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Effect of Different Shading Color on Growth and Yield Performance of (Black Ginger) *Kaempferia parviflora* Wall. *ex* Baker

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

A study was conducted to investigate the impact of different shading colors on the growth and yield performance of (black ginger) *Kaempferia parviflora* Wall. ex Baker. The experiment was conducted in a glasshouse at MARDI Jerangau, Terengganu, from September 2022 to May 2023. The experiment followed a randomized complete block design (RCBD) with three replications. The shade treatments consisted of non-shade (T1), green shade (T2), yellow shade (T3), and red

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shade (T4). The results revealed that the application of colored shading significantly enhanced both the growth and yield of *K. parviflora*. Notably, the growth performance at the 5-month after planting (MAP) stage was crucial for rhizome yield, with any decrease in plant height potentially leading to diminished rhizome weight measurements. Among the shading colors, green shade emerged as the most effective, boosting total rhizome weight compared to non-shaded conditions. Correlation analysis between yield components demonstrated a strong positive relationship between rhizome length and rhizome weight (0.894), followed by rhizome weight and root weight (0.835). In conclusion, the study highlights the beneficial effects of colored shading on the yield components of *K. parviflora*, emphasizing the potential for optimized cultivation practices to enhance crop productivity.

Keywords: Black ginger; color shade; growth; yield.

1. INTRODUCTION

K. parviflora, commonly known as black ginger, is a perennial herbaceous plant in the Zingiberaceae family native to Southeast Asia, particularly Thailand. It has been traditionally used in Thai traditional medicine for its various health benefits. The root of *K. parviflora* is rich in bioactive compounds such as flavonoids, terpenoids, and phenolic compounds, which contribute to its medicinal properties [1]. One of the most well-known benefits of *K. parviflora* is its aphrodisiac effects [2,3]. In addition, *K. parviflora* has also been found to have anti-inflammatory and antioxidant properties [4,5]. These properties help reduce inflammation in the body and protect cells from oxidative stress, which can help prevent chronic diseases such as heart disease and cancer.

The application of shade on horticultural crops is becoming more popular in recent years. Shading modifies the micro-environment and can provide plants with some protection from frequent heat, drought, frost, and hail induced by climate change and has the potential to improve plant growth, yield, and quality [6,7]. Shading was reported to improve the yield and quality of a number of horticultural crops, including fruits, vegetables, ornamentals, herbs, and tea [8,9]. Colored shading, specifically the use of a blue shade net, resulted in significant improvements in plant height, leaf area, chlorophyll content, and essential oil yield in lemon balm plants [10]. The blue shade net led to a 116% increase in plant height, 168% increase in leaf area, 42% increase in chlorophyll content, and a 30% increase in essential oil yield, making it a suitable cultivation practice for commercial use. A study on the effects of different colored shading nets and shading degrees on highbush blueberries found that colored shading nets significantly decreased PAR radiation, with varying effects on air temperature, soil moisture, and relative humidity. Yields were found to increase with white 50%, gray 35%, and red 50% shading nets compared to the control (non-shade) treatment [11].

Various studies have indicated that shading can indeed enhance the yield and quality of various horticultural crops. However, the specific effects of different shading colors on *K. parviflora*, a valuable medicinal plant, are still not well-understood. In this study, we aim to investigate the impact of different shading colors on the growth and yield of *K. parviflora*, contributing to a deeper understanding of the potential benefits of shading in its cultivation.

2. MATERIALS AND METHODS

2.1 Cultivation and Experimental Design

Plants were vegetatively propagated from rhizome cuttings and germinated in peat moss. The plants were then transplanted into polybags after 1 month under the greenhouse in MARDI Jerangau (latitude 04 57 ' 22" N and longitude 103 10 ' 05 E) in Terengganu, Malaysia, from September 2022 to May 2023. Four plants were planted in four rows with 30 cm spacing between them. Fertilization and irrigation were carried out identically for all plants. Shade cover was installed after transplanting the plants under the greenhouse structure. Plants with four shade treatments, including no shade (control), green, yellow, and red shade, were evaluated. RH, temperature, and light intensity were recorded using an anemometer, air flow meter, humidity meter, and light meter (Table 1). Each shade cover measured 180 cm in length, 120 cm in width, and 120 cm in height. The experiment was conducted using a randomized complete block design (RCBD) with three replications, with shade treatment as the experimental factor. There were 16 plants for each shade treatment within each replication.

Table 1. Average reading of RH, temperature and light intensity under different shade

	No shade	Green	Yellow	Red
RH	75.2 %	68 %	69.5 %	71.2 %
Temperature	30.5 °C	34.0 °C	33.7 °C	31.3 °C
Light	14380 lx	550 lx	610 lx	757 lx
PAR	195	136	103	186

Fig. 1. Plant growth parameter for *K. parviflora* plant

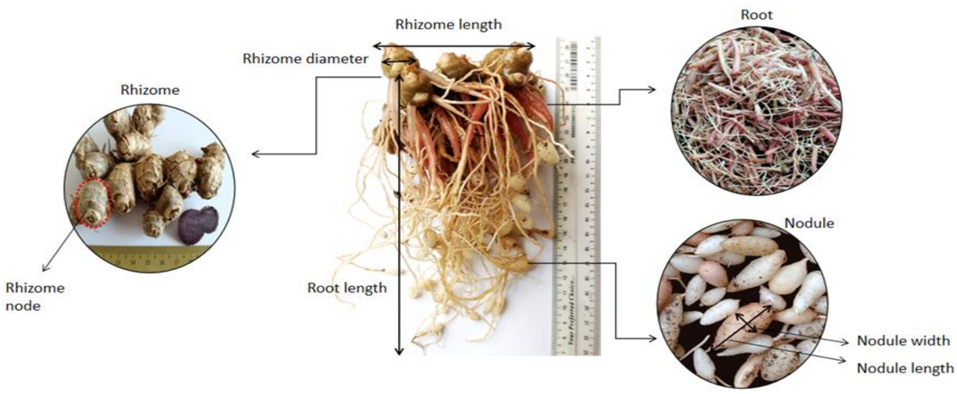

Fig. 2. Yield parameter for *K. parviflora* plant

2.2 Plant Performance (Figs. 1 and 2)

Plant growth was recorded at 3-months after planting (MAP), 5 MAP, and 7 MAP. The parameters recorded included plant height, tiller number, and leaf number. Data for yield components were also recorded, including rhizome length, rhizome width, rhizome diameter, number of rhizome nodes, rhizome weight, number of nodules, nodule length, nodule width, nodule weight, root length, and root weight.

3. RESULTS AND DISCUSSION

Plant growth performance shows that plant height at 5 MAP under green shade contributed significantly higher readings compared to the control and other shade colors. A difference of 27.16% was observed between green and yellow shades (Fig. 3). No significant differences were observed at 3 MAP and 7 MAP. Correlation analysis found that plant height was significantly positively correlated with rhizome weight at 5 MAP (Table 2). Tiller number was not significantly affected by the different shade color treatments (Fig. 4). The highest reading was 23.67 at 5 MAP under green shade. Correlation analysis shows that the number of tillers exhibited a significant positive correlation with yield in the 5 MAP stage (Table 3). However, tiller number was not significantly affected by the treatment. Leaf number also was not significantly affected by the different shade color treatments (Fig. 5). The highest reading was 73.00 at 7 MAP under green shade. Correlation analysis shows that the number of leaves exhibited a significant positive correlation with yield in the 5 MAP stage (Table 4).

The results of the study on the effect of different shading colors on the growth performance of *K. parviflora* reveal that plant height at 5 MAP under green shade significantly surpassed both the control and other shade colors, indicating a robust response to green light. This finding aligns with previous research demonstrating the positive impact of green light on plant growth and development, attributed to its efficient absorption by chlorophyll and stimulation of photosynthesis [12]. This suggests that maximizing plant height at 5 MAP is critical for achieving higher rhizome yields, emphasizing the importance of optimizing light conditions during the early growth phase to promote vigorous plant growth and subsequent yield performance. Contrary to plant height, tiller number and leaf number were not significantly affected by the different shading color treatments. Although the highest tiller number was observed at 5 MAP under green shade, correlation analysis revealed no significant correlation between tiller number and rhizome yield. Similarly, leaf number showed no significant differences among the treatments and exhibited a positive correlation with yield only at the 5 MAP stage.

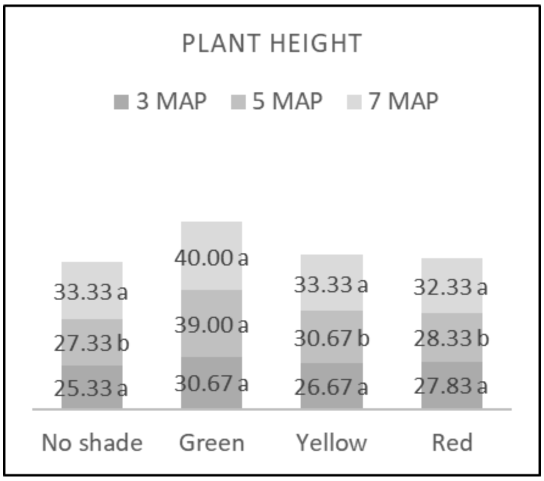

Fig. 3. Mean comparison of plant height

Table 2. Correlation analysis of plant height with rhizome weight

	3 MAP	5 MAP	7 MAP	Rhizome weight
3 MAP	1			
5 MAP	0.596*	1		
7 MAP	0.003	0.563	1	
Rhizome weight	0.361	0.661*	0.339	1

*** Correlation is significant at the 0.01 level (2-tailed)*

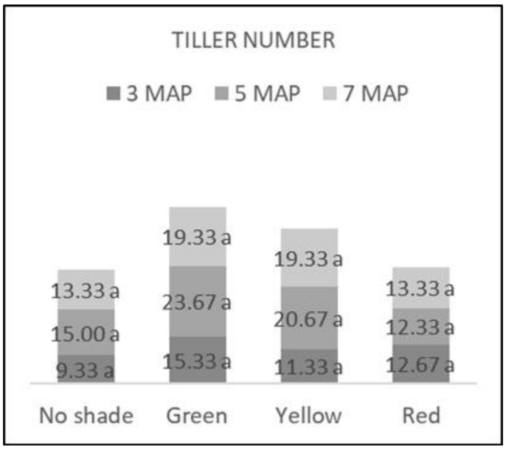

Fig. 4. Mean comparison of tiller number

Table 3. Correlation analysis of tiller number with rhizome weight

	3 MAP	5 MAP	7 MAP	Rhizome weight
3 MAP	1			
5 MAP	0.42	1		
7 MAP	-0.099	0.413	1	
Rhizome weight	0.251	0.802**	0.493	1

*** Correlation is significant at the 0.01 level (2-tailed)*

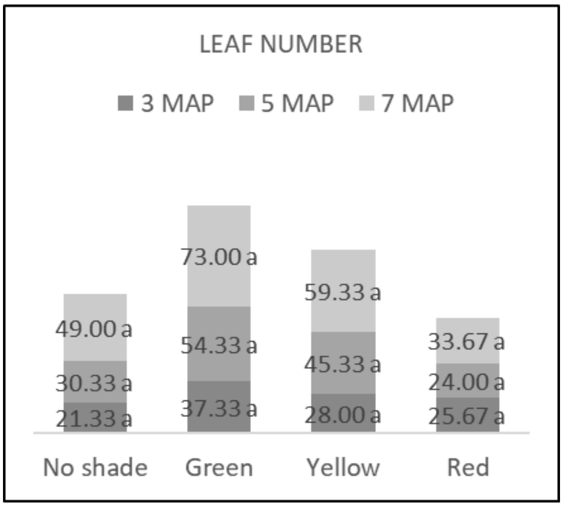

Fig. 5. Mean comparison of leaf number

Table 4. Correlation analysis of leaf number with rhizome weight

	3 MAP	5 MAP	7 MAP	Rhizome weight
3 MAP	1			
5 MAP	0.746**	1		
7 MAP	0.087	0.437	1	
Rhizome weight	0.439	0.807**	0.567	1

*** Correlation is significant at the 0.01 level (2-tailed)*

The effect of different color shades on yield performance of *K. parviflora* is presented in Table 5. **Rhizome characteristics:** Across all treatments, rhizomes tend to be longest in the yellow treatment (17.00 cm), followed by green (15.67 cm) and non-shaded (13.17 cm), while red has the shortest rhizomes (9.50 cm). The same trend applies to width and diameter, with yellow having the widest and largest diameter rhizomes. Green treatment shows the highest number of rhizome nodes (55.33), followed by yellow (46.67), non-shaded (38.00), and finally red (29.67). This suggests that the presence of green light promotes more vigorous rhizome growth. The weight of the rhizomes showed a significant difference (P<0.05), with the green shade treatment contributing to the highest significant reading of 202.67 g, followed by the yellow shade treatment with 200.94 g, non-shaded (123.42 g) and red shade (74.67 g). This indicates that green light contributes to greater biomass accumulation in rhizomes.

Nodule characteristics: The green treatment exhibits the highest values for all nodule characteristics, followed by yellow, non-shaded, and red. This implies that green light is most conducive to the development and growth of nodules, which are important for nitrogen fixation in many plant species. **Root characteristics:** Interestingly, non-shaded treatment shows the longest root length (29.33 cm), followed by green and yellow (25.33 cm) respectively and red (18.00 cm). However, green treatment results in the highest root weight (116.91 g), followed by yellow (91.54 g), non-shaded (54.25 cm, and red (40.36 cm). This suggests that although non-shaded conditions promote longer roots, green light leads to denser or heavier root mass.

Table 5. Colour shade affect yield of *K. parviflora*

	Rhizome length (cm)	Rhizome width (cm)	Rhizome diameter (cm)	No. of rhizome nodes	Rhizome weight (g)	No. of nodules	Nodule length (cm)	Nodule width (cm)	Nodule weight (g)	Root length (cm)	Root weight (g)
No Shade (T1)	13.17 ± 1.17 **ab**	7.00 ± 1.00 a	1.70 ± 0.10 a	38.00 ± 5.00 **ab**	123.42 ± 12.23 **b**	12.67 ± 3.71 **b**	4.17 ± 0.17 a	0.63 ± 0.09 a	18.13 ± 5.26 **ab**	29.33 ± 6.49 a	54.25 ± 19.42 a
Green (T2)	15.67 ± 1.86 **a**	9.33 ± 0.33 a	1.70 ± 0.10 a	55.33 ± 4.91 **a**	202.67 ± 18.52 **a**	41.00 ± 7.37 **a**	4.33 ± 1.33 a	0.90 ± 0.06 a	36.42 ± 5.51 **a**	25.33 ± 3.28 a	116.91 ± 33.41 a
Yellow (T3)	17.00 ± 1.15 **a**	9.00 ± 1.00 a	1.67 ± 0.17 a	46.67 ± 5.36 **ab**	200.94 ± 4.84 **a**	25.00 ± 5.20 **ab**	3.00 ± 0.58 a	0.73 ± 0.13 a	15.72 ± 5.87 **ab**	25.33 ± 6.01 a	91.54 ± 14.25 a
Red (T4)	9.50 ± 0.76 **b**	6.50 ± 0.76 a	1.33 ± 0.17 a	29.67 ± 4.63 **b**	74.67 ± 8.19 **b**	13.67 ± 4.10 **b**	2.50 ± 0.00 a	0.63 ± 0.09 a	7.57 ± 2.83 **b**	18.00 ± 2.08 a	40.36 ± 10.10 a

**Means with similar letter are not significantly different at p<0.05*

**The collected data were analysed statistically and the means were compared by the Tukey test at P ≤ 0.05 (Software; IBM Statistics SPSS 27.0)*

Table 6. Correlation analysis of yield component

	Rhizome length	Rhizome width	Rhizome diameter	No. of rhizome nodes	Rhizome weight	No. of nodules	Nodule length	Nodule width	Nodule weight	Root length	Root weight
Rhizome length	1										
Rhizome width	0.515	1									
Rhizome diameter	0.381	0.06	1								
No. of rhizome nodes	0.725**	0.644*	-0.008	1							
Rhizome weight	**0.894****	0.757**	0.359	**0.808****	1						
No. of nodules	0.263	0.725**	0.029	0.687*	0.607*	1					
Nodule length	0.309	0.248	0.065	0.467	0.419	0.236	1				
Nodule width	0.367	0.302	0.058	0.624*	0.427	0.593*	-0.074	1			
Nodule weight	0.309	0.620*	0.043	0.757**	0.607*	**0.826****	0.701*	0.454	1		
Root length	0.137	0.525	0.110	0.248	0.332	0.292	0.596*	0.033	0.543	1	
Root weight	0.750**	0.668*	0.186	0.667*	**0.835****	0.403	0.613*	0.243	0.573	0.378	1

*** Correlation is significant at the 0.01 level (2-tailed)*

** Correlation is significant at the 0.05 level (2-tailed)*

The results indicate that light conditions significantly influence various aspects of plant growth, including rhizome, nodule, and root development. The result also supported by previous study on the effects of shade nets on the microclimate and growth of tomatoes which the findings revealed the greatest fruit weight was obtained from the green shade group, followed by the yellow shade group, the pearl blue shade group, and the non-shaded group [13]. Another study explored the effect of applying colored shade nets on the physiological traits of marigold and violet plants revealed that yellow shade nets outperformed the other nets in improving plant growth [14].

The findings highlight the importance of light quality in modulating the growth and yield performance of *K. parviflora*. Understanding how different light affect specific plant traits can inform agricultural practices aimed at optimizing yield and quality. Farmers or growers cultivating *K. parviflora* can potentially manipulate light conditions to enhance rhizome growth and yield. For example, using green or yellow shade nets or adjusting artificial lighting in controlled environments may promote desired growth characteristics and improve overall productivity.

3.1 Correlation Analysis

The correlation analysis between yield components revealed significant and positive associations among several variables. Rhizome length, rhizome width, number of rhizome nodes, rhizome weight, number of nodules, and nodule length were all positively associated with each other, as well as with other traits (Table 6). Notably, there was a very strong positive correlation between rhizome length and rhizome weight (0.894). Additionally, rhizome weight was positively correlated with root weight (0.835), number of nodules with nodule weight (0.826), and number of nodes with rhizome weight (0.808). Increasing rhizome yields will also result in increased production of roots and nodules.

4. CONCLUSION

The study demonstrated that the use of colored shading significantly increased the yield component of *K. parviflora*. Specifically, shading with green shade proved to be the most effective in producing a higher rhizome yield, increasing the total rhizome weight compared to the non-shaded conditions. The correlation analysis revealed significant and positive associations among several variables, emphasizing the importance of growth performance during the 5 MAP stage for achieving high rhizome yield. Overall, the findings suggest that shading had a positive impact on both the growth and yield of *K. parviflora*. These results provide valuable insights for optimizing the cultivation of *K. parviflora* and enhancing its yield through the strategic implementation of colored shading techniques. Further research in this area could explore additional factors that may influence the growth and yield of *K. parviflora*, contributing to a more comprehensive understanding of its cultivation and potential applications.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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