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Morphophysiological Response of Peranggi Chili (*Capsicum annum* L. var chinensis) to Drought Stress

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Abstract:
Peranggi chili (*Capsicum annum* L. var chinensis) is a red chili that has a spicy taste. Peranggi chili is not widely studied and known by the community. In addition, peranggi chili is very easily exposed to drought so its growth is easily disrupted. This study aimed to determine morphophysiology of peranggi chili with PEG treatment as drought stress. This research was conducted from June to November 2024. The study used an experimental method with a completely randomized design (CRD) to test the growth of peranggi chili with PEG 6000 treatment as drought stress with concentrations of 0%, 10%, 20%, and 30%. The treatment was given after the chili grew 30 days after transfer (DAT). Vegetative growht measurements were taken at 40, 50, 60, and 70 DAT. Chlorophyll content was measuret at 50 and 70 DAT using spectrofotophotometer. The results showed that the morphology of peranggi chili plants was not affected by different concentrations of PEG 6000 except root length which decreased significantly at 70 DAT. The shoot: root fresh and dry weight ratios decreased until 50 DAT and reduced slowly until 70 DAT. Similarly, physiological measurements in the form of chlorophyll a, b, and total content decreased from 50 to 70 DAT, but the treatment level had a different impact. From this study, the effect of drought stress using PEG 6000 0%, 10%, 20%, and 30% began to affect the vegetative growth of peranggi chili at 50 DAT.

Keywords: Drought stress, PEG 6000, peranggi chili, vegetative growth, chlorophyll

1. Introduction

Chili is a species in Solanaceae family that is indispensable for various usages. It's high content of vitamin C and vitamin A become chili peppers as an antioxidant while providing an effect to rise stamina (Afra, 2023). The capsaicin content provides health to the heart (Zhang et al., 2022) although in some people it affects the digestive tract. Aside from being a paste, chili peppers give color and flavor to variations of chili sauce and traditional culinary delights such as rendang, red seasoning for dishes such as fish, chicken or meat which are irreplaceable traditional foods. With high demand and no season, chili production needs to be increased in both intensification and extensification. Chili production reached 25,405 cwt in 2023 in West Kalimantan (BPS Kalbar, 2024).

One of the major types of chili in West Kalimantan is peranggi chili. Peranggi chili (*Capsicum annum* L. var chinensis) is a red chili that has a spicy taste. Peranggi chili is often used by the Sambas community (West Kalimantan) for the purpose of adding spicy flavors to various culinary delights. The fruit shape resembles a jagged bell pepper with a smaller size and often does not look attractive. However, with its spicy sensation, other people begin to look at peranggi chilies in addition to other red chilies. The shape of peranggi chilies is similar to kotokkon chilies that are usually grown in Tana Toraja, Sulawesi, Indonesian. However, the katokkon fruit stalk and fruit stick up like cayenne pepper. Meanwhile, peranggi chilies are just like other red chilies, the fruit dangles down. Unlike katokkon chilies (Flowrenzhy & Harijati, 2017), peranggi chilies have the potential to meet these needs because of their spicy flavor in a smaller number of fruits. Peranggi chilies are not widely studied and known by all communities. The existence of katokkon chilies similar to peranggi has included the two hottest types of chilies in Indonesia besides gendot chilies originating from West Java (Amadea, 2020). Therefore, the study of the potential of peranggi chilies needs to be explored to optimize the availability of more peranggi chilies.

The problem of developing peranggi chili is that peranggi chili is very easily exposed to drought so its growth is easily disrupted. Lack of water can cause plants to experience stress and make plants unable to absorb water to replace losses due to excessive transpiration, thus causing fatigue in plants and even death (Fao 2007 in Jumawati, et al. 2014).

At certain temperatures such as 15ºC and more than 32ºC will produce poor chili fruit (Haryati, 2020). Drought stress is an obstacle faced in plant cultivation. Drought stress has an impact on almost all stages of plant growth, starting from germination, budding process, root and shoot elongation in a plant (Manalu, Listiawati & Asnawati, 2024).

Drought stress can be stimulated by applying polyethylene glycol (PEG). PEG is a polymer compound that does not enter into plant cells, but creates osmotic pressure outside the cell to reduce the availability of water to the plants (Pharwati, Wirasiti, & Wirasiati, 2017). Limited water in the soil can cause changes in chlorophyll content due to a decrease in nutrients uptake including formation of chlorophyll content that is important in photosynthesis. Therefore, it is necessary to know the effect of drought stress on the vegetative growth and fisiology of chili peppers using PEG 6000 at different concentrations.

2. Material dan Method

This research was an experiment with a Completely Randomized Design (CRD) with two blocks and sampling of two plants carried out four times and observed on 40, 50, 60, and 70 days after transfer (DAT). The materials were peranggi chili seeds, PEG 6000 with concentrations of 0%, 10%, 20%, and 30%, distilled water, and planting media in the form of a mixture of alluvial soil, sand, and manure with a ratio of 2:1:1 in pots measuring 35 cm in diameter. Treatments were given every 3 days in an ongoing manner 2 days watered with water and 1 day with PEG 6000. Watering was not done on rainy days. Fertilizers and pesticides/fungicides were applied if needed. The pots were located under shading of paranet 70%. Air temperature humidity and light intensity were measure daily.

3. Procedure

3.1 Procedure for Preparation of PEG 6000 Solution

The preparation of PEG 6000 was done by first calculating the weight of PEG needed using the percent concentration formula as follows.

$$PEG\% = \frac{PEG\ Weight}{1000ml} \times 100$$

The concentration of PEG 6000 that had been dissolved with distilled water was then homogenized (Wulandari & Yulkifli, 2018).

3.2 Seeding Procedure

Seeding was done by soaking the seeds in warm water for 2 hours to allow imbibition, germination and ensure the release of chemicals if any. Then the seeds were planted in soil trays for germination until they grown3-5 leaves. Watering was done daily and treatment started after the seedlings were transferred into the potting media on 30 DAT.

3.3 Planting and Maintenance Procedures

Planting was done when the seedlings that have been planted have 3-5 leaves planted into the pot media that had been labeled. Each pot was planted with five plants and watered with 200 ml of water. Then, plant maintenance was carried out by weeding the plants from weeds every week and embroidering if any died. NPK fertilizer was applied at 1/3 of the recommended rate once every 2 weeks. Pests or fungi were dealt with if any.

3.4 Plant Observation Procedure

Growth observations were made destructively at 40, 50, 60, and 70 DAT. Plant observations included measurements of vegetative growth in the from of fresh and dry weight of roots, shoot, number of leaves, shoot root ratio of fresh and dry weigth, and root length.

3.5 Morphological Observation Procedure

Observations of plant morphology in the form of fresh and dry weight measurements of roots, shoots, number of leaves, shoot: root ratio, and root length. Weighing the fresh weight used a two-digit scale while the dry weight at the beginning of growth was done with an analytical balance. Dry weight was obtained by drying the plants in an oven at 80° C until constant weight.

3.6 Physiological Observation Procedure

Plant physiological observations were made on 50 and 70 DAT. Measurement of chlorophyll a, b, and total content used a spectrophotometer. Leaf samples were crushed first using a pestle and mortar by adding a 5ml with concentration of 80% acetone. The samples were filtered through the funnel using paper number one and collected in the erlenmeyer 50ml. Aseton 80% was added into the funnel until filtered solution reach up to 50ml (modified Clarah, Budihastuti & Darmanti, 2017). After that, it was covered using aluminum foil and macerated in the refrigerator for 7 days. The filtered samples were measured using a spectrophotometer with wavelengths of 663 nm and 645 nm. Calculation of chlorophyll a, b, and total using the Mac Kinner formula (1941) in (Clarah, Budihastuti & Darmanti, 2017) as follows:

Chlorophyll a : $12{,}7\ \lambda_{663} + 2{,}69\ \lambda_{645}$ Chlorophyll b : $22{,}9\ \lambda_{645} + 0{,}02\ \lambda_{663}$ Total Chlorophyll: $20{,}2\ \lambda_{645} + 0{,}02\ \lambda_{663}$

4. Results and Discussion

Observation data were analyzed using Analysis of Variance (ANOVA) at the 5% level and continued with the Least Significance Different (LSD) test if the treatment was significant.

4.1 Results

The observation of vegetative growth of peranggi chili peppers exposed to drought stress with PEG 6000 concentrations of 0%, 10%, 20%, and 30% showed almost the same response among treatments. The results of the analysis of measurements of root length, number of leaves, and ratio of fresh and dry weight of the shoot: roots, and chlorophyll were listed in the figures below:

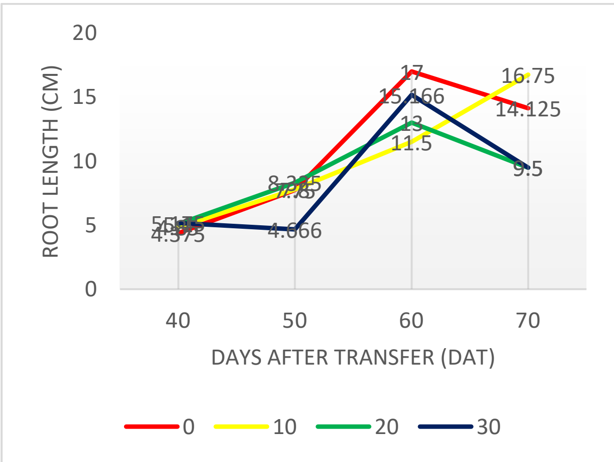

Figure 1: Root length of peranggi chili with drought stress treatment using PEG 6000 at 0%, 10%, 20%, and 30% concentration.

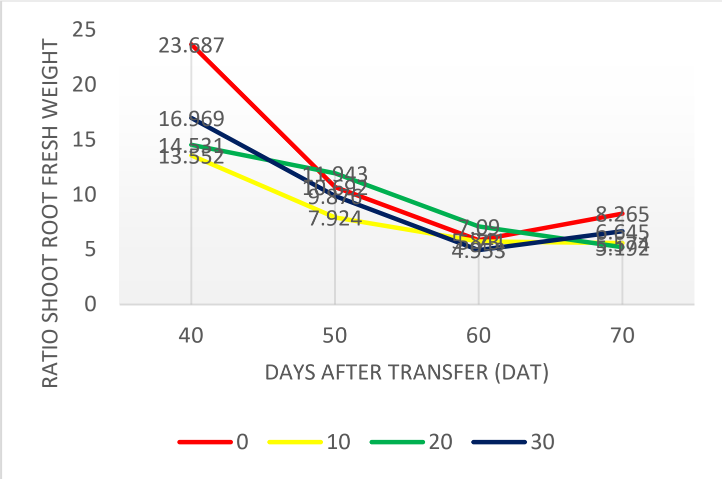

Figure 2: Growth of shoot: root fresh weight ratio of peranggi chili with drought stress treatment using PEG 6000 with concentration of 0%, 10%, 20% and 30%.

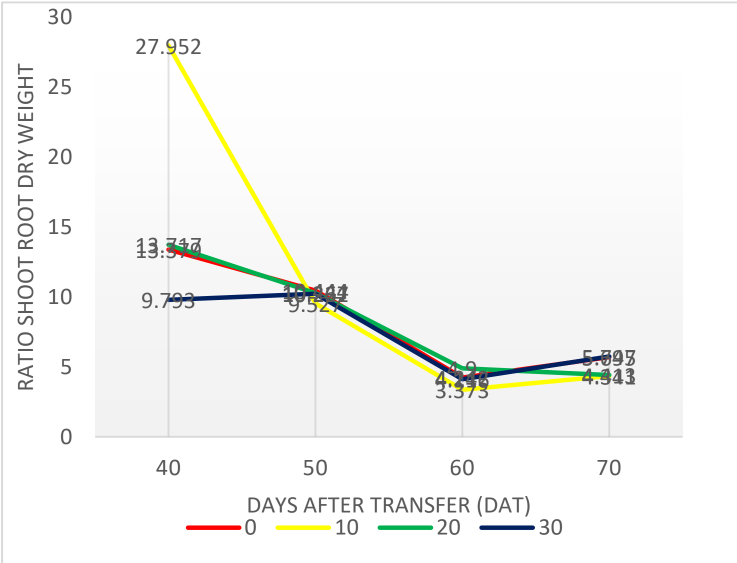

Figure 3: Growth of the ratio of the shoot: root dry weight of peranggi chili with drought stress treatment using PEG 6000 with concentrations of 0%, 10%, 20%, and 30%.

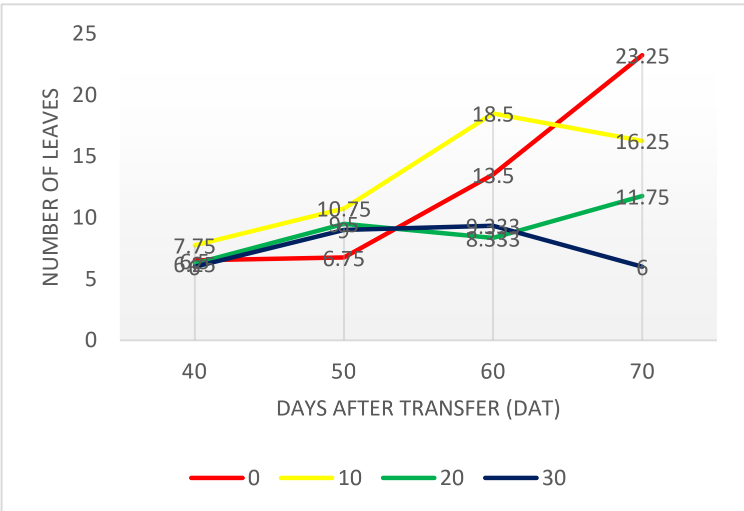

Figure 4: Number of leaves of peranggi chili with drought stress treatment using PEG 6000 with concentrations of 0%, 10%, 20%, and 30%.

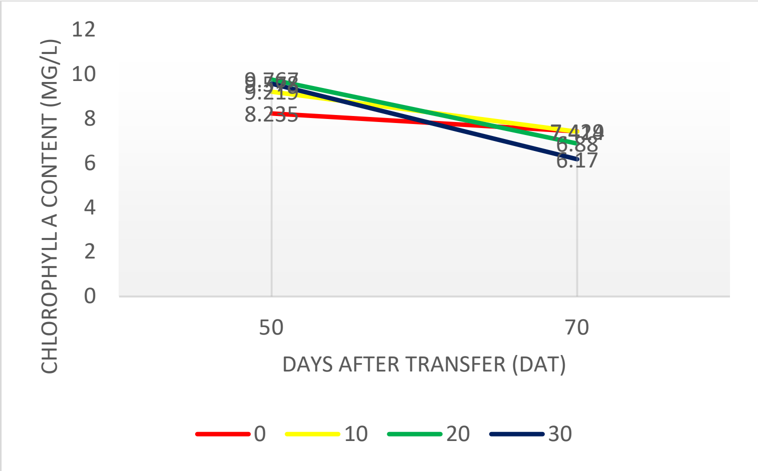

Figure 5: Chlorophyll a content of peranggi chili with drought stress treatment using PEG 6000 with concentrations of 0%, 10%, 20% and 30%.

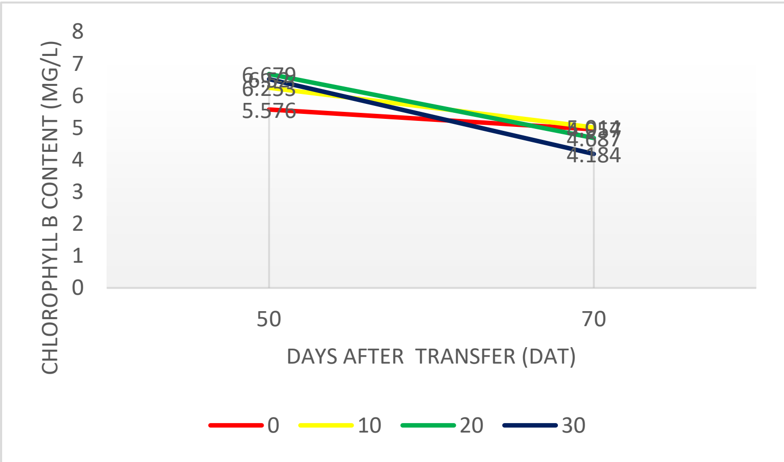

Figure 6: Chlorophyll b content of peranggi chili with drought stress treatment using PEG 6000 with concentrations of 0%, 10%, 20%, and 30%.

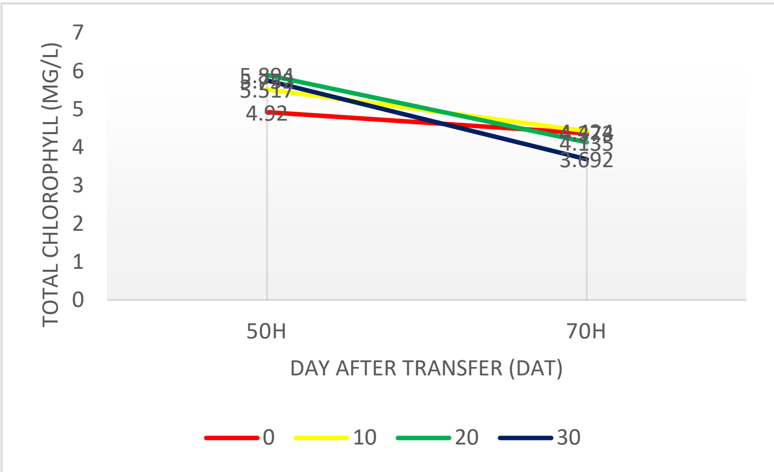

Figure 7: Total chlorophyll content of peranggi chili with drought stress treatment using PEG 6000 with concentrations of 0%, 10%, 20%, and 30%.

4.2 Discussion

Plant growth to determine production yields in the reproductive phase will be influenced by the conditions of the vegetative phase. Meanwhile, the vegetative phase is also inseparable from environmental conditions that affect its growth. Peranggi chili, which is one of the varieties of large chili peppers (*Capsicum annum*), has a shape similar to the chili peppers in a smaller shape form katokkon in Sulawesi. Peranggi in West Kalimantan is like Carolina reaper (*Capsicum chinense*). Peranggi chilies are often grown in the Sambas area but the availability of peranggi chilies in the market is still seasonal and not much with a high price (IDR 100,000 - 130,000.kg^{-1}) compared to other chilies.

Peranggi chilies live in the lowlands in the tropics with frequent dry and rainy seasons. Therefore peranggi chilies are potentially exposed to drought stress. During the dry season, peranggi chili as a variety of chili plants has a sensitivity to drought and has a negative impact on vegetative growth which results in the production phase. Abdurrafi (2021) stated drought reduced the growth of Peranggi chili. This drought stress was stimulated by the use of Polyethylene Glycol (PEG) every two days. PEG has the ability to absorb water so as to reduce water potential and cells in plants experience limitations with water availability. Limited water availability can interfere with the process of nutrient absorption (Novanursandy & Rachmawati, 2023) transpiration events (Subantoro, 2014), photosynthesis (Roziqoh et al., 2023) and ultimately physically seen in the morphology. In this study, the morphology and physiology of peranggi chili were studied after being treated with PEG 6000 with concentrations of 0%, 10%, 20%, and 30%, and the plant organs observed were roots, shoot, leaves, shoot: root ratio, fresh weight and dry weight as morphological observations.

Roots as a plant organ that are directly exposed to respond to the presence of drought stress with its function anchor and look for water sources by gravity. The roots will be longer and possibly higher weight. Root length on 40 to 60 DAT with PEG 6000 increased with increasing concentration of PEG 6000 but decreased on 70 DAT. Root length increased up to 60 DAT; however, there was not any differences among the treatments. On 70 DAT root length reduced from 17%-40% in length except concentration at 10% (Figure 1). The increase in root length would impact to the fresh or dry weight of the root. On the other hand, the shoot growth would slowly increase compare to the root eventualy it would reduce the ratio of shoot: root fresh and dry weight.

The increase in root growth at PEG 6000 concentrations of 0% and 10% was not significantly different from PEG 6000 concentrations of 20% and 30%. Drought stress was only seen on 70 DAT. The treatment of prolonged PEG 6000 30% concentration significantly reduced root length (Figure 1). The multiplication and elongation of cells in the root caused reduced photosynthetic transport in the shoot and resulted in a decrease in the shoot: root ratio throughout the 40 days of the vegetative phase (Figure 2 and Figure 3). However, there was no significance in the fresh and dry weight of roots and shoot. A decrease in the growth rate of the shoot and an increase in the growth rate of the root resulted in a decrease in the ratio of the shoot: root fresh and dry weight (Figure 2 and Figure 3). The results of this study indicated that the effects of PEG 6000 drought stress began to have an impact at 50 DAT. Prolonged drought resulted in plant cells not getting enough water supply so that the concentration increases and metabolic processes are limited (Salemi et al., 2019). PEG 6000 with a highest concentration (30%) caused low osmotic potential and turgor pressure which can result in decreased opening of stomatal cells and results in decreased CO_2 supply and ultimately decreased photosynthesis. According to Novanursandy & Rachmawati (2023), stomatal closure or reduced stomata will negatively affect photosynthesis. Similarly, water shortage can reduce the rate of photosynthesis (Kotagiri & Kolluru, 2017), especially in the event of a light reaction in photosynthesis, and therefore a low shoot: root ratio was seen in peranggi chili. PEG 6000 treatment with concentrations below 30% also did not affect cayenne pepper on day 27 (Novanursandy & Rachmawati, 2023).

Drought stress using reduced field capacity associated with PEG osmopriming reduced the growth of fresh and dry weight of roots, shoot, and the number of leaves. The number of leaves was also not affected by PEG treatment in cayenne pepper (Novanursandy & Rachmawati, 2023) but leaf area, length, and width were significantly different between control and plant leaves affected by PEG. The number of leaves, leaf area, and plant height were usually more related to the environment (Anggun et al., 2017) including PEG. In this study of chili peppers, leaf area, length, and width were not measured. However the amount of chlorophyll content was measured and showed a decrease in chlorophyll content from 50 to 70 DAT (Figures 5, 6, and 7) but not significantly different among PEG 6000 concentrations of 0%, 10%, 20%, and 30%. In orchid plants (Putri et al., 2022) chlorophyll content decreased with increasing concentration of

PEG 6000. In peranggi chilies at 50 DAT the increase in PEG 6000 concentration resulted in an increasing tendency in chlorophyll content but at 70 DAT the tendency was reversed. Increasing the concentration of PEG 6000 actually stimulated the growth of chlorophyll levels. At 50 DAT, peranggi chili plants try to adapt by increasing chlorophyll content with the aim of increasing the rate of photosynthesis (Mensah et al., 2006). However, prolonged drought stress caused the metabolism of chlorophyll formation to be inhibited because the supply of nutrients from the soil cannot help chlorophyll formation (Pratama & Laily, 2015). Thus peranggi chili was affected by the concentration of PEG 6000 at 50 DAT with an increase of chorophyll content along with the increase of constranstion PEG. And prolonged drought stress caused a negative growth with a decline in chloropyll content with an increase in concentration of PEG 6000.

5 Conclusion

Vegetative growth of peranggi chilies under drought stress with PEG 6000 concentrations of 0%, 10%, 20%, and 30% still increased up to 60 days after transfer (DAT) both in fresh and dry weight of roots, shoot, and number of leaves. However at 70 DAT, 30% concentration of PEG 6000 decreased all parameters but had no effect on the concentration below. Of all the parameters measured, the root shoot: ratio of the fresh and dry weight of peranggi chili decreased from 40 to 60 DAT, and the shoot: root ratio did not increase on the 70 DAT. Increasing the concentration of drought stress resulted in reduced water content so that the ratio of shoot: root decreased. In addition, root length was most affected by 30% concentration. At 50 DAT, the presence of drought stress with PEG 6000 caused the content of chlorophyll a, b, and total to slightly increased with increasing concentrations of PEG 6000 but the impact became negative at 70 DAT where the chlorophyll content decreased with the lowest amount at 30% PEG 6000 concentration. Thus it can be concluded that peranggi chili plants still tolerate drought stress up to 20% PEG 6000 concentration, but experience a negative impact at 30% concentration of PEG 6000.

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