



Growth and Yield Response of Purple Pakcoi (*Brassica rapa* var. *chinensis*) to Shading and Watering Intervals in a Split-Plot Experiment to Support Science Literacy

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Abstract: Optimization of purple pakcoi vegetable cultivation can be done through the management of environmental factors such as shade and watering intervals. This study aims to determine the effect of shade and watering intervals on the growth and yield of purple pakcoi. The experiment used a split-plot design with two factors. The main plot consisted of: N0 (no shade), N1 (50% shade), and N2 (75% shade). The subplots consisted of: P1 (watering every day), P2 (watering every 2 days), and P3 (watering every 3 days). The variables observed were: plant height, number of leaves, fresh shoot weight, dry shoot weight, fresh root weight, dry root weight, shoot-root ratio, and SPAD value. The results showed that the highest average values of each variable were: plant height 34,55 cm; number of leaves 10; fresh shoot weight 96 g; dry shoot weight 3,7 g; fresh root weight 2,4 g; dry root weight 0,32 g; shoot-root ratio 14%; and a SPAD value of 38. Plants grown under 75% shade showed good tolerance to reduced light intensity. These findings suggest that purple pakcoi has the potential to be cultivated in confined urban areas and as an intercrop to improve land use efficiency.

Keywords: Photosynthesis; Shading; Soil moisture; Sunlight

Introduction

Pakcoi (*Brassica rapa* var. *chinensis*), a one of Brassicaceae family, is a vegetable crop rich in nutrients such as calories, protein, fat, carbohydrates, fiber, calcium (Ca), phosphorus (P), iron (Fe), vitamins A, B, C, and E, and magnesium, which are essential for humans (Syahputra, 2022). Pakcoi includes several varieties, including purple Pakcoi. This variety not only serves as an alternative cultivation crop but also adds aesthetic value with its appealing color. Particularly in urban areas, understanding the tolerance limits of purple pakcoi's growth and production under varying levels of sunlight intensity is crucial for successful cultivation (Hao et al., 2020). Light and water availability are two important environmental factors affecting plant growth

and productivity. Sunlight acts as the primary energy source for photosynthesis, and adequate light intensity can enhance plant growth. However, excessive sunlight intensity, especially at midday, may cause physiological stress and lead to plant wilting (Pertamasari et al., 2023). One of the strategies used to regulate light intensity is shading. According to (Ghany et al., 2020), shading combined with appropriate watering management can help maintain optimal environmental conditions for plant growth.

Previous studies have shown that shading affects the quantity and quality of light received by plants, which in turn influences plant growth and development (Arif & Hidayah, 2017). Research by Yustiningsih (2019) shows that the intensity of light intercepted by plants plays a vital role in providing the energy needed for

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photosynthesis, which in turn facilitates cell formation. Additionally, shading serves to protect plants from heavy rainfall during the rainy season. Haryanti (2010) further noted that shading pak choi plants helps create favorable environmental conditions for growth and significantly affects soil moisture content. Both the frequency and the amount of watering influence the soil's water availability. Longer watering intervals reduce soil water availability, potentially causing drought stress in plants (Sakya et al., 2015). Both overwatering and underwatering are detrimental to plants: underwatering leads to insufficient oxygen supply, while overwatering can cause root rot (Tampubolon et al., 2017). Based on research by Nugroho & Setiawan (2022), watering every 2 days with 620 ml of water resulted in optimal growth for pakchoi plants. This study aims to investigate the effects of shading and watering on the growth and yield of purple pakcoi (*Brassica rapa var. chinensis*).

Method

This research was conducted from December 2023 to February 2024 at the Experimental Farm of the Faculty of Agriculture, Baturaja University. The tools used in the study included an oven. A Split-Plot Design (SPD) was applied with two factors: shading treatments (N) as the main plot with three levels – N0 (no shading), N1 (50% shading), N2 (75% shading) – and watering interval treatments (P) as the subplots with three levels – P1 (daily watering), P2 (watering every two days), P3 (watering every three days). Each treatment combination was replicated three times, yielding 27 combinations.

Shading treatments were applied using lightweight polyethylene mesh supported by a shade house frame measuring 2 m x 4 m. Purple pak choi seedlings were transplanted into 25 cm x 30 cm polybags 18 days after sowing (DAS). The polybags were filled with red-yellow podzolic soil mixed with chicken manure in a 3:1 ratio as the planting medium. Fertilization was applied at a rate of 1,5 g per plant (equivalent to 312,5 kg/ha) (Zhu et al., 2025) by sprinkling fertilizer around the plants, maintaining a 5 cm distance from the plant base, at 24 DAS. According to Hermiza et al (2018), irrigation was applied at 300 ml (100% field capacity) per polybag. The experimental area was not covered with plastic, as the study was conducted during the dry season.

The data collected included plant height (cm), number of leaves, fresh shoot weight (g), dry shoot weight (g), fresh root weight (g), dry root weight (g), shoot-root ratio (%), and SPAD values. SPAD values

were measured using a Chlorophyll Meter (Konica Minolta SPAD-502 Plus). Dry weight was determined by oven-drying the samples at 70°C for 48 hours. Analysis of variance (ANOVA) was performed, and significant differences among treatments were assessed using the Least Significant Difference (LSD) test at the 5% significance level. Data analysis was carried out using statistical analysis software (SAS 9.0 for Windows, SAS Institute Inc., Cary, North Carolina, USA).

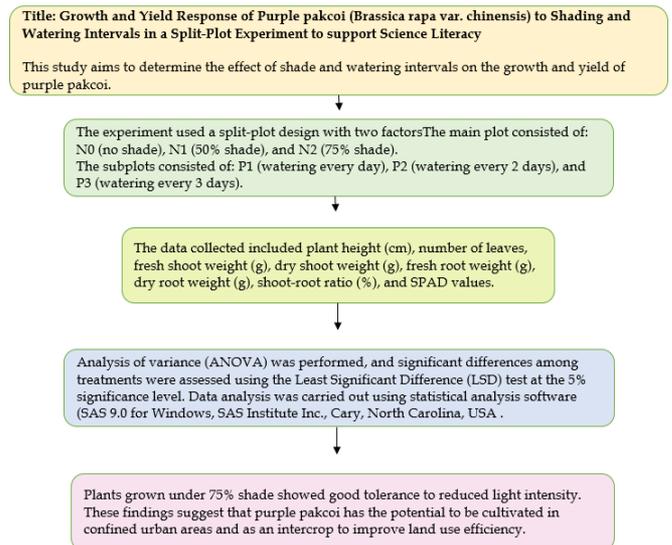


Figure 1. General overview of the research flow carried out

Result and Discussion

Based on statistical analysis, the highest average height of pakcoi plants was observed in the 70% shade treatment (32 cm) and a watering interval of every 2 days (31,6 cm). The highest average number of leaves was in the 70% shade treatment (9,3 leaves) and a watering interval of every 3 days (9,11 leaves). The highest average shoot-root ratio was in the 50% shade treatment (11,93 cm) and a watering interval of every 3 days (12,45%). The average SPAD value, which indicates chlorophyll content, was highest in plants grown without shade (35,81) and watered every 2 days (34,80), although it did not show a significant effect in all treatments (Table 1). The highest average plant height was observed in plants grown under 50% shade combined with watering every 3 days, reaching 34,55 cm. Meanwhile, the highest number of leaves was recorded in the 70% shade treatment combined with watering every 2 and 3 days with an average of 10 leaves. The highest average shoot-root ratio was 14% in 50% shade and watering every 3 days. The SPAD value, which indicates chlorophyll content, was highest at 38 in plants grown without shade and watering every 3 days (Figure 2).

Table 1. The effect of shading and irrigation intervals on plant height, number of leaves, shoot root ratio, and SPAD value on pakcoi plant

Treatment	Plant height (cm)		Number of leaves		Shoot root ratio (%)		SPAD value	
<i>Shading treatment</i>								
No Shade	29.04	± 0.88 a	8.04	± 0.64 a	11.83	± 0.65 a	35.81	± 1.55 a
Shading 50%	30.67	± 1.56 a	8.56	± 0.40 a	11.93	± 0.92 a	32.76	± 0.04 a
Shading 70%	32.00	± 0.95 a	9.37	± 0.60 a	11.02	± 1.12 a	32.77	± 1.69 a
LSD	3.44		1.64		1.82		3.93	
<i>Irrigation intervals</i>								
Everyday	29.56	± 0.34 a	7.81	± 0.47 a	10.94	± 1.03 a	31.83	± 1.27 b
Every 2 days	31.67	± 1.28 a	9.04	± 0.62 b	11.40	± 0.76 a	34.80	± 1.87 a
Every 3 days	30.48	± 1.77 a	9.11	± 0.55 a	12.45	± 0.90 a	34.70	± 1.10 a
LSD	2.66		0.97		1.95		2.12	

Note: Data are presented as mean ± standard error from 9 samples and 3 replicates. Values followed by different lowercase letters within each column indicate significant differences among shading treatments, bulbil weights, and bulbil conditions. Values followed by the same lowercase letters within each column indicate no significant differences among shading treatments, bulbil weights, and bulbil conditions based on LSD at the 0,05 level

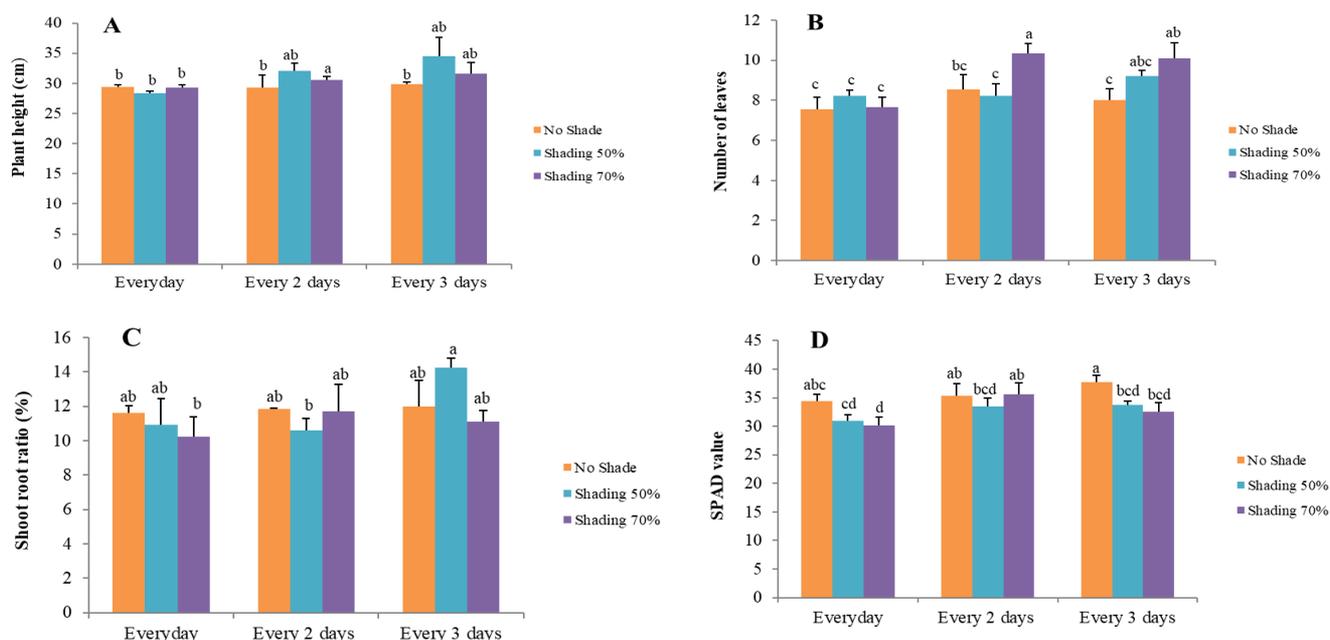


Figure 2. Interaction effect of shading and irrigation intervals of plant height (A) and number of leaves (B), shoot root ratio (C) and SPAD value (D) on pakcoi plant

According to Tripathi et al (2019), plant growth and development depend not only on the products of photosynthesis but also on light itself, which can influence plant development through the pigment systems involved in photomorphogenesis. It is important to note that sunlight also significantly affects the color of plant leaves. Photomorphogenesis is a term used to describe a plant's response to light stimuli, where the direction and timing of this response are not specific. Stem elongation in plants grown in darkness is a result of photomorphogenesis, known as etiolation. The shoot-root ratio is also influenced by the dry weight of the shoots and roots. The higher the dry weight of the shoots, accompanied by a lower dry weight of the roots, the higher the shoot-to-root ratio (Sari et al., 2016). A

high shoot-to-root ratio indicates a faster distribution of photosynthetic products to shoots rather than roots, resulting in a lower root proportion (Rusmana, 2017). The shoot is the edible part of the plant, so a higher shoot-to-root ratio is beneficial because it increases the portion of the plant that can be utilized.

According to Sisriana et al (2021), chlorophyll is a green pigment essential to photosynthesis. This pigment is influenced by adequate water supply, nitrogen (N) and phosphorus (P) uptake by plants, direct sunlight, and the plant's genetics. Andini & Yuliani (2020) reported that tighter shading at 75% results in greener leaves.

Astutik et al (2019) explained that either a deficiency or excess of water and certain nutrients can

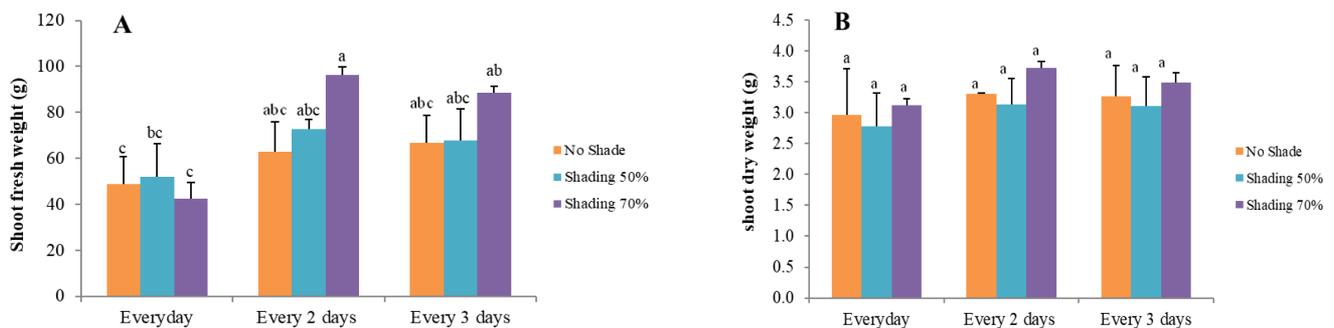
disrupt protein and chlorophyll biosynthesis, cell metabolism, photosynthesis, and ultimately hinder plant growth. Adequate water supply results in higher chlorophyll content compared to insufficient water. Stress conditions due to water shortage reduce chlorophyll content to prevent photoinhibition. Under water stress, chlorophyll fluorescence inhibits damage during electron transfer in Photosystem II (Souza et al., 2009). Plants under 70% shading show good growth, as evidenced by the higher fresh shoot weight of pakcoi under 70% shading. The highest average shoot fresh weight of pakcoi was observed in the 70% shade treatment (75,65 g) and a 2-day watering interval (77,32 g). The highest average shoot dry weight was observed in the 70% shade treatment (3,45 g) and a 2-day watering interval (9,11 g). The highest average root fresh weight was observed in the 50% shade treatment (1,84 g) and a 2-day watering interval (1,67 g). The highest average root dry weight was observed in the 70% shade treatment (0,32 g) and a 2-day watering interval (0,30 g). These results suggest that moderate watering intervals provide more favorable soil moisture conditions for plant growth compared with excessive watering (Table 2). The highest average shoot fresh weight was observed in plants under 70% shade combined with 2-day

watering, reaching 96 g. The highest average root dry weight was recorded in the 70% shade treatment combined with 2-day watering at 3,7 g. The highest average fresh root weight was observed in plants grown under 50% shade combined with daily watering, reaching 2,4 g. The highest average root dry weight was observed in plants grown under 70% shade combined with watering every 2 days, reaching 0,32 g (Figure 3). The interaction between shading and watering interval showed that watering every day under 70% shading produced the best interaction. The interaction between shading and watering intervals also influenced plant growth performance. Plants grown under 70% shading combined with appropriate watering intervals showed better biomass production. This result indicates that shading modifies the microclimate around the plant, including temperature, humidity, and light intensity, which may reduce transpiration rates and improve water use efficiency. This indicates that shading modifies the microclimate around the plant, including temperature, humidity, and light intensity. These changes in microclimate can affect the transpiration rate, ensuring that water remains available in the soil even when watered every 2 days.

Table 2. Effect of shading and irrigation intervals of shoot fresh weight, shoot dry weight, root fresh weight and root dry weight on pakcoi plant

Treatment	Shoot fresh weight (g)		Shoot dry weight (g)		Root fresh weight (g)		Root dry weight (g)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
<i>Shading treatment</i>								
No Shade	59.56	± 12.27	3.18	± 0.43	1.12	± 0.19	0.27	± 0.04
Shading 50%	64.17	± 10.76	3.01	± 0.48	1.84	± 0.53	0.26	± 0.05
Shading 70%	75.65	± 4.53	3.45	± 0.13	1.17	± 0.33	0.32	± 0.04
LSD	13.11		0.37		0.57		0.08	
<i>Irrigation intervals</i>								
Everyday	47.74	± 11.11	2.96	± 0.47	1.48	± 0.36	0.28	± 0.07
Every 2 days	77.32	± 6.89	3.40	± 0.18	1.67	± 0.47	0.30	± 0.02
Every 3 days	74.33	± 9.56	3.29	± 0.38	0.98	± 0.21	0.27	± 0.04
LSD	21.15		0.80		0.82		0.09	

Note: Data are presented as mean ± standard error from 9 samples and 3 replicates. Values followed by different lowercase letters within each column indicate significant differences among shading treatments, bulbil weights, and bulbil conditions. Values followed by the same lowercase letters within each column indicate no significant differences among shading treatments, bulbil weights, and bulbil conditions based on LSD at the 0,05 level



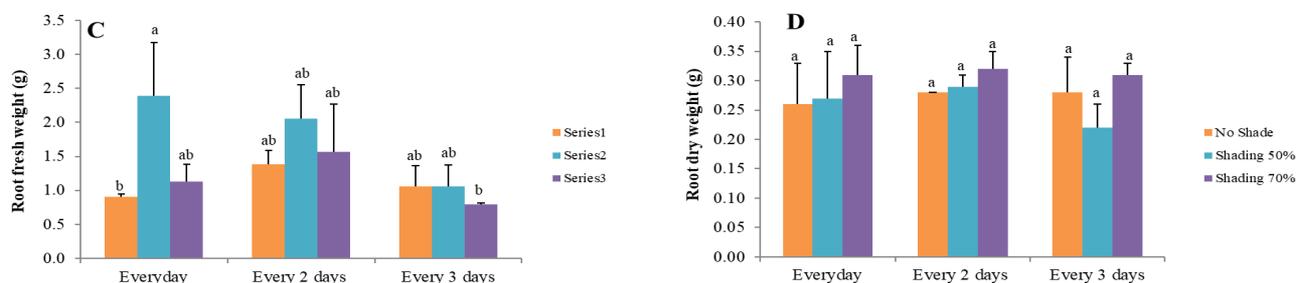


Figure 3. Interaction effect of shading and irrigation intervals of shoot fresh weight (A), shoot dry weight (B), root fresh weight (C) and root dry weight (D) on pakchoi plant

Watering can enhance plant growth by ensuring that the soil moisture required for growth and development is readily available. According to Lestari et al (2018), water plays a crucial role in plant growth and development. A reduction in available water can hinder plant growth. Longer watering intervals can lead to the soil drying out. Oktavia et al (2022) noted that plant growth improves when its water needs are met. This aligns with Castrena et al (2018), who emphasized that sufficient water availability is necessary for plant survival, as water is essential for sustaining life processes, and that water requirements vary throughout the plant's growth phases. Sari et al (2016) stressed that both water deficiency and excess can harm plants. Atikah et al (2016) reported that shading helps regulate temperature and humidity around plants, reducing stress caused by drought. Therefore, plants must be watered, as they rely on water for metabolic processes such as photosynthesis. Naomi *et al.* (2018) explained that photosynthesis requires both water and sunlight to convert CO₂ and water into glucose and O₂. Leaves contain stomata that regulate respiration and help plants maintain water levels, preventing dehydration while stabilizing the plant's temperature. Melfian et al (2015) added that plants can grow well if their water needs are met at the right quantity and timing, alongside sufficient availability of nutrients, carbon dioxide, temperature, and sunlight. Purple pak choi showed good adaptability under shaded conditions. The results demonstrated that 70% shading produced the highest shoot fresh weight, indicating that reduced light intensity can create a more favorable microclimate for plant growth. Shading likely reduced temperature and transpiration rates, allowing plants to maintain better water balance. Watering interval also influenced plant growth, where watering every two days resulted in better biomass production compared with daily watering. This suggests that moderate watering intervals can maintain optimal soil moisture without causing excessive water accumulation in the growing medium. The interaction between shading and watering interval indicates that shaded conditions combined with appropriate watering

management can improve plant growth performance. These findings suggest that purple pak choi has strong potential for cultivation in shaded environments such as agroforestry systems or urban farming systems where light availability is limited.

Conclusion

Purple pak choi showed good adaptability under shaded conditions. The results indicated that 70% shading produced the highest shoot fresh weight, suggesting that reduced light intensity can create a favorable microclimate that lowers temperature and transpiration, thereby supporting plant growth. In addition, watering every two days resulted in better growth performance than daily watering, indicating that moderate watering intervals maintain optimal soil moisture. These findings suggest that purple pak choi has potential for cultivation in shaded environments such as urban farming systems, agroforestry, or limited-land agriculture. However, this study only evaluated specific shading levels and watering intervals under controlled conditions. Future studies should examine the interaction of shading with other agronomic factors, such as nutrient management, planting density, and irrigation strategies, to further optimize purple pak choi production.

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Author Contributions

D.F.N.: Developing ideas, data collection, analyzing, writing, reviewing, responding to reviewers' comments; K.A., S.D., R.P.R., S.A.M.: supervising data collection, analyzing data, reviewing data and writing.

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Conflicts of Interest

The authors declare no conflict of interest.

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