02	18.75 ± 9.41	9.98 c
Vertisol	10.42 ± 12.27	20.17 ± 9.75	13.50 ± 6.06	21.33 ± 6.06	16.35 b
Regosol	9.58 ± 3,22	19.17 ± 7.08	17.92 ± 12.91	41.50 ± 29.50	22.04 a
Average	8.42 c	15.61 b	13.28 b	27.19 a	

Note: The same lowercase letters following the mean values within the same column indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level.

There was a significant effect of soil type (*p*-value = 0.048) and shade intensity (*p*-value = 0.012), but no interaction between the treatments (*p*-value = 0.649). The best increase in vine length of Javanese pepper was observed in the Regosol soil type and the 90% shade intensity treatment. Regosol soil possesses physical and chemical properties that support early plant growth. Regosol has high porosity and better drainage than Latosol and Vertisol, allowing roots to develop well and supporting faster vine growth. Regosol soil, which has a coarse texture or is rich in sand, exhibits high porosity due to the abundance of macropores in this soil type (Fadlyla *et al*., 2025). Therefor, Regosol soil is easily penetrated by plant roots. This porous nature also accelerates root growth and development, which can increase fresh and dry root production as well as enhance root length and volume (Paulus *et al*., 2018).

The number of vines (Table 4) and increase in stem diameter (Table 5) showed no significant effects for either soil type or shade intensity treatments. These two variables also exhibited no interaction between treatments.

Table 4. Effect of treatments on the number of vines of Javanese pepper

Soil Type	Shade Intensity				Average
	0%	50%	70%	90%	
Latosol	1.67 ± 0.15	2.33 ± 0.58	2.67 ± 0.58	2.33 ± 0.58	2.25
Vertisol	1.33 ± 0.58	2.00 ± 0.01	2.00 ± 1.15	2.67 ± 0.58	2.00
Regosol	2.33 ± 0.58	3.67 ± 1.53	3.00 ± 1.73	2.67 ± 1.53	2.92
Average	1.78	2.67	2.56	2.56	

Table 5. Effect of treatments on the increase in stem diameter (cm) of Javanese pepper

Soil Type	Shade Intensity				Average
	0%	50%	70%	90%	
Latosol	0.63 ± 0.06	0.48 ± 0.03	0.55 ± 0.22	0.57 ± 0.21	0.56
Vertisol	0.52 ± 0.18	0.58 ± 0.10	0.37 ± 0.20	0.85 ± 0.20	0.58
Regosol	0.55 ± 0.09	0.67 ± 0.25	0.60 ± 0.23	0.45 ± 0.15	0.57
Average	0.57	0.58	0.51	0.62	

The increase in leaf number (Table 6) showed a significant effect for the shade intensity treatment (p-value 0.019*), whereas the soil type treatment did not show a significant effect (p-value 0.203). The highest increase in leaf number was observed in the 90% shade intensity treatment, amounting to 8.61. Under low light conditions, Javanese pepper seedlings exhibit an adaptive response by optimizing leaf surface area and producing more leaves to enhance light capture capacity. At lower light intensities, the ratio of auxin to cytokinin increases, resulting in stimulation of aboveground plant growth, including leaf formation. Regosol soil contains higher macronutrients (N, P, and K) than Vertisol and Latosol soil, where these nutrients are required for meristematic tissue formation and vegetative growth,

Table 6. Effect of treatments on the increase in leaf number of Javanese pepper

Soil Type	Shade Intensity				Average
	0%	50%	70%	90%	
Latosol	4.67 ± 0.29	4.17 ± 1.89	3.00 ± 1.32	7.33 ± 2.47	4.79 a
Vertisol	5.83 ± 2.93	5.33 ± 1.61	5.17 ± 3.51	7.83 ± 1.26	6.04 a
Regosol	4.67 ± 0.58	7.00 ± 5.29	5.17 ± 2.72	10.67 ± 4.51	6.88 a
Average	5.06 bc	5.50 b	4.44 c	8.61 a	

Table 7. Effect of treatments on the fresh weight (g) of Javanese pepper plant

Soil Type	Shade Intensity				Average
	0%	50%	70%	90%	
Latosol	4.85 ± 0.29 d	8.50 ± 1.25 cd	12.58 ± 1.08 bc	10.48 ± 1.31 c	9.10
Vertisol	3.99 ± 0.98 d	12.26 ±1.84 bc	12.24 ± 0.74 bc	14.96 ± 0.17 b	10.86
Regosol	9.28 ± 0.29 cd	24.55 ± 2.10 a	24.80 ± 4.32 a	26.23 ± 1.98 a	21.22
Average	6.04	15.10	16.54	17.22	

Note: The same lowercase letters following the mean values within the same column indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level.

Table 8. Effect of treatments on the dry weight (g) of Javanese pepper plant

Soil Type	Shade Intensity				Average
	0%	50%	70%	90%	
Latosol	0.77 ± 0.32 e	7.98 ± 0.88 ab	3.04 ± 0.47 cd	2.46 ± 0.63 d	3.56
Vertisol	0.94 ± 0.09 e	3.26 ± 0.14 cd	3.44 ± 0.67 cd	4.35 ± 0.12 bc	3.00
Regosol	2.88 ± 0.74 d	7.43 ± 1.18 ab	7.76 ± 0.97 ab	9.22 ± 1.04 a	6.82
Average	1.53	6.22	4.75	5.34	

Note: The same lowercase letters following the mean values within the same column indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level.

including vine development (Virgiawan, 2023). To assess plant nutrient uptake during the nursery phase, analyses of plant fresh weight and dry weight were conducted (Tables 7 and 8).

Based on the analysis, soil type and shade intensity treatments together had a significant effect on fresh weight (p-value <0.001) and dry weight (p-value <0.001). The condition of Javanese pepper plants during the vegetative phase is shown in Figure 2. The mean fresh weight values showed a positive increasing trend with increasing shade intensity from 0% (6.04 g) to 90% (17.22 g). This indicates that plants grow more optimally under moderate to high shade conditions (70–90%), which results in more stable soil temperatures and reduced water loss due to transpiration (Hajawa *et al*., 2025).

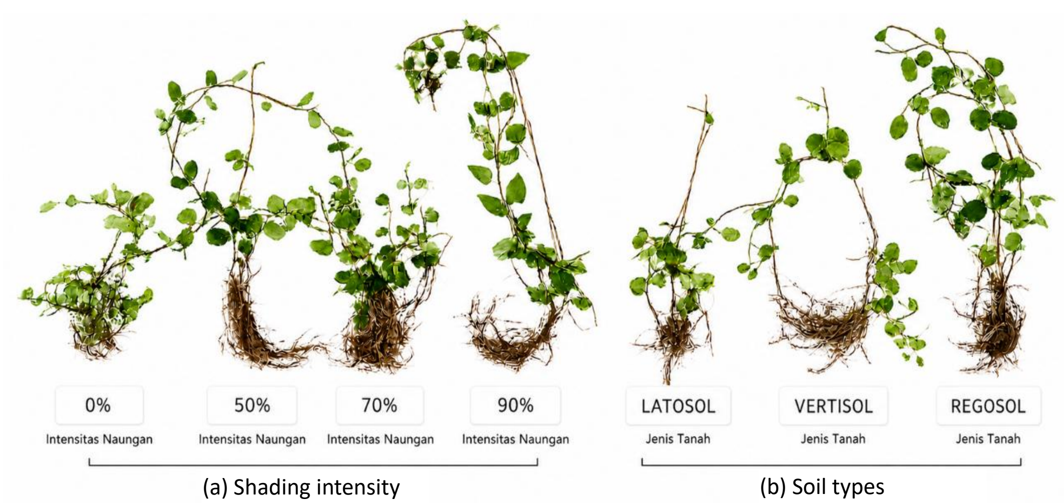

Figure 2. Growth of Javanese pepper plants under various treatments: (a) shadding intensity, (b) Soil types

These results demonstrate that the appropriate combination of growing medium and light conditions plays an important role in supporting plant biomass accumulation during the nursery phase. Regosol soil is presumed to support better vegetative growth due to its sandier texture, good aeration and drainage, and higher organic matter and nutrient content compared to other soil types. These conditions support root system development, water uptake, and nutrient absorption efficiency required for plant biomass formation (Teh *et al*., 2017). Furthermore, the near-neutral pH of Regosol soil also enhances the availability of macronutrients such as nitrogen, phosphorus, and potassium, which play important roles in plant vegetative growth (Huang *et al*., 2025).

Shade intensities of 70–90% are also presumed to create microclimatic conditions more suitable for Javanese pepper, which is naturally a shade-tolerant plant. High shade can reduce radiation intensity and ambient temperature, thereby reducing water loss through transpiration and maintaining growing medium moisture (Popova & Popova, 2021). These conditions allow the plant to allocate more energy to vegetative growth, particularly leaf, vine, and biomass formation. Thus, the combination of Regosol soil and 70–90% shade demonstrates optimal suitability for Javanese pepper nursery, as it maintains a balance between light availability for photosynthesis and supportive environmental conditions.

Based on the root volume observation data (Table 9), there was an interaction between soil type and shade intensity. The combination that showed the highest root volume was Regosol soil at 90% shade intensity. This indicates that Regosol soil, which has a high sand content, facilitates root development, especially during the nursery phase (Mustikawati, 2019). The results of root length observations are shown in Table 10.

Table 9. Effect of treatments on the root volume (mL) of Javanese pepper plant

Soil Type	Shade Intensity				Average
	0%	50%	70%	90%	
Latosol	1.53 ± 0.50 fg	1.83 ± 0.32 ef	3.70 ± 0.81 cd	2.90 ± 0.30 de	2.49
Vertisol	0.60 ± 0.30 g	2.13 ± 0.12 ef	1.87 ±0.60 ef	3.63 ± 0.60 cd	2.06
Regosol	0.77 ± 0.06 g	8.43 ± 0.40 ab	5.67 ± 0.70 bc	9.13 ± 0.60 a	6.00
Average	0.97	4.13	3.74	5.22	

Note: The same lowercase letters following the mean values within the same column indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level.

Table 10. Effect of treatments on the root length (cm) of Javanese pepper plant

Soil Type	Shade Intensity				Average
	0%	50%	70%	90%	
Latosol	10.50 ± 1.50 ef	20.67 ± 1.53 cd	28.00 ± 3.00 bc	18.00 ± 3.50 de	19.29
Vertisol	5.50 ± 1.50 f	28.00 ± 3.00 bc	17.67 ± 1.61 de	34.00 ± 3.50 ab	21.29
Regosol	9.33 ± 1.04 f	44.33 ± 14.01 a	29.67 ± 7.50 bc	30.33 ± 2.08 bc	28.42
Average	8.44	31.00	25.11	27.44	

Note: The same lowercase letters following the mean values within the same column indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level.

Based on the root length data, the longest root was shown in the treatment combination of Regosol soil with 50% light intensity. Regosol soil has high macro-nutrient (N, P, and K) and organic matter content, thereby supporting plant growth, including tissue formation during the nursery phase, particularly root formation (Virgiawan, 2023).

Based on the results of chlorophyll A, B, and total chlorophyll analysis (Table 11), there was an interaction between soil type and shade intensity, where the highest chlorophyll A was shown in the use of Regosol soil with 50–70% shade intensity. The highest chlorophyll B was shown in the use of Regosol soil at 50% shade intensity. These treatment combinations support pigment accumulation under conditions of not excessively high light.

The highest total chlorophyll value was found in the use of Regosol soil with 50% shade intensity, indicating optimal photosynthetic efficiency under these conditions. Regosol soil generally has a loose texture and good aeration, allowing roots to absorb water and nutrients more efficiently, especially nitrogen and magnesium, which are two important elements in chlorophyll formation (Selfandi *et al*., 2021). The use of 50–70% shade intensity creates moderate light conditions, which is presumed to reduce excessive light stress. Under such conditions, plants are able to

Table 11. Effect of treatment combinations on the chlorophyll content of Javanese pepper plant

Soil type and shade intensity	Chlorophyll A	Chlorophyll B	Chlorophyll
Latosol 0%	0.18 b	0.09 c	0.27 d
Latosol 50%	0.18 b	0.11 c	0.28 d
Latosol 70%	0.20 b	0.10 c	0.30 cd
Latosol 90%	0.21 b	0.11 c	0.31 cd
Vertisol 0%	0.14 c	0.11 c	0.25 d
Vertisol 50%	0.23 b	0.11 c	0.33 c
Vertisol 70%	0.24 b	0.15 b	0.39 b
Vertisol 90%	0.20 b	0.10 c	0.29 d
Regosol 0%	0.24 b	0.11 c	0.36 c
Regosol 50%	0.50 a	0.28 a	0.78 a
Regosol 70%	0.46 a	0.17 b	0.42 b
Regosol 90%	0.23 b	0.11 c	0.34 c

Note: The same lowercase letters following the mean values within the same column indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level.

increase the production of photosynthetic pigments (chlorophyll A and B). Using too low shade intensity (0%) results in high incoming light intensity, which can damage pigments (photooxidation), while using too high shade intensity (90%) is presumed to decrease photosynthetic activity due to insufficient light (Carpentier, 2005). An increase in chlorophyll content in plants indicates plant adaptation to light conditions and optimal nutrient availability (Kisman *et al*., 2007).

To support the research data, measurements of light conditions, temperature, and humidity were conducted under various shade intensity treatments. The following are the mean observational data recorded daily for three months (Table 12). Based on these data, the use of shade at various intensities influences the microclimatic conditions of the Javanese pepper nursery site. The use of shade with 90% light absorption intensity provides ideal microclimatic conditions for the plant nursery phase.

Table 12. Mean Light Condition, Temperature, and Humidity

Shade Intensity (%)	Light Intensity (LUX)	Temperature (°C)	Humidity (%)
0	3680	41	56
50	2510	36	50
70	2100	32	49
90	1010	29	50

4. CONCLUSION AND SUGGESTION

Based on the results of this study, it can be concluded that shade intensity and soil type significantly affect the growth of Javanese pepper (*Piper retrofractum* Vahl.) seedlings during the nursery phase. This study demonstrates that the use of Regosol soil combined with 50–90% shade intensity provides the best growth conditions compared to other treatments. These conditions are presumed to provide a more optimal growing environment through good medium aeration and drainage, as well as appropriate light intensity to support the vegetative growth of Javanese pepper seedlings.

The findings of this study offer practical implications, suggesting that the use of Regosol soil and 50–90% paranet shade can be recommended as a nursery technique for Javanese pepper, particularly in yard cultivation systems and urban farming areas with environmental characteristics similar to those of the Special Region of Yogyakarta. These findings also serve as a basis for developing cultivation technology for Javanese pepper during the early growth stage to support improved seedling quality and field cultivation success.

Further research is required to evaluate the effects of shade treatment and soil type on subsequent growth phases, plant productivity, and the content of secondary metabolites such as piperine, so that more comprehensive and sustainable cultivation recommendations for Javanese pepper can be obtained.

AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
RS	✓	✓			✓	✓		✓	✓	✓		✓	✓	✓
AI									✓	✓	✓			
WD				✓						✓		✓	✓	
DA						✓	✓							✓

C: Conceptualization	Fo: Formal Analysis	O: Writing - Original Draft	Fu: Funding Acquisition
M: Methodology	I: Investigation	E: Writing - Review & Editing	P: Project Administration
So: Software	D: Data Curation	Vi: Visualization	
Va: Validation	R: Resources	Su: Supervision	

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