Research Article

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# Effect of various varieties and dosage of potassium fertilizer on growth, yield, and quality of red chili (*Capsicum annuum* L.)

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**Abstract:** Red chili is one of the important commodities with increasing demand. However, the quality, continuity of supply, and quantity have not been realized to meet domestic market demand. Increasing growth, yield, and quality can be pursued through superior varieties, and the effort to increase crop productivity is the application of various doses of potassium fertilizer. Therefore, this study aimed to determine the effect of various varieties and doses of potassium fertilizer on the growth, yield, and quality of red chili. The split-plot experimental design consisting of two factors was also used. The first factor is the variety, as the main plot consisting of UNPAD CB2, Tanjung 2, and Lingga. The second factor was the dose of potassium fertilizer as sub-plots which consisted of four levels, namely 0, 100, 200, and 300 kg/ha KCl. The results showed an interaction between variety and dose of potassium fertilizer on plant height at 8 weeks after planting (WAP), stem diameter at 8 WAP, and leaf area index at 9 WAP. Meanwhile, UNPAD CB2 showed the best results for 6 WAP plant height, fruit weight per plant, number of fruits per plant, fruit length, dihydrocapsaicin, total capsaicinoid, and scoville heat unit. Potassium fertilizer doses of 200 and 300 kg/ha KCl showed high yields for stem diameters of 6 WAP.

**Keywords:** chili pepper, horticulture, nutritional compounds, phytochemical, plant production

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## 1 Introduction

Red chili (*Capsicum annuum* L.) is one of the leading horticultural commodities from the Solanaceae family, widely cultivated and used commercially. It has also become one of the popular vegetable commodities in terms of its color, taste, and nutritional value of the fruit [1]. The red chili contains some phytochemical compounds, such as alkaloids, flavonoids, and carotenoids, which have the potential as antioxidants [2]. In the 2015–2019 period, production of red chili experienced fluctuating developments but tended to increase yearly in Indonesia. The increase in chili production is accompanied by an increase in consumption, projected to rise by 11.7%. However, the supply in some central areas is limited due to weather disturbances and floods [3]. The supply is expected to meet market demand and maintain price stability without relying on imports [4]. Concerning the obstacle, the quality, continuity of supply, and quantity of red chili have not been realized. Furthermore, the storage of horticultural products can cause a decrease in quality. It is necessary to optimize production through various applications of technological innovations [5–7].

The increasing market demand for chili commodities requires farmers to increase production. The development of production, optimization, and innovations can be carried out through quality varieties. Plant varieties that match market demand, such as color, taste, appearance, and size, are usually selected. Farmers can select varieties suitable for their growing environment and have high yield potential to meet market demand.

There are some local Indonesian red chili varieties. Each variety has different characteristic, depending on each genetic trait. In general, farmers choose varieties based on productivity, quality, and pest resistance. In addition, the economic value is a consideration in the selection of varieties. Production optimization in terms of yield and quality can be conducted by applying potassium fertilizer to increase fertility [8]. One of the important nutrients needed is potassium (K), an important nutrient for plants and soil. Elements of K in large quantities are required to obtain optimal production [9]. Furthermore, when potassium is deficient, $CO_2$ fixation, photosynthesis, and transportation can be reduced [10]. The deficiency can also result in chlorophyll degradation [11], which plays a role in physiological and biochemical processes, such as cell division and elongation, carbohydrate metabolism, protein compounds, and antioxidants [12]. The application with a dose of 200 kg/ha KCl on chili plants affects vegetative growth (plant height and total fruit), fruit length, and fruit weight of the plant [13]. Application with a dose of 100 kg/ha KCl on tomato plants can increase fruit yields, while 300 kg/ha KCl can increase the water content of tomatoes [14]. However, lack of studies examined the effect of KCl on local Indonesian red chili varieties, especially UNPAD CB2, Tanjung 2, and Lingga varieties. Hence, this study aimed to determine the best KCl dose to obtain the optimum red chili yield based on various vegetative and generative parameters. The finding of this study is expected to be a reference for farmers and red chili industry in determining the KCl dose to obtain optimum crop yields.

# 2 Materials and methods

## 2.1 Experimental design

The experiment was conducted in the plastic house, at an altitude of 730 m above sea level, and the Horticulture Laboratory, Faculty of Agriculture, Universitas Padjadjaran. This study used a split-plot design consisting of two factors. The first was the variety, as the main consisting of UNPAD CB2, Tanjung 2, and Lingga. Several local varieties include the UNPAD CB2, Tanjung 2, and Lingga. These are local varieties with different characteristics and advantages. UNPAD CB2 has a strong red color and high levels of capsaicin. Meanwhile, Tanjung 2 has resistance to thrips and anthracnose disease, and Lingga has high yield potential. The second factor was the dose of potassium fertilizer as sub-plots, consisting of 0, 100, 200, and 300 kg/ha KCl. In addition, 12 treatments were replicated 3 times to obtain 36 experimental units of 3 plant samples.

Red chili was planted in polybag plastic (40 cm × 40 cm) with growing media of rice husk, goat manure, and soil (1:1:2, by volume). The application of KCl fertilizer dose according to the treatment was a dose of 100 (2.94 g/plant), 200 (5.88 g/plant), and 300 kg/ha (8.82 g/plant). KCl was applied at 5 days before planting. Fertilization using NPK (16:16:16) was carried out once a week starting at 8 weeks after planting (WAP) to 12 WAP. All plants for each treatments were given the same doses of NPK. The average temperature in the planting environment ranges from 22 to 23.6°C with humidity around 73.6–91%. Plant maintenance consists of watering, replanting, weeding, irrigation, and controlling plant pests and diseases. Subsequently, red chili was harvested six times with an interval of once every 5 days. The criterion is that the chili is ripe and 100% red.

Observations of plant growth included plant height, stem diameter, and leaf area index (LAI). The results comprised the number of fruit per plant, fruit weight per plant, fruit length, and fruit diameter. Meanwhile, the quality observations were fruit moisture content, fruit skin color and texture, capsaicin, dihydrocapsaicin, total capsaicinoid, scoville heat unit (SHU), total flavonoid, total carotenoid, and antioxidant activity.

## 2.2 Analysis of fruit color

Measurement of fruit peel color was conducted quantitatively using CM-600d color spectrophotometer (Konica Minolta, Inc, Japan). The samples used were three red chilies measured at top, middle, and bottom. The color value was visualized in the $L^*$ (lightness) measurement scale for values 0 (black), 100 (white), $a^*$ [value 100 (red), −100 (green)], and $b^*$ [value 100 (yellow), −100 (blue)] [15]. Chroma ($C^*$) measurement was used to determine the color intensity. The hue angle ($h$°) was measured to determine the center angle value of the base color pair. The $C^*$ and $h$° measurements are formulated as follows:

$$C^* = \sqrt{(a^*)^2 + (b^*)^2}, \tag{1}$$

$$h^{\circ} = \mathrm{Tan}^{-1}\frac{b^*}{a^*}. \tag{2}$$

## 2.3 Analysis of fruit texture

Measurement of fruit texture was carried out using a TA.XT Express Enhanced (Stable Micro Systems, Surrey, UK), a maximum load of 5 kg, a depth of pressing 2 mm, a speed of decreasing load 10 s, and a probe diameter of 6 mm. The determination of fruit texture was done at three parts that represents the whole part of fruit. Measurements were made at the fruit's top, middle, and bottom using three samples per treatment. The value of the chili fruit texture was expressed in grams of Force (gF).

## 2.4 Analysis of fruit moisture content

Moisture content is calculated based on the weight loss of heating at a temperature of 105°C. About 2–4 g of fresh samples for the moisture content test were weighed and put into an aluminum foil with a known initial weight. Furthermore, it was put in an oven (Memmert Schutzart DIN 40050-IP 20, Schwabach, Germany) at 105°C until a constant weight was obtained [16–18]. The results of the dry samples were weighed using an analytical balance and calculated using the formula:

$$\%\text{moisture content} = \frac{\text{wet sample} - \text{dry sample}}{\text{wet sample}} \times 100\%. \quad (3)$$

## 2.5 Powder sample preparation

The sample used for the chemical analysis was a dry powder sample obtained from 50 g of fresh red chili, thinly sliced, and dried in an oven at 50°C for 20 h [19]. The dried chili samples are mashed using a grinder machine. Furthermore, 50 g of fresh chili produce about 5 g of dry powder samples because drying causes a 95% loss of water content in the fruit.

## 2.6 Analysis of capsaicin, dihydrocapsaicin, and SHU

Measurement of capsaicin and dihydrocapsaicin followed the procedure of Thapa et al. [20], which has been modified using high-performance liquid chromatography (HPLC) (Shimadzu, LC 20AT Prominence, Tokyo, Japan). The sample was obtained from the extraction result after being filtered using a 0.4 m PTFE pore filter system and analyzed under the same conditions as the standard [21]. Total capsaicinoids were obtained from the sum of capsaicin and dihydrocapsaicin values. Capsaicin and dihydrocapsaicin compounds are converted into SHU using the following formula [22]:

$$\text{SHU} = (\text{capsaicin} \times 16.1) + (\text{dihydrocapsaicin} \times 16.1). \quad (4)$$

## 2.7 Analysis of total carotenoid

Measurement of total carotenoids followed the procedure of Pinheiro-santana et al. [23] and Biswas et al. [24], which has been modified using UV-Vis spectrophotometer (Shimadzu, UV mini-1240, Tokyo, Japan). The extracted sample was measured at a wavelength of 449 nm. Various standard concentrations of β-carotene were prepared and measured at the same wavelength. The total carotenoid is expressed in β-carotene equivalent, which is done by calculating the absorbance of the sample and the standard curve equation.

## 2.8 Analysis of total flavonoid

Measurement of total flavonoids followed the procedure of Sytar et al. [25], with some modification. 0.5 mL of extracted sample, 1.5 mL of methanol, 0.1 mL of aluminum chloride, 0.1 mL of potassium acetate, and 2.8 mL of distilled water were prepared in a test tube. Methanol was used as a blank in the reaction step, and various standard concentrations of quercetin were prepared and reacted as samples and blanks. Each sample, blank and standard to which the reagent was added, was homogenized and incubated for 30 min at room temperature.

Samples and standards were measured at 415 nm using the UV-Vis spectrophotometer. The regression equation from the standard calibration curve was used to calculate the total flavonoid content (TFC). The sample used in the test is a dry powder sample, and the absorbance results are plotted on a standard curve and the TFC is calculated as follows:

$$\text{Total flavonoid QE} = \frac{C \times V}{\text{DW}}. \quad (5)$$

## 2.9 Analysis of the antioxidant activity

Measurement of antioxidant activity followed the modified Lim and Murtijaya [26] procedure using the DPPH (1,1-diphenyl-2picryl hydrazil) method. A total of 0.5 mL of sample was added with 1 mL of DPPH with 1.5 mL of methanol in a 10 mL amber vial. The absorbance was measured using the UV-Vis spectrophotometer at 515 nm [27].

## 2.10 Data analysis

The data were statistically processed using the analysis of variance. Furthermore, when the test results are significantly different, it is continued with the Duncan's multiple range test at a 5% significance level.

# 3 Results and discussion

## 3.1 Plant height

Plant height measured at 2, 4, 6, and 8 WAP shows the interaction effect at 8 WAP, as seen in Table 1. This shows the interaction of potassium fertilizer and varieties on plant height 8 WAP. The three varieties have different plant height characteristics from the beginning of growth, influenced by genetic factors.

The response of plant height growth to the treatment of varieties at 2, 4, and 6 WAP can be seen in Table 2. This showed that the treatments of varieties 2 and 4 WAP were not significantly different in plant height. The varietal treatment showed significant effect at 6 WAP, namely UNPAD CB2, which provided the highest plant height yield of 87.76 cm, significantly different from Lingga and Tanjung 2 at 79.51 and 75.38 cm, respectively. Differences in plant height are caused by different genetic characters and phenotypes, as revealed by Kesumawati et al. [28], where the adaptability of each variety is different to the environment, both climatic factors and growing media.

At 2 WAP, the treatment of KCl fertilizer did not influence plant height; however, at 4 and 6 WAP, there were substantial differences. At 4 WAP, doses of 0 and 200 kg/ha showed a significant effect, where a dose of 200 kg/ha resulted in higher plant height. However, it was not significantly different from treatments of 100 and 300 kg/ha KCl. At 6 WAP, doses of KCl 200 and 300 kg/ha also resulted in higher plant height than KCl 0 and 100 kg/ha. Based on the results of Maryono et al. [29], which applied KCl fertilizer to the UNIB C H13 chili variety with a dose of 250 kg/ha, it increased the plant height by an average of 109.1 cm. Potassium plays an important role in plants, and young growing tissues need element K for cell elongation and division. According to Hasanuzzaman et al. [11], this increase in plant height was probably due to increased cell division and elongation.

**Table 1:** Effect of interaction between dosage of potassium fertilizer and red chili varieties on plant height at 8 WAP

| Varieties | Dosage of potassium fertilizer (kg/ha KCl) | | | |
|---|---|---|---|---|
| | 0 ($p_0$) | 100 ($p_1$) | 200 ($p_2$) | 300 ($p_3$) |
| UNPAD CB2 ($v_1$) | 98.50a C | 109.33b C | 105.83b C | 104.67ab C |
| Tanjung 2 ($v_2$) | 83.72a A | 87.50b A | 89.50b A | 87.33b A |
| Lingga ($v_3$) | 87.50a B | 89.33a B | 96.33b B | 97.50b B |

Lowercase notation is read horizontally, and capital letter notation is read vertically. The average value followed by the same letter shows no significant difference based on Duncan's multiple range test at a 5% significance level.

## 3.2 Stem diameter

Stem diameter measured at 2, 4, 6, and 8 WAP shows the interaction effect at 8 WAP, as shown in Table 3. The interaction of potash fertilizer and varieties on stem diameter of 8 WAP was reported. The interaction of the Tanjung 2 treatment and a dose of 200 kg/ha resulted in the largest stem diameter, significantly different from the others. In contrast, the treatment with the smallest diameter was obtained by Tanjung 2 and a dose of 0 kg/ha. The three varieties have characters causing different responses. Each variety has varied characteristics due to genetic differences and the influence of environmental conditions such as rainfall, temperature, and soil type [30].

**Table 2:** Effect of dosage of potassium fertilizer and red chili varieties on plant height at 2, 4, and 6 WAP

| Treatment | Plant height (cm) | | |
|---|---|---|---|
| | 2 WAP | 4 WAP | 6 WAP |
| **Varieties** | | | |
| $v_1$ = UNPAD CB2 | 20.30a | 45.25a | 87.76c |
| $v_2$ = Tanjung 2 | 20.90a | 47.89a | 75.38a |
| $v_3$ = Lingga | 20.44a | 48.04a | 79.51b |
| **Potassium fertilizer dosage** | | | |
| $p_0$ = 0 kg/ha KCl | 20.89a | 44.29a | 78.77a |
| $p_1$ = 100 kg/ha KCl | 19.88a | 47.34ab | 78.65a |
| $p_2$ = 200 kg/ha KCl | 21.01a | 49.38b | 83.51b |
| $p_3$ = 300 kg/ha KCl | 20.40a | 47.22ab | 82.60b |

The average number in each column followed by the same letter shows that it is not significantly different according to Duncan's multiple range test at the 5% level.

**Table 3:** Effect of interaction between dosage of potassium fertilizer and red chili varieties on stem diameter at 8 WAP

| Varieties | Potassium fertilizer dosage (kg/ha KCl) | | | |
|---|---|---|---|---|
| | 0 ($p_0$) | 100 ($p_1$) | 200 ($p_2$) | 300 ($p_3$) |
| UNPAD CB2 ($v_1$) | 8.25a | 8.33a | 8.82b | 8.73b |
| | B | A | A | A |
| Tanjung 2 ($v_2$) | 8.11a | 8.78b | 9.27d | 9.04c |
| | A | B | B | B |
| Lingga ($v_3$) | 8.27a | 8.40a | 8.70b | 8.92b |
| | B | A | A | B |

Lowercase notation is read horizontally, and capital letter notation is read vertically. The average value followed by the same letter shows no significant difference based on Duncan's multiple range test at a 5% significance level.

The growth response of stem diameter can be seen in Table 4, showing that the treatment of varieties at 2, 4, and 6 WAP significantly differed in stem diameter. The growth of stem diameter at 2 WAP on Tanjung 2 and UNPAD CB2 produced the largest and smallest diameter of 3.41 and 3.06 mm. At 4 WAP, Tanjung 2 still produced the largest diameter, while UNPAD CB2 and Lingga were not significantly different. At 6 WAP, it showed the largest stem diameter of 7.42 mm, significantly different from Lingga and UNPAD CB2 at 7.09 and 6.68 mm, respectively. The results showed that the three varieties have different stem diameter characters since the beginning of growth.

The potassium fertilizer dose significantly affected stem diameter, where the growth of 2 WAP has shown a different response. The treatment without potassium fertilizer was significantly different from the doses of 100 and 200 kg/ha KCl. At 4 WAP, it also showed a significant effect between treatments without potassium fertilizer at a dose of 200 kg/ha KCl, resulting in a stem diameter of 5.14 mm, but not significantly different from treatments at 100 and 300 kg/ha KCl. At 6 WAP with various doses of potassium fertilizer, stem diameter was significantly affected. Treatment with a 200 kg/ha KCl fertilizer resulted in a wider diameter of 7.29 mm, but not significantly different from a dose of 300 kg/ha KCl at 7.14 mm. In comparison, the treatment of 0 kg/ha KCl resulted in a smaller diameter of 6.80 mm, which was not significantly different from the treatment of 100 kg/ha KCl. The difference in stem diameter results at various doses of potassium fertilizer is because K plays a role in the preparation of plant tissue, specifically in lateral meristem tissue [31].

**Table 4:** Effect of potassium fertilizer dosage and red chili varieties on stem diameter at 2, 4, and 6 WAP

| Treatment | Stem diameter (mm) | | |
|---|---|---|---|
| | 2 WAP | 4 WAP | 6 WAP |
| Varieties | | | |
| $v_1$ = UNPAD CB2 | 3.06a | 4.70a | 6.68a |
| $v_2$ = Tanjung 2 | 3.41c | 5.37b | 7.42c |
| $v_3$ = Lingga | 3.20b | 4.71a | 7.09b |
| Potassium fertilizer dosage | | | |
| $p_0$ = 0 kg/ha KCl | 3.11a | 4.72a | 6.80a |
| $p_1$ = 100 kg/ha KCl | 3.24b | 4.86ab | 7.02ab |
| $p_2$ = 200 kg/ha KCl | 3.32b | 5.14b | 7.29c |
| $p_3$ = 300 kg/ha KCl | 3.22ab | 4.99ab | 7.14bc |

The average number in each column followed by the same letter shows that it is not significantly different according to Duncan's multiple range test at the 5% level.

## 3.3 Leaf area index

The LAI illustrates the ratio of the surface to the area overgrown by plants because it reflects the ability to produce photosynthate. LAI was measured at 9 WAP and showed an interaction effect in Table 5. The treatment of varieties and various doses of KCl fertilizer showed a significantly different effect on the LAI. The interaction of the Lingga treatment and the dose of 300 kg/ha resulted in the highest LAI. Meanwhile, the treatment with the lowest LAI was obtained by Lingga at 100 kg/ha and UNPAD CB2 at 200 kg/ha of KCl. The increase in leaf area is influenced by nutrient absorption, and when the fertilizer is absorbed properly, it will increase photosynthesis and leaf area [32].

## 3.4 Number of fruits and their weight per plant

The treatment of varieties significantly differed from the number of fruits and weight per plant, as shown in Table 6. UNPAD CB2 produced the highest number with 70.78 fruit, while Tanjung 2 and Lingga were not significantly different. The fruit weights of UNPAD CB2 and Lingga were significantly different, while Tanjung 2 was not significantly different. Differences in fruit weight can occur due to genetic variations in each variety tested, specifically in character [33]. The fruit weight per plant in UNPAD CB2 was higher than Lingga. The weight of each red chili of UNPAD CB2 was 237.30 g, while Tanjung 2 and Lingga were 200.60 and 176.50 g, respectively.

**Table 5:** Effect of potassium fertilizer doses and red chili varieties interaction on LAI at 9 WAP

| | LAI | | | |
|---|---|---|---|---|
| **Varieties** | **Potassium fertilizer dosage (kg/ha KCl)** | | | |
| | **0 ($p_0$)** | **100 ($p_1$)** | **200 ($p_2$)** | **300 ($p_3$)** |
| UNPAD CB2 ($v_1$) | 0.39b<br>A | 0.57d<br>B | 0.34a<br>A | 0.51c<br>A |
| Tanjung 2 ($v_2$) | 0.63b<br>B | 0.65bc<br>C | 0.66c<br>B | 0.57a<br>B |
| Lingga ($v_3$) | 0.61b<br>B | 0.27a<br>A | 0.63c<br>B | 0.70d<br>C |

Lowercase notation is read horizontally, and capital letter notation is read vertically. The average value followed by the same letter shows no significant difference based on Duncan's multiple range test at a 5% significance level.

The results were not significantly different from the number of fruits and weight per plant at various doses of potassium fertilizer. The formation and filling of fruit are influenced by nutrients, one of which is K, which plays a role in the photosynthesis process as a constituent of proteins and carbohydrates [34]. However, in this experiment, KCl fertilizer at a dose of 0–300 kg/ha has not affected the number of fruits and their weight per plant. This is presumably due to biotic factors such as pests and diseases that interfere with the flowering and fruiting process.

## 3.5 Fruit length and diameter

Fruit length and diameter can be seen in Table 6, where UNPAD CB2 had the highest fruit length (12.64 cm) and smallest diameter (9.63 mm). Tanjung 2 and Lingga had fruit lengths that were not significantly different at 10.97 and 11.06 cm, respectively. However, Tanjung 2 produced the largest fruit diameter of 14.88 mm and Lingga at 11.01 mm has a fruit diameter significantly different from the other two varieties.

Genetic factors influence the three varieties to produce different fruit lengths and diameters, as shown in Figure 1. Our finding was similar to the research reported by Suherman et al. [35], the fruit length of UNPAD CB2 is 12.30 cm. Tanjung 2 has also been studied by Soetiarso et al. [36], and it has a fruit length and a diameter with a value range of 9–15 cm and 13–18 mm, respectively.

The results showed a significant effect on fruit length at various doses of potassium fertilizer. The treatment with a dose of 300 kg/ha KCl showed a high fruit length of 12.34 cm but was not significantly different from those of 100 and 200 kg/ha KCl. The increase in fruit length and diameter is influenced by the supply of K in the photosynthesis process. The results of photosynthesis in the form of carbohydrates that accumulate during development affected fruit size [37]. At various doses of potassium fertilizer, the results were not significantly different from fruit diameter. Based on the results of Mardanluo et al. [38], the application of KCl fertilizer dose range of 200–600 kg/ha did not affect the diameter of chili fruit.

## 3.6 Fruit peel color

Based on Table 7, the experimental results did not show the interaction effect between the use of red chili varieties and the dose of potassium fertilizer on the average values of $L^*$, $a^*$, $b^*$, $C^*$, and $h°$. The varietal treatments were significantly different for the colors $L^*$, $a^*$, $b^*$, and $C^*$, while there was no significant difference in the $h°$ value.

**Table 6:** Effect of potassium fertilizer dosage and varieties on number of fruits per plant, fruit weight per plant, length, and diameter

| **Treatment** | **Number of fruits per plant (fruit)** | **Fruit weight per plant (g)** | **Fruit length (cm)** | **Fruit diameter (mm)** |
|---|---|---|---|---|
| Varieties | | | | |
| $v_1$ = UNPAD B2 | 70.78b | 237.30b | 12.64b | 9.63a |
| $v_2$ = Tanjung 2 | 35.78a | 200.66ab | 10.97a | 14.88c |
| $v_3$ = Lingga | 40.46a | 176.50a | 11.06a | 11.01b |
| Potassium fertilizer dosage | | | | |
| $p_0$ = 0 kg/ha KCl | 49.63a | 216.93a | 10.78a | 11.65a |
| $p_1$ = 100 kg/ha KCl | 50.11a | 199.63a | 11.55ab | 11.70a |
| $p_2$ = 200 kg/ha KCl | 49.63a | 207.93a | 11.55ab | 11.96a |
| $p_3$ = 300 kg/ha KCl | 46.89a | 194.67a | 12.34b | 12.05a |

The average number in each column followed by the same letter shows that it is not significantly different according to Duncan's multiple range test at the 5% level.

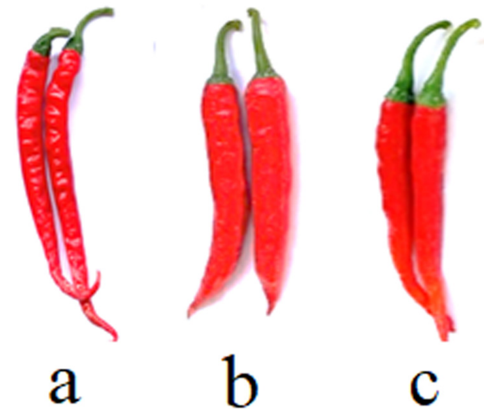


**Figure 1:** Fruit shape of UNPAD CB2 (a), Tanjung 2 (b), and Lingga variety (c).

The $L^*$ value indicates that Lingga has the highest value at 38.52. The $a^*$ value shows the result where UNPAD CB2 has a high value of 40.12 but is not significantly different from Tanjung 2. The $a^*$ value means that UNPAD CB2 and Tanjung 2 have more intense red color than Lingga, in line with the total carotenoid content (TCC) test (Table 8). The $b^*$ and $C^*$ values showed the results where UNPAD CB2 and Lingga are not significantly different. The $h^\circ$ values were not significantly different in the three varieties, with a range of 28.02–28.85. The treatment of various doses of potassium fertilizer significantly affected the values of $a^*$ and $C^*$ but did not significantly affect the average values of $L^*$, $b^*$, and $h^\circ$.

## 3.7 Fruit moisture content

Moisture content is one of the important components in chili fruit [16,17,39]. Figure 2 shows that the varietal treatments significantly differed from the fruit's moisture content. Tanjung 2 and Lingga produced moisture content that was not significantly different, namely 84.27 and 83.86%, respectively. However, they significantly differed from UNPAD CB2, which produced the lowest of 82.04%. The morphology of UNPAD CB2 of red chili dense with seeds and thin peel causes less moisture content compared to Tanjung 2 and Lingga chilies with thicker peels. Generally, fresh red chilies have an average moisture content of 75–84% [40], but the three varieties had high moisture content, ranging from 82.04 to 84.59%.

Treatment of various doses of potassium fertilizer showed results that were not significantly different from the moisture content of the fruit. The range of moisture content values based on potassium fertilizer is 83.18–83.67%. Based on the results of Woldemariam et al. [14], the treatment of 0–250 kg/ha KCl fertilizer dose range could not increase the moisture content of tomatoes.

## 3.8 Fruit texture

The texture is an important characteristic that determines the physical quality of the fruit. It becomes an assessment of consumer acceptance of vegetables and fruit. It directly affects postharvest processing and is an important indicator of quality evaluation [41–43]. The experimental results showed no interaction effect between red chili varieties and the dose of potassium fertilizer on fruit texture. Figure 2 shows that the treatment of varieties significantly differed from the fruit texture. Lingga produced a high fruit texture value of 2,603.12 gF but was not significantly different from UNPAD CB2, which was

**Table 7:** Effect of variety and potassium fertilizer dosage on color coordinates $L^*$, $a^*$, $b^*$, $C^*$, and $h^\circ$

| Treatment | Color coordinates | | | | |
|---|---|---|---|---|---|
| | $L^*$ (brightness) | $a^*$ (green-red) | $b^*$ (blue-yellow) | $C^*$ (intensity) | $h^\circ$ (hue angle) |
| Varieties | | | | | |
| $v_1$ = UNPAD CB2 | 37.13a | 40.12b | 22.03b | 40.22b | 28.16a |
| $v_2$ = Tanjung 2 | 37.39a | 39.80b | 20.37a | 33.38a | 28.02a |
| $v_3$ = Lingga | 38.52b | 38.73a | 21.96b | 41.73b | 28.85a |
| Potassium fertilizer dosage | | | | | |
| $p_0$ = 0 kg/ha KCl | 37.71a | 38.98a | 21.28a | 39.35ab | 27.94a |
| $p_1$ = 100 kg/ha KCl | 38.19a | 39.36ab | 21.79a | 40.45b | 28.50a |
| $p_2$ = 200 kg/ha KCl | 37.37a | 39.73ab | 21.77a | 37.41ab | 28.92a |
| $p_3$ = 300 kg/ha KCl | 37.45a | 40.09b | 20.97a | 36.67a | 28.00a |

The average number in each column followed by the same letter shows that it is not significantly different according to Duncan's multiple range test at the 5% level.

2,426.40 gF. Meanwhile, Tanjung 2 produced the lowest fruit texture value of 1,639.78 gF. UNPAD CB2 and Lingga have a harder fruit texture than Tanjung 2. The morphology is dense with seeds, thin peels, and a small diameter. Lingga has a similar texture as UNPAD CB2, while Tanjung 2 has a large diameter with few seeds. Therefore, a space causes the fruit texture value to be low. The value of the fruit texture varies due to genetic factors. The higher the pericarp thickness of a variety, the better the fruit texture [44].

The treatment of various doses of potassium fertilizer was not significantly different from the texture of chilies. The analysis was not affected by the increasing amount of KCl fertilizer applied. Mardanluo et al. [38] stated that the application of KCl fertilizer dosage range of 200–600 kg/ha did not significantly affect the texture. The harvest period influences the texture of the data fruit, and the changes in the texture of horticultural products are closely related to the cell wall composition. Several enzymes play a role in cell wall breakdown, namely galactosidase, polygaktunorse, cellulose, and hemicellulose [45,46].

**Table 8:** Effect of variety and dosage of potassium fertilizer on capsaicin, dihydrocapsaicin, total capsaicinoid, total carotenoids, TFC, and antioxidant activities

| Treatment | Capsaicin (mg/100 g dry sample) | Dihydrocapsaicin (mg/100 g dry sample) | Total capsaicinoid (mg/100 g dry sample) | SHU | Total caretonoids (mg/100 g dry sample) | Total flavonoid (mg QE/100 g dry sample) | Antioxidant activities IC50 (mg/L) |
|---|---|---|---|---|---|---|---|
| Varieties | | | | | | | |
| UNPAD CB2 | 98.57b | 35.43c | 134.00c | 21574.00c | 772.03b | 210.51b | 8263.67ab |
| Tanjung 2 | 29.51a | 16.52a | 46.03a | 7411.50a | 763.97b | 262.03c | 9105.92b |
| Lingga | 88.87b | 27.87b | 116.74b | 18794.34b | 573.98a | 173.19a | 7346.28a |
| Dose | | | | | | | |
| 0 kg/ha KCl | 67.01a | 22.88a | 89.90a | 14473.54a | 680.36a | 211.07a | 8949.66b |
| 100 kg/ha KCl | 76.00a | 28.09a | 104.09a | 16758.49a | 723.88a | 233.10a | 8874.00b |
| 200 kg/ha KCl | 75.09a | 28.80a | 103.89a | 16727.01a | 696.46a | 213.84a | 7049.86a |
| 300 kg/ha KCl | 71.16a | 26.65a | 97.81a | 15747.54a | 712.60a | 202.97a | 8080.97ab |

The average number in each column followed by the same letter shows that it is not significantly different according to Duncan's multiple range test at the 5% level.

## 3.9 Capsaicin, dihydrocapsaicin, total capsaicinoid, and SHU

Capsaicinoid is an important part of chili responsible for spiciness, divided into capsaicin, dihydrocapsaicin, nordihydrocapsaicin, homocapsaicin, and homodihydrocapsaicin. Capsaicin and dihydrocapsaicin are the most dominant capsaicinoid in nature, specifically in *Capsicum* species, and placental epidermal cells are the main site of biosynthesis [47]. The two main capsaicinoids are capsaicin and dihydrocapsaicin, which are approximately 60 and 30% [48], respectively. The degree of spiciness is indicated in SHU based on the concentration of the compounds in the fruit. The SHU scale (1 ppm = 1 SHU) measures the number of times the extract is diluted to make the spice undetectable in sugar water.

The experimental results did not show the interaction effect between red chili varieties and the dose of potassium fertilizer on capsaicin, dihydrocapsaicin, capsaicinoid, and SHU. Table 8 shows that the varietal treatments significantly differed in the yield of capsaicin, dihydrocapsaicin, capsaicinoid, and SHU. UNPAD CB2 had a high capsaicin, 98.57 mg/100 g dry sample, but not significantly different from Lingga at 88.87 mg/100 g dry sample. In contrast, Tanjung 2 produced the lowest capsaicin, which was 29.51 mg/100 g dry sample.

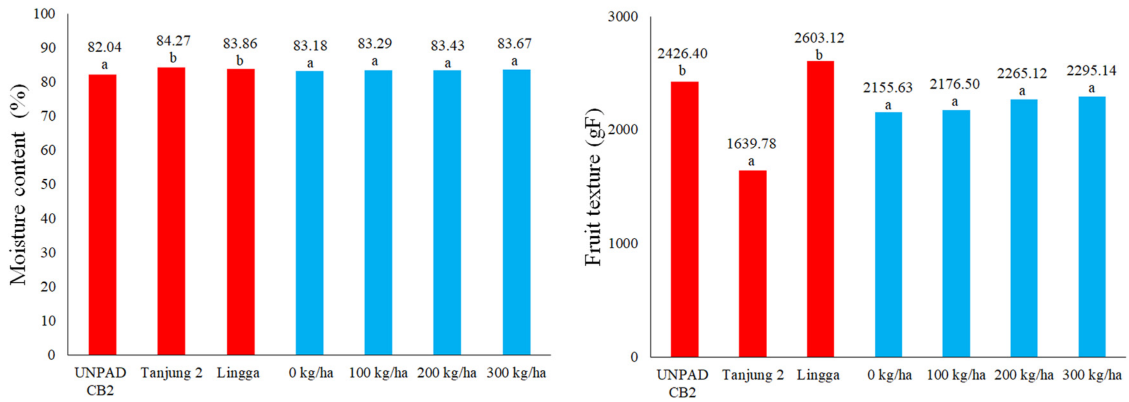


**Figure 2:** Effect of individual treatment of variety (red) and potassium fertilizer (blue) on fruit moisture content and texture. For each group color, the same letters indicate not significantly different means within each group color.

Regarding the dihydrocapsaicin, UNPAD CB2 had the highest value of 35.43 mg/100 g dry sample, significantly different from Tanjung 2 and Lingga at 16.52 mg/100 g and 27.87 mg/100 g dry sample, respectively. The difference in the levels capsaicin and dihydrocapsaicin showed a ratio of 3:1 (Figure 3a and c), in contrast to Tanjung 2, which showed a ratio of 2:1 (Figure 3b). These differences are the uniqueness of the red chili genetics, and the biosynthesis and accumulation of capsaicinoid is a genetically determined trait [49].

These results indicate that capsaicin's content is more dominant than dihydrocapsaicin. It has previously been studied on other varieties of *Capsicum annuum* and *Capsicum pusbecens* by Vera-Guzmán et al. [50]. Capsaicin in *C. annuum* was higher (4.9–142 µg/mL) than dihydrocapsaicin (1.5–65.5 µg/mL). The total capsaicin level was significantly higher in UNPAD CB2 at 134 mg/100 g dry sample, which was significantly different from the treatment of others. Other varieties of *C. annum* have also been studied by Liu et al. [51], showing the results of the analysis of capsaicinoid with a range of 105–369 mg/100 g dry sample. This study showed that the total capsaicinoid was 46–134 mg/100 g dry sample.

SHU is an important measure to evaluate the spiciness of chili varieties. The level of spiciness based on SHU is divided into not spicy (0–700 SHU), slightly spicy (700–3,000 SHU), medium spicy (3,000–25,000 SHU), very spicy (25,000–70,000 SHU) and very aromatic (>80,000 SHU) [49]. Based on this scale, UNPAD CB2, Tanjung 2, and Lingga can be classified as medium spicy with a range of 7,411–21,574 SHU. UNPAD CB2 had the highest degree of spiciness, which is 21,574 SHU, and it resulted from a cross of Serrano chili, which ranges from 10,000 to 23,000 SHU. Therefore, UNPAD CB2 is included in the classification and has a higher spiciness than Tanjung 2 and Lingga.

Potassium fertilizer dose treatment showed no significant difference between capsaicin, dihydrocapsaicin, capsaicinoid, and SHU. Doses of KCl 100, 200, and 300 kg/ha could not increase the capsaicin and dihydrocapsaicin. Medina-Lara et al. [52] stated that treatment with KCl fertilizer doses of 0–250 kg/ha could not increase the capsaicin of Habanero chilies. Meanwhile, the increasing amount of KCl fertilizer applied did not affect the analysis of capsaicin and dihydrocapsaicin. This can occur because potassium fertilizer does not affect the activity of enzymes in capsaicin biosynthesis. The increase in the concentration of capsaicin was more strongly influenced by hydrate stress. Hydration stress increases capsaicinoid levels because water deficit affects the biosynthetic pathway (phenylpropanoid pathway) and increases the activity of enzymes involved in capsaicin biosyntheses such as phenylalanine ammonia-lyase and cinnamic acid-4-hydroxylase [53].

## 3.10 TCC

Carotenoids are secondary metabolites and act as natural color pigments that give yellow, orange, to red colors. It consists of several types based on visible color, including α-carotene, β-carotene, lycopene, lutein, zeaxanthin, astaxanthin, β-cryptoxanthin, and fucoxanthin [54]. Furthermore, analysis of total carotenoids in chili is expressed in mg/100 g dry sample units.

The experiment results did not show the interaction effect between red chili varieties and the dose of KCl fertilizer on the TCC, as shown in Table 8. The varietal

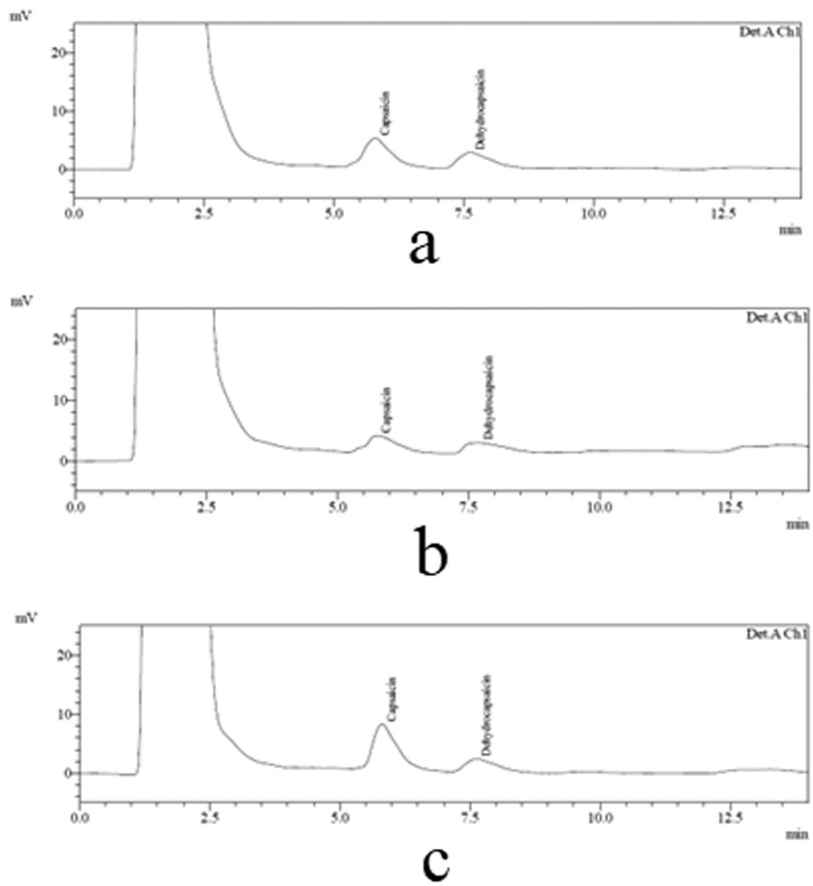


**Figure 3:** HPLC chromatogram of capsaicin and dihydrocapsaicin content in UNPAD CB2 (a), Tanjung 2 (b), and Lingga (c).

treatments significantly differed from the TCC, and UNPAD CB2 has a high TCC of 772.03 mg/100 g dry sample. However, it is not significantly different from Tanjung 2 with 763.97 mg/100 g dry sample. Lingga produced the lowest total carotenoids of 573.98 mg/100 g dry sample. Carotenoids develop and accumulate rapidly as the fruit ripens [55]. During the ripening process, chloroplasts differentiate into chromoplasts containing carotenoids that contribute to fruit color [56]. The carotenoid content has been previously investigated by Tundis et al. [57], where two cultivars of *C. annum* var. *acuminatum* and *C. annuum* var. *cerasiferum* contain 324.2 and 133.9 mg/100 g of dry sample. Genetics is one of the most influential elements affecting the carotenoid content of chili [53]. Varietal factors alter the carotenoid of fruits and vegetables in the range of 573–772 mg/100 g dry sample.

Potassium fertilizer dose treatment showed no significant difference in total carotenoids. Treatment with doses of KCl 100, 200, and 300 kg/ha did not increase the TCC in chilies. The biosynthesis requires several types of enzymes such as isopentenyl pyrophosphate isomerase, carotenoid isomerase, lycopene-β-cyclase, zeaxanthin epoxidase, and capsanthin-capsorubin-synthase [58]. Changes in the fruit indicate carotenoid biosynthetic activity. However, the application of various doses of KCl fertilizer did not affect the enzyme activity in carotenoid biosynthesis.

## 3.11 TFC

Flavonoids are secondary metabolites belonging to the group of polyphenolic compounds and have a role in antioxidant activity [22]. They have antimicrobial and anticancer effects as well as health benefits, such as preventing heart disease, cancer, inflammation, and diabetes [59]. The experimental results did not show the interaction effect between red chili varieties and the dose of KCl fertilizer, as shown in Table 8. This indicates that the various treatments significantly differ in the TFC. Tanjung 2 has the highest TFC of 262.03 mg QE/100 g dry sample, significantly different from UNPAD CB2 at

210.51 mg QE/100 g dry sample. Meanwhile, Lingga produces the lowest total flavonoid at 173.19 mg QE/100 g dry sample. The flavonoid content in the three varieties is in the range of 173-262 mg QE/100 g dry sample. According to Ghasemzadeh [60], the flavonoid content of red chili (93.3 mg QE/100 g dry sample) is higher than other plants such as green chilies, carrots, and white radishes. Howard et al. [61] stated that the variation in flavonoid content is related to the type of variety.

Treatment of various potassium fertilizer doses showed no significant difference in the total flavonoid. The analysis is not affected by the increasing amount of KCl fertilizer because potassium fertilization does not affect flavonoid biosynthesis. Potassium plays a role in protein and carbohydrate biosynthesis [11]. However, the application of various KCl fertilizer doses does not affect the enzyme activity in flavonoid biosynthesis.

### 3.12 Antioxidant activity

Antioxidant activity can be determined by an inhibition concentration of 50% ($IC_{50}$), where the $IC_{50}$ is inversely proportional to the antioxidant content [62]. The experimental results showed no interaction between the variety of of red chili and the dose of potassium fertilizer, which could affect the antioxidant activity (Table 8). However, results showed that the various treatment significantly affects antioxidant activity. Lingga produces significantly different antioxidant activity from Tanjung 2 but not significantly different from Unpad CB. Antioxidant activity results from secondary metabolites in chili fruit extracts, such as flavonoids [63], and also from genetic factors [64].

Treatment of various potassium fertilizer doses shows significantly different results on antioxidant activity. The treatment of 200 kg/ha KCl is significantly different from the treatment of 0 and 100 kg/ha KCl but not 300 kg/ha KCl. The difference can also be caused by K, the main cation in the cell cytoplasm acting as a coenzyme in metabolic processes [65]. Consequently, antioxidants derived from secondary metabolic pathways show an effect due to potassium fertilization [66].

## 4 Conclusion

This study showed the interaction between varieties and doses of potassium fertilizer on plant height at 8 WAP, stem diameter at 8 WAP, and LAI at 9 WAP. UNPAD CB2 showed the best results for plant height at 6 WAP, fruit weight per plant, fruit number per plant, fruit length, dihydrocapsaicin, total capsaicinoid, and SHU. Furthermore, potassium fertilizer doses of 200 and 300 kg/ha KCl showed high results for stem diameter at 6 WAP. From the economic efficiency of using potassium fertilizer, it is more economical at a dose of 200 kg/ha KCl.

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**Data availability statement:** The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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