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ARTICLE

Vegetative growth response of *Phalaenopsis* sp. hybrids (Moon Orchid) in response to light intensity and fertilizer concentration

Crescimento vegetativo de *Phalaenopsis* sp. híbrido (Moon Orchid) em resposta à intensidade luminosa e concentração de fertilizantes

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Abstract: Orchid plants are one of the most popular floral decorative plants. Among the several species of orchids, *Phalaenopsis* sp. or moon orchid is popular because of its distinctive color, shape, and size. However, orchids have a slow growth rate due to their long juvenile phase; thus, culture technique modification is required to boost their growth, i.e., shading and fertilizer application. This research was carried out to obtain the best shade percentage and fertilizer concentration to increase the growth of moon orchid. The experiment was conducted from June to December 2022 at the greenhouse of Bale Tatanan Padjadjaran, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor, Sumedang, Jawa Barat. The experiment used a split-plot design of eight shade and fertilizer treatments. The plants were cultivated in two shading intensities, namely 60% and 70%, then treated with four different complete foliar fertilizer compound concentrations (1, 2, 3, and 4 g L^{-1}). The results showed that 60% shade combined with 2 g L^{-1} of foliar fertilizer significantly increased the leaf area and root length, whereas 70% shade combined with 4 g L^{-1} significantly increased the leaf area, root number and CCI of moon orchid.
Keywords: flower, Orchidaceae, shading net, tropical plants.

Resumo: As orquídeas são uma das plantas decorativas florais mais populares. Dentre as diversas espécies de orquídeas, *Phalaenopsis* sp. ou a moon orchid é popular por causa de sua cor, formato e tamanho distintos. No entanto, as orquídeas apresentam taxa de crescimento lenta devido à sua longa fase juvenil; portanto, é necessária modificação da técnica de cultivo para impulsionar seu crescimento, ou seja, sombreamento e aplicação de fertilizantes. Esta pesquisa foi realizada com o objetivo de obter a melhor porcentagem de sombra e concentração de fertilizante para aumentar o crescimento da moon orchid. O experimento foi conduzido de junho a dezembro de 2022 na estufa de Bale Tatanan Padjadjaran, Faculdade de Agricultura, Universitas Padjadjaran, Jatinangor, Sumedang, Jawa Barat. O experimento utilizou o delineamento de parcelas subdivididas com oito tratamentos de sombra e fertilizantes. As plantas foram cultivadas em duas intensidades de sombreamento, 60% e 70%, e posteriormente tratadas com quatro concentrações diferentes de compostos fertilizantes foliares completos (1, 2, 3 e 4 g L^{-1}). Os resultados mostraram que 60% de sombra combinada com 2 g L^{-1} de fertilizante foliar aumentou significativamente a área foliar e o comprimento da raiz, enquanto 70% de sombra combinada com 4 g L^{-1} aumentou significativamente a área foliar, número de raízes e o CCI da moon orchid.
Palavras-chave: flor, Orchidaceae, plantas tropicais, rede de sombreamento.

Introduction

Orchids are members of the Orchidaceae family, the largest family of Monocotyledonous plants. The Orchidaceae family has approximately 28,000 species, and 6,000 species of them are found in Indonesia (Djordjević and Tsiftsis, 2019). *Phalaenopsis* (moon orchid) is one of the most popular orchid types because of their unique color, shape, size, and flower resistance, thus, the price is relatively high and quite stable (Suyanto et al., 2021). In Indonesia, the orchid has been designated as the icon of the national flower, namely Puspa Pesona Indonesia (Widiarsih and Dwimahyani, 2013). The growth rate of orchids is very slow (Amalia et al., 2022) thus, special treatment to boost their growth is required (Suradinata et al., 2019).

Light plays a crucial role in plant photosynthesis (Rahmat et al., 2023). However, in orchids it is important to control sun exposure, as excess light can result in brown spots similar to burns on the leaves, while a lack of sunlight harms their growth. For moon orchids, the light intensity required by is at most 30% (Dewir et al., 2015). Therefore, the use of shade in orchid cultivation must be considered.

Besides being influenced by light intensity, the growth of orchid plants is also influenced by the availability of nutrients. The nutrient absorption of moon orchids is very limited via roots because of the epiphytic growth manner. Applying fertilizer through the leaves, also known as foliar feeding, can increase nutrient absorption because most of the nutrient absorption in orchids occurs through the leaves (Niu et al., 2021). The choice to use foliar fertilizer can also be based on economic calculations of horticultural products with a high selling value (Zude-Sasse et al., 2021).

During vegetative growth, the fertilizer needed is Nitrogen, Phosphor and Potassium compound fertilizer with a higher nitrogen composition than other elements (Tini et al., 2019). There are differences between orchids and other plants. When exposed to the nutrient-deficient condition, orchids do not immediately show any deficiency symptoms. Because orchids have a slow growth rate (Tini et al., 2019). Liu et al. (2021) stated that fertilizer application must be made appropriately and in accordance with the recommended concentration. Excessive fertilizer application will harm plants, while applying less fertilizer will cause less optimal plant growth. Based on the background described, this study aims to determine the vegetative growth response of moon orchid plants in response to the difference in shade intensity and fertilizer concentration.

Materials and Methods

Plant preparation

The plant material used in the present experiment was moon orchid, 6 months old after acclimatization. Orchid plants are then planted on fern chopping media that has been soaked with fungicides. The pot containing the orchid plant was then put into a pot tray and stored in Greenhouse Bale Tatanen Padjadjaran, Faculty of Agriculture, Universitas Padjadjaran, Sumedang Regency from June to December 2022 with the altitude of 730 m, above sea level. The plants were cultivated in the greenhouse with the temperature of 29.4 ± 2 °C and a relative humidity of 64.0 ± 10%. The

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experiment consisted of eight treatments, with the combination of two types of shading net (60% or 12,033 lux and 70% or 9,309 lux), and four different fertilizer concentration (1, 2, 3, and 4 g L^{-1}). Those treatment was repeated three times.

Fertilizer Application

The fertilizer used in the present experiment was foliar fertilizer, containing 32% Nitrogen, 10% Phosphor, and 10% Potassium. Foliar fertilizer was then sprayed into orchid, based on predetermined concentrations. Fertilizer is sprayed on orchid leaves in equal quantities, as much as 15 mL or 10 sprays per plant. Fertilizer application is carried out in the morning, with an interval of application once a week.

Plant Growth Analysis

Observations were made to determine the response of plants to the treatment given. The main observations observed include:

a. Increase in the number of leaves. The increase in the number of leaves is determined by calculating the difference of number of leaves at 18 weeks after treatment (WAT) compared to 0 WAT. The leaves counted are fully opened ones.

b. Increase in the leaf length. Leaf length is measured using a ruler. Measurement starts from the leaf base to the tip of the longest leaf. The increase in the leaf length is determined by calculating the difference of leaf length at 18 WAT compared to 0 WAT.

c. Increase in the leaf width. Leaf width is measured using a ruler. Measurements are made on the widest part of the leaves. The increase in the leaf width is determined by calculating the difference of leaf width at 18 WAT compared to 0 WAT.

d. Leaf area. Leaf area measurements were carried out at the end of the study. The measured leaf area is the second leaf. Measurement of leaf area is carried out using the gravimetric method (Irwan and Wicaksono, 2017) with the Equation 1.

$$\text{Leaf area} = \frac{\text{Weight of leaf replica}}{\text{Weight of paper at a size of 10 cm x 10 cm}}\ x\ 100\ cm^2$$

e. The number of roots. The number of roots were calculated at the end of the study by counting the number of plant roots.

f. The length of root. The root length was measured at the end of the study using a ruler. Measurements are made at the longest root.

Chlorophyll content index (CCI) Analysis

CCI measurements were carried out on the second leaf from the top of the plant at 18 WAT by using *Soil Plant Analysis Development* (SPAD). The SPAD value describes the chlorophyll levels of leaves in plants.

Number of stomata Analysis

The number of stomata were calculated at the end of the study using a microscope on the abaxial leaf surface. The observed leaf is the second leaf from the top of the plant.

Statistical Data Analysis

The obtained data were analyzed by using F-test and then continued by Duncans Multiple Range Test at 5%. Statistical software used in present experiment was Statistical Tool for Agricultural Research (STAR) (Shrestha, 2019), version 2.0.1.

Results

The application of complete foliar compound fertilizer affects leaf length and leaf area but did not affect in the number of leaves

After 18 WAT there showed the differences of plant performance and plant size of moon orchis as an effect of different concentration of foliar fertilizer under two different shading net intensity. The use of 1 g L^{-1} of foliar fertilizer resulted the lowest of plant size under 60% and 70% of shading, but increased concentration resulted the increasing plant size at 18 WAT (Fig. 1).

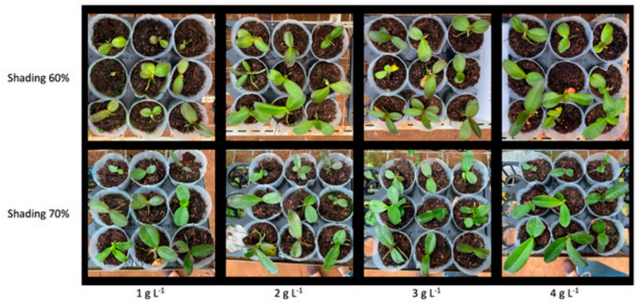

Fig. 1. Representative picture of moon orchid as an effect different concentration of foliar fertilizer under two shading intensities at 18WAT.

Based on the statistical data analysis showed that, various foliar fertilizer concentrations and shading intensity had a significant effect in the increase leaf length and leaf area (Fig. 2A and B), but no effect on the increase in the number of leaves of moon orchid (Figure 2C). The highest leaf length of moon orchid was got from the orchid treated with shading 60% combined with 3 and 4 g L^{-1} of fertilizer (Fig. 2A). The treatment of various fertilizer concentrations has a significant effect on the leaf area of moon orchid plants under two types of shading intensity. At 60% shade, applying foliar fertilizer at 2 g L^{-1} gave the highest mean value on orchid leaf area by 20.16 cm^2, but did not differ significantly compared to concentrations of 3 and 4 g L^{-1} with leaf areas of 17.07 and 19.73 cm^2, respectively. However, at 70% shading net, 4 g L^{-1} of foliar fertilizer gave the highest leaf area of moon orchid by 20.87 cm^2 (Fig. 2B). Although the shade and foliar fertilizer affect in the leaf length and leaf area, but it did not affect in the number of leaves of moon orchid. The leaves number of moon orchid statistically similar each other with the range of leaves number from 1.89 to 2.44 (60% shade fertilizer) and from 1.89 to 2.33 (70% shade fertilizer) (Fig. 2C).

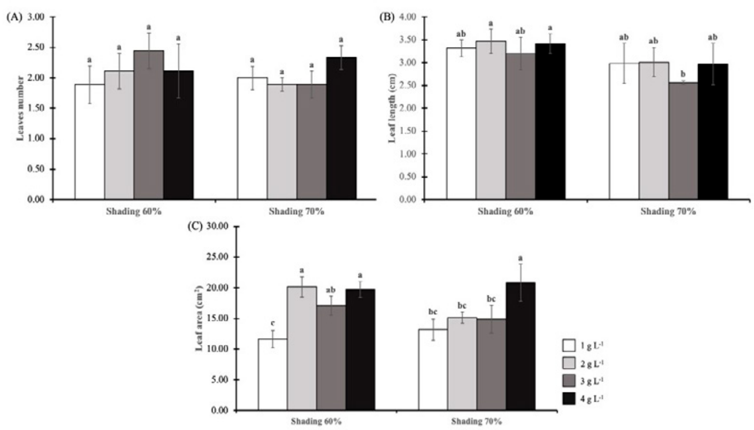

Fig. 2. The effect of shading intensity and fertilizer concentration on the leaves number (A), leaf length (B), and leaf area (C) of moon orchid plants at 18 WAT. The mean value of ± SE (n = 9) followed by the same letter did not significantly differ based on Duncan's Multiple Range Test at the level of 5%.

The application of complete foliar compound fertilizer affects the root number and root length of moon orchid plants in two shade conditions

The statistical analysis showed that various foliar fertilizer concentrations and shading intensities affect the number and length of root of moon orchid at 18 WAT (Fig. 3A and 3B). It can be seen that the treatment of various fertilizer concentrations and shading intensities had a significant effect on the number and length of roots of moon orchid plants, with values varying between treatments. At 60% shade, foliar fertilizer application of 2 g L^{-1} gave the highest root number and root length of moon orchid, which were 13.11 and 17.53 cm, respectively. Whereas, at 70% shade, the application 4 g L^{-1} of fertilizer gave the highest root number by 14.22 that was significantly different compared with other treatments. However, for root length, it was not significantly affected (Fig. 3A and 3B)

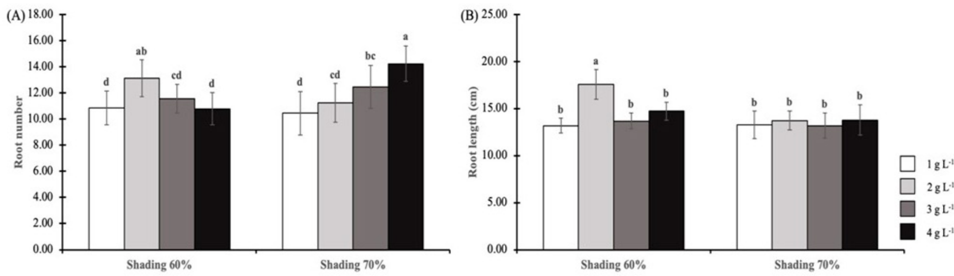

Fig. 3. The effect of shading intensity and fertilizer concentration on the root number (A) and root length (B) of moon orchid plants at 18 WAT. The mean value of ± SE (n = 9) followed by the same letter did not differ significantly based on Duncan's Multiple Range Test at the level of 5%.

The application of complete foliar compound fertilizer affects the chlorophyll content index of moon orchid plants in two shade conditions

Based on the results of statistical analysis, the use of various concentrations of foliar fertilizer in two types of shade percentage affects the amount of chlorophyll of moon orchid plants (Fig. 4). Applying various fertilizer concentrations in two shade percentages significantly affected the CCI of moon orchid plants (Fig. 4). At 60% shade, foliar fertilizer application of 2 g L^{-1} gave the highest average value of 44.57 but did not differ markedly compared to concentrations of 3 and 4 g L^{-1} with CCI values of 39.86 and 38.89, respectively. In similar to 60% shade, foliar fertilizer applications of 2, 3, and 4 g L^{-1} at 70% shade had a high average amount of chlorophyll with values of 52.78, 55.33, and 55.35, respectively.

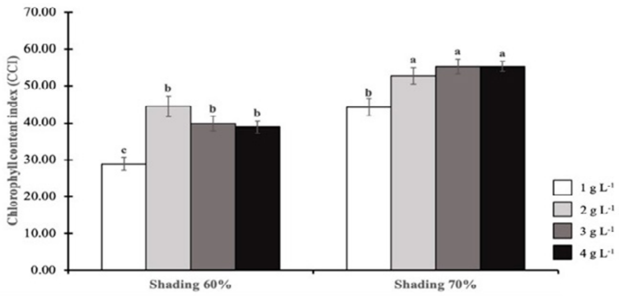

Fig. 4. The effect of shading intensity and fertilizer concentration on the Chlorophyll Content Index of moon orchid leaves at 18 WAT. The mean value of ± SE (n = 9) followed by the same letter did not differ significantly based on Duncan's Multiple Range Test at the level of 5%.

The application of complete foliar compound fertilizer affects the number of stomata of moon orchid plants in two shade conditions

The results of statistical analysis showed that the use of various concentrations of foliar fertilizer in two types of shade percentage affected the number of stomata of moon orchid plants at 18 WAT (Fig. 5). Based on Fig. 5, it can be seen that the treatment of fertilizer concentration at 60% shade does not have a noticeable effect, but the treatment of fertilizer concentration at 70% shade has a real effect on the number of stomata of moon orchid plants. At 70% shade, the highest average value of stomata was obtained from plants that received 3 g L^{-1} leaf fertilizer, with a number of stomata 28.03 per mm^2, but not significantly different compared to plants that received fertilizer with concentrations of 2 and 4 g L^{-1}, with the number of stomata, respectively, 22.93 and 17.3 per mm^2.

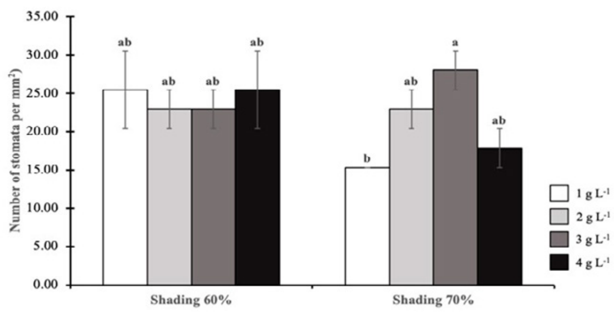

Fig. 5. The effect of shading intensity and fertilizer concentration on the number of stomata on moon orchid leaves at 18 WAT. The mean value of ± SE (n = 9) followed by the same letter did not differ significantly based on Duncan's Multiple Range Test at the level of 5%.

Discussion

Based on Fig. 1, it can be seen that the treatment of various fertilizer concentrations did not significantly affect the increase in the number of leaves and leaf length of moon orchid planted under 60% and 70% shade. This study is in line with previous research, which showed that the application of foliar fertilizer with different concentrations in the vegetative phase had no significant effect on the number of leaves (Agustiar et al., 2020), leaf length (Hartati et al., 2019), leaf width of orchid (Ayuningtyas et al., 2020).

According to Hartati et al. (2019), orchid plants take a long time to grow a new organ because of its genetically slow growth and development. Agustiar et al. (2020) also state that applying foliar fertilizer with a high concentration did not cause an increase in the number of orchid leaves. The vegetative growth period of orchids is quite long, while the impact of fertilizer on growth is relatively small, so it is difficult to observe. The application of 2 g L^{-1} fertilizer has been effective and efficient in increasing the leaf area of moon orchid plants. This study is in line with previous research showing that this application was the best concentration that can increase the leaf area of moon orchids (Tini et al., 2019).

In contrast to 60% shade, at 70% shade treatment, the highest mean value was obtained in the treatment of 4 g L^{-1} leaf fertilizer, with a leaf area of 20.87 cm^2 and significantly different compared to plants that received fertilizer at concentrations of 1, 2, and 3 g L^{-1}. Applying fertilizer at the right concentration can increase plant growth, especially nitrogen that highly need by the plant during its early vegetative phase. The N content contained in the fertilizer can form wider leaf blades with higher chlorophyll content, so plants can produce high amounts of carbohydrates to support vegetative growth. Guo et al. (2019) stated that the absorption of nutrients, especially nitrogen affects the formation of leaf area.

In addition to being influenced by the concentration of fertilizer, leaf area is also influenced by the intensity of light received by orchid plants in shade with different percentages. Based on the results of this study, it can be shown that the highest average leaf area is found in shade with a higher percentage (70%). Rellam et al. (2017) stated that shaded plants have a wider leaf area because shaded plants will expand the surface of their leaves to get optimal light.

Roots are vegetative organs of plants that grow well if environmental factors such as sunlight, water, nutrients, and space for growth are met (Calleja-Cabrera et al., 2020). The number and length of roots are parameters that can be used to determine how wide the root range is in finding water sources (Dorlodot et al., 2007). Previous research showing that applying 2 g L^{-1} foliar fertilizer had the greatest effect on orchid root length (Hasanah et al. 2014) and can increase the number of roots (Agustiar et al., 2020).

Similar to 60% shade, applying various fertilizer concentrations at 70% shade also affected the number of orchid roots. However, at 70% shade, a high concentration of fertilizers is required, where a concentration of 4 g L^{-1} is able to produce the greatest number of roots, which is 14.22, and differs markedly compared to other concentrations. According to Pasley et al. (2019), the increasing application of N fertilizer enhances the uptake of non-N nutrients, a balanced application of multiple essential nutrients is needed to sustainably increase yields. It will spur photosynthetic activity and vegetative growth of plants. Applying various fertilizer concentrations at 70% shade did not significantly affect the length of orchid roots. However, applying fertilizers with various concentrations affects the length of the roots in 60% shade condition. The higher the shading percentage, the less light is received by the plant and causes reduced root development.

Chlorophyll is a green-colored pigment found in chloroplasts along with carotene and xanthophylls in all living things that can perform photosynthesis (Ebrahimi et al., 2023). This study, fertilizer application of 1 g L^{-1} both at higher light intensity (60%) and lesser light intensity (70%), provides the smallest amount of chlorophyll. Because 1 g L^{-1} fertilizer has an N content that is too low. According to Lawlor et al. (2021), nitrogen supply can form wider leaf blades with higher chlorophyll content so that plants are able to produce high amounts of carbohydrates to support vegetative growth.

Shade with lesser light intensity (70%) has a higher amount of chlorophyll compared to higher light intensity (60%). Increasing the amount of chlorophyll in the leaves of shaded plants aims to optimize the capture of available light. Thompson et al. (1988) also stated that the increase in leaf chlorophyll content is one of the characteristics of adjustment to low irradiation due to shade. Applying 2 g L^{-1} foliar fertilizer has been effective and efficient in increasing the number of stomata of moon orchid plants.

The number of stomata in plants is very important in ensuring the efficiency of photosynthesis, water balance, and adaptation to different environmental conditions. The application of various concentrations of foliar fertilizer can affect the number of stomata in plants (Arsic et al., 2022). This study reported that foliar fertilizer application at 60% shade did not affect the number of stomata on moon orchid leaves. However, applying fertilizers with various concentrations affected the number of stomata of orchid leaves under the shade of 70%. it was likely that the light in the shade of 70% is more suitable for the growth of moon orchid. orchid plants. According to Casson and Gray (2008), several environmental factors affect the number of stomata on leaves, namely light intensity, temperature, humidity, and CO_2 concentration in the air. The increasing number of stomata is a process of adaptation of plants to environmental conditions (Buckley, 2019)

The impact of various fertilizer concentrations on moon orchid plants is influenced by factors such as shade intensity and the specific growth phase of the plant. The application of foliar fertilizers with different concentrations during the vegetative phase may not significantly affect parameters such as the number of leaves, leaf length, and leaf width in orchids. The effectiveness of fertilizer concentrations can vary depending on the shade intensity. at 70% shade, higher concentrations of fertilizer resulted in significant differences in leaf area, root number and CCI compared to lower concentrations (Fig. 2C, 3A, and 4). Whereas at 60% shade, just needed a lower concentration (2 g L^{-1}) that was effective in increasing the leaf area, root number, root length, and CCI (Fig. 2C, 3A, 3B and 4)

Conclusions

The study highlights the complex interactions between fertilizer concentration, shade intensity, and plant physiological responses in moon orchid cultivation. Understanding these dynamics is essential for optimizing fertilizer applications and promoting healthy growth in orchid crops. Under lesser light intensity (60% shade), the lower concentration of foliar fertilizer (2 g L^{-1}) is just enough to increase leaf area, root number and root length, while in higher light intensity (70% shade) is needed a higher concentration of foliar fertilizer (4 g L^{-1}) that can increase leaf area, root number, and CCI.

Author Contribution

SM: conceptualization, data curation, formal analysis, writing original draft, writing review and editing. VY: formal analysis, writing original draft. FF: conceptualization, formal analysis, writing original draft.

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Disclosure statement

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author, [SM], upon reasonable request.

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