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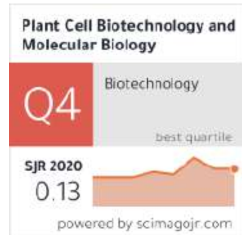

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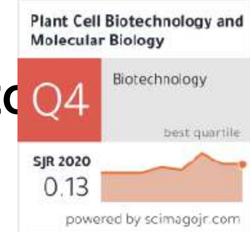

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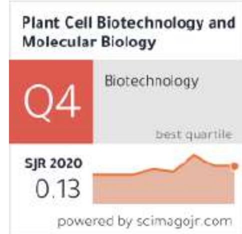

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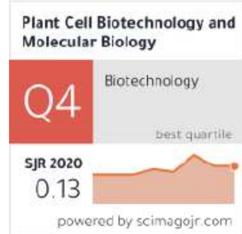

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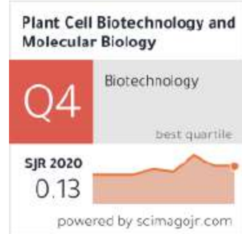

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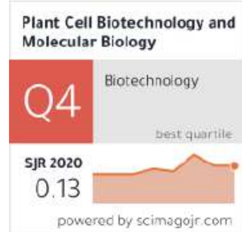

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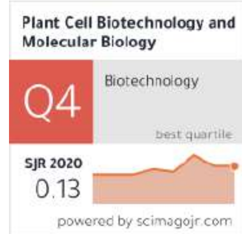

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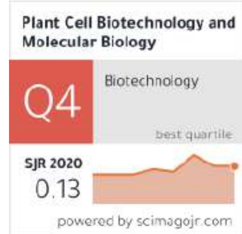

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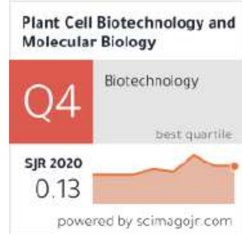

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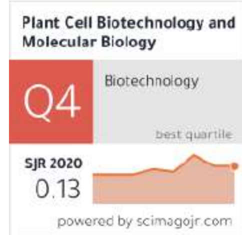

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A MYSTICAL PLANT Azadirachta indica USED AS PHYTOMEDICINE: STATE-OF-THE-ART (https://ikprress.org/index.php/PCBMB/article/view/7356)

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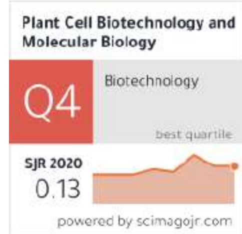

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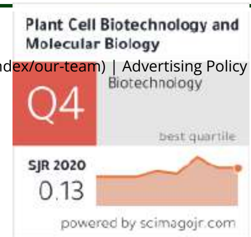

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EFFECTS OF POTASSIUM FERTILIZER ON GROWTH, CAPSAICIN, AND ASCORBIC ACID CONTENT OF LOCAL AND HYBRID CHILI (*Capsicum annum* L.)

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ABSTRACT

Potassium plays an important role in plant's physiological processes, such as photosynthesis, plant reproductive development, and physiological maturity which is connected with crop yield and quality. The aim of the experiment is to determine the best varieties and appropriate potassium doses in improving the yield and quality of chili. The experiment used a factorial randomized completely block format with two factors, i.e. chili varieties (Local and Gada) and potassium (KCl) doses (0, 60, 120, 180 kg ha^{-1}). The result showed that the Gada variety is taller than the local variety, also produced a higher number of fruits per plant. The local variety produced bigger chili fruit and higher productive branches than Gada variety. Application of 120 kg K ha^{-1} was enough to increase the weight of fruit per plant, a number of fruits per plant, and a number of productive branches in chili. Application of 180 kg K ha^{-1} in ripe local and Gada fruit resulted from the highest capsaicin content. Unripe fruits of local variety did not produce capsaicin, whereas the highest capsaicin content on unripe Gada fruit was shown in 120 kg K ha^{-1}. The highest ascorbic acid content in the Gada variety resulted from 60 kg K ha^{-1}, meanwhile in local variety was obtained from 120 kg K ha^{-1}.

Keywords: Chili hybrids; chili nutrition; growth and yield; postharvest quality.

INTRODUCTION

Red pepper (*Capsicum annuum* L.) is one of the most popular horticultural crops in Indonesia because of its high economic value and people's preferences in using pepper for food preparations. In Indonesia, pepper consumption has become a part of traditional culture and international identity. In addition, pepper is in high demand for food additives because of its spiciness. Production of shallots, cayenne pepper, potatoes, and red pepper in 2020 has increased when compared to

2019. Pepper become one of the top five seasonal vegetable commodities with the largest production in 2020, i.e. shallots (1.58 million tons), cabbage (1.41 million tons), cayenne pepper (1.37 million tons), potatoes (1.31 million tons), red pepper (1.21 million tons) [1]. The average red pepper national price in markets was increased from Rp 30.063 kg^{-1} in July 2020 to Rp 33.763 kg^{-1} in July 2021 [2]. Red pepper harvested area had declined (133.729 ha) compared to 2019 (133.434 ha) [1]. Therefore, red pepper production needs to be increased to fulfill the market needs through agronomy cultivation with fertilization application which is appropriate for plant needs and its agroecology.

Red pepper requires mineral fertilization, especially potassium (K) and nitrogen (N) to obtain maximum productivity. The potassium element is one of the essential macronutrients which important to physiological processes in plants, such as photosynthesis and respiration enzyme activation, osmoregulation, and opened/closed stomata regulator. [3] stated that red pepper cv. 'Cyklon' required a large amount of potassium (40%) and nitrogen (31%) if compared to other horticultural crops. Higher levels of nitrogen (350 mg dm^{-1} substrate) and potassium fertilization (400 mg dm^{-3} substrate) had a positive effect on the analyzed biometric parameters of fruits, except for the fresh weight of a single fruit.

Widyanti and Susila [4] Added that K fertilizer application at 3, 6, and 9 weeks after transplanting increases plant height, leaf number, weight per plant, fruit weight, fruit diameter, fruit length, marketable yield per lot, unmarketable yield per plot, marketable yield per hectare, and unmarketable yield per hectare with linear response pattern. While the addition of potassium did not affect the time of anthesis and fruit ripening. Total yield per plot and total yield per hectare increased with the addition of potassium fertilizer with a quadratic response pattern. In medium K soil content (146.2 ppm), potassium fertilizer recommendation for red chili in inceptisols is 487.5 kg K_2O ha^{-1}.

The effect of potassium (K) is most connected with the quality of seeds and fruits, also it was required for the early ripening of crops, improved the quality of fruits and vegetables, and prolonged the products for a longer period time [5]. [6] Added that P and K were critical nutrients for vegetative growth parameters, total fruit yield, fruit quality, and chemical composition of sweet chili plants (total acidity, total ascorbic acid, and total capsaicin content). Total acidity in fruit with combinations of 100 P kg/ha and 120 K kg ha^{-1} is 169.67 mg g^{-1} while application of 120 kg ha^{-1} single K fertilizer is 166 mg g^{-1}. The highest content of ascorbic acid (176.66 mg 100 g^{-1}) and capsaicin content in fruit (129.17 mg 100 g^{-1}) was obtained from combinations of 200 P kg ha^{-1} and 120 K kg ha^{-1}. The aim of the experiment is to determine the best varieties and appropriate potassium fertilization doses to improve the yield and quality of chili.

MATERIALS AND METHODS

The experiment was conducted in Banjarsari Village, Bangsalsari Subdistrict, from February to August 2018 with an experimental pattern using a factorial randomized completely block format with two factors and 3 replications. The first factor was varieties with 2 levels (local varieties and hybrid varieties (Gada)) and the second factor was potassium fertilizer (KCl) with 4 levels (0 kg ha^{-1}, 60 kg ha^{-1}, 120 kg ha^{-1}, and 180 kg ha^{-1}). Potassium content (K_2O) in the experimental field was reported to be 0.049%, analyzed with wet oxidation method, HNO_3 + $HClO_4$, AAS, Flamephotometry.

Combinations of media used in this study were soil, sand, and compost/manure (2:1:1). Furadan 3G was applied in planting media to prevent pests in soil. Mashed planting media then put into polybags. The height of the planting medium is about 5 cm from the lip of the polybag. The fertilizers used were Urea, SP-36, and KCl with a dose of urea (4.5 gr per plant or 150 kg ha^{-1}), SP-36 (4.5 gr per plant or 150 kg ha^{-1}). Potassium fertilization was done at intervals of 3, 6, and 9 weeks after planting.

Fruit harvesting was done in 70-90 days after planting depending on the variety, which is indicated by 60% of the chilies being red. Harvesting can be done at intervals of 3-7 days continuously until the plants do not produce fruit. Harvesting was done by picking chilies with the stalks, doing it selectively and carefully so that the flowers did not fall out.

The following parameters were measured: plant height, fruit diameter, fruit weight per plant, number of fruits per plant, number of productive branches, capsaicin content of ripe and unripe fruit, and ascorbic acid content. The observed data were analyzed using analysis of variance (ANOVA). Means were separated using the DUNCAN test with an error rate of 5%.

Capsaicin Analysis (µg g^{-1})

Capsaicin analysis was conducted to determine the content of *capsaicin* chili peppers. Analysis *Capsaicin* using TLC (Thin Layer Chromatography) method. In 1 ml of ethanol the sample was homogenized, sonicated for 1 hour. Post supernatant as much as 25 µl on silica gel 60 F254 plates by including capsaicin standard. Then put into a chamber that already contains the saturated mobile phase toluene – chloroform – acetone (45:25:30). Extend to the limit, lift and dry. Determination of capsaicin levels at a wavelength of 228 nm. Rf. 0.51.

Determination of Ascorbic Acid

Testing the value of ascorbic acid was measured by redox titration using an iodine solution [7]. A total of 0.1 grams of sample extract was dissolved in 100 ml of distilled water. The sample solution (50 ml) was pipetted into the Erlenmeyer flask and 2 ml of 1% soluble starch solution was added. The sample is titrated with KI solution until the color changes to bluish, ascorbic acid as a standard to determine the value of vitamin C.

RESULTS AND DISCUSSION

Yield Parameters of Chili Plant

Chili varieties and potassium dose did not have any interaction on the five observed parameters of chili plant. The difference of the chili varieties (local and Gada) showed significant results on plant height (cm), fruit diameter (cm), fruit weight per plant (g), and numbers of fruit per plant. The numbers of productive branches did not differ between local variety and Gada. Plant height and fruit diameter of chili plants were not significantly different on the application of potassium doses. Meanwhile, the difference in potassium doses was significantly affected fruit weight per plant, number of fruits per plant, and number of productive branches on chili plant (Table 1).

Golcz et al. [3] analyzed the difference effect of potassium sources (KCl, K_2SO_4, KNO_3) with one level nitrogen-potassium (250 mg N + 300 mg K) during one year on red pepper cv Cyklon plants and resulted in no significant effect on the height of the plant. A significant effect was observed in the total number of red pepper fruits during two years of the experiment with different levels of nitrogen-potassium. [5] stated that there was a significant effect among the different levels of potassium on chili from var hybrid Sitara plant height at first flowering and at final harvest, but not significantly different at first harvest. Combination treatment of nitrogen and potassium had a significant effect on plant height from first flowering to final harvest. [8] also observed the influence of nitrogen and potassium application on chili plants, and showed no difference result on plants height. It can be assumed that plant height was a function of genetic and influenced by chili varieties.

Table 1. Influence of varieties and potassium doses on growth, yield, and fruit quality of chili

Variable	P-value		
	Varieties (V)	Potassium doses (K)	Varieties × Potassium doses (V×K)
Plant height (cm)	*	ns	ns
Fruit diameter (cm)	*	ns	ns
Fruit weight per plant (g)	*	*	ns
Number of fruits per plant	*	*	ns
Number of productive branches	ns	*	ns

Note: * = significant, ns= not significant in the Duncan test at alpha 5% level

The enhancement of potassium levels on chili from var hybrid Sitara increased the number of fruits per plant [5]. The previous study about the interactive effect of phosphorus and potassium on the exotic landrace of chili (Padron) also showed the significant result on the number of branches per plant, the number of fruits per plant, and the weight of fruit per plant [6]. [9] added that number of fruits per plant and fruit weight of California type cv Requena pepper on a hydroponic system also influenced by different K^+ concentrations using sodium nitrate ($NaNO_3$) and potassium chloride (KCl). [10] stated that potassium activates at least 60 different enzymes involved in plant growth. The K changes the physical shape of the enzyme molecule, exposing the appropriate chemical active sites for reaction. Furthermore, [11] concluded that potassium plays vital regulatory functions in biochemical and physiological processes that contribute to plant growth and development.

The different potassium doses showed no interaction with chili varieties (Fig. 1). Each variety showed a different response to the different levels of potassium. [12,13] explained that the different responses of chili varieties (Kopay, Bemeri, Perintis) on growth and yield parameters were influenced by a variety of different adaptations, both climate and growing media, also the genetic. Gada is a hybrid variety that was produced by East-West Seed Indonesia and it was claimed that produced a high yield. Gada variety is taller ($\bar{X}$= 225.3 cm) than local variety ($\bar{X}$= 155.8 cm) (Fig. 1A), but fruit size of Gada is smaller ($\bar{X}$= 2.65 cm) than local fruit ($\bar{X}$= 4.18 cm) (Fig. 1C). [8] stated that plant height was a function of genetic, so the difference of chili varieties played a greater role on plant height than the application of nitrogen and potassium. The weight of fruit per plant (Fig. 1B) and the number of productive branches (Fig. 1E) were not different between Gada and the local variety. Local variety was heavier ($\bar{X}$ = 43.10 g) than Gada variety ($\bar{X}$ = 39.96 g). Local variety produced higher productive branches ($\bar{X}$ = 15.25) than Gada variety ($\bar{X}$ = 14.75). Gada variety produced the higher number of fruits per plant ($\bar{X}$= 68.25 fruits) (Fig. 1D) than local variety did ($\bar{X}$= 56.25 fruits). It can be assumed that Gada variety had better genotype characteristics in yield than the local variety.

Different potassium doses influenced fruit weight per plant (g), the number of fruits per plant, and the number of productive branches on chili (Fig. 2). Potassium doses of 0 kg ha^{-1} and 60 kg ha^{-1} resulted in no difference in fruit weight per plant, respectively 12.4 g and 12.7 g. The same trend was observed for 120 kg ha^{-1} and 180 kg ha^{-1} potassium doses which resulted in no significant difference in fruit weight per plant to 14.8 g and 15.4 g, respectively. However, the application of 60 kg K ha^{-1} showed different fruit weights per plant with 120 kg K ha^{-1} (Fig. 2A). In other words, the application of 120 kg K ha^{-1} was enough to increase the weight of fruit per plant in chili. [6] reported that maximum fruit weight per plant (465.5 g) was obtained from the combination of 100 kg P ha^{-1} and 120 kg K ha^{-1}. Potassium doses of 0 kg ha^{-1} and 200 kg P ha^{-1} resulted in the lowest weight of fruit per plant 137.1 g. [9] stated that application of compost (1.35 kg per planting hole) + Urea (75 kg ha^{-1}) + SP36 (75 kg ha^{-1}) + KCl (75 kg ha^{-1}) resulted the highest fruit weight in chili var Lado F1 to 253.35 g.

The number of fruits per plant in chili was not significantly different on 0, 60, and 120 kg K ha^{-1} to 19.3, 20.2, and 20.7 fruits per plant, significantly. Application of 180 kg K ha^{-1} resulted in the highest number of fruit per plants to 22.8 (Fig. 2B). [5] observed the influence of potassium fertilizer in chili var hybrid Sitara and resulted that the highest number of fruit per plant was found in 60 kg K ha^{-1} (7.2 fruits). Potassium is most connected with the quality of seeds and fruits, also necessary for the early ripening of crops. [8] found that application of 50 kg K ha^{-1} resulted in the highest number of fruit per plant to 47.7 fruits, but not different with the application of 40 kg K ha^{-1} to 47.5 fruits. This highest result on the number of fruit per plant is probably due to the vigor of the chili plant and more number of leaves per plant.

Potassium doses of 120 kg ha^{-1} were enough in producing the high number of fruit per plant in chili (Fig. 2B). [6] reported that the combination of 100 kg P ha^{-1} and 120 kg K ha^{-1} resulted in the highest number of fruits per plant to 30.17 in the exotic landrace of chili (Padron). This result was

2.4 times higher if compared with plants that were not applied with fertilizer (12.5 fruits). [9] added that California type cv Requena pepper with 7 and (14)-10 mM K^+ produced the highest fruit number to 17.6 and 15.19 fruits per plant respectively. The number of fruits per plant was strongly decreased with low K^+ in nutrient solution (6.1 fruits with 0.5-0 mM K^+ and 10.52 fruits with 0.5 mM K^+) and slightly reduced with high K^+ (14 fruits per plant with 14 mM K^+).

The number of productive branches in chili was not different in application of 0 and 60 kg K ha^{-1} to 3.5 and 3.7, respectively. Application of 180 kg K ha^{-1} resulted in the highest number of productive branches to 7.3. The number of productive branches which was resulted from the application of 120 kg K ha^{-1} (5.5) was significantly different with 60 (3.7) and 180 (7.3) kg K ha^{-1}). [8] stated that 50 kg K ha^{-1} resulted in the highest branches per plant to 13.2 in chili, it was not significantly different with 0, 30, and 40 kg K ha^{-1} (13; 12.9; 12.9 respectively). [6] added that a combination of 100 kg P ha^{-1} and 120 kg K ha^{-1} resulted in a maximum number of branches per plant (41.20). The minimum number of branches per plant (15.00) was obtained from a no fertilizer plant.

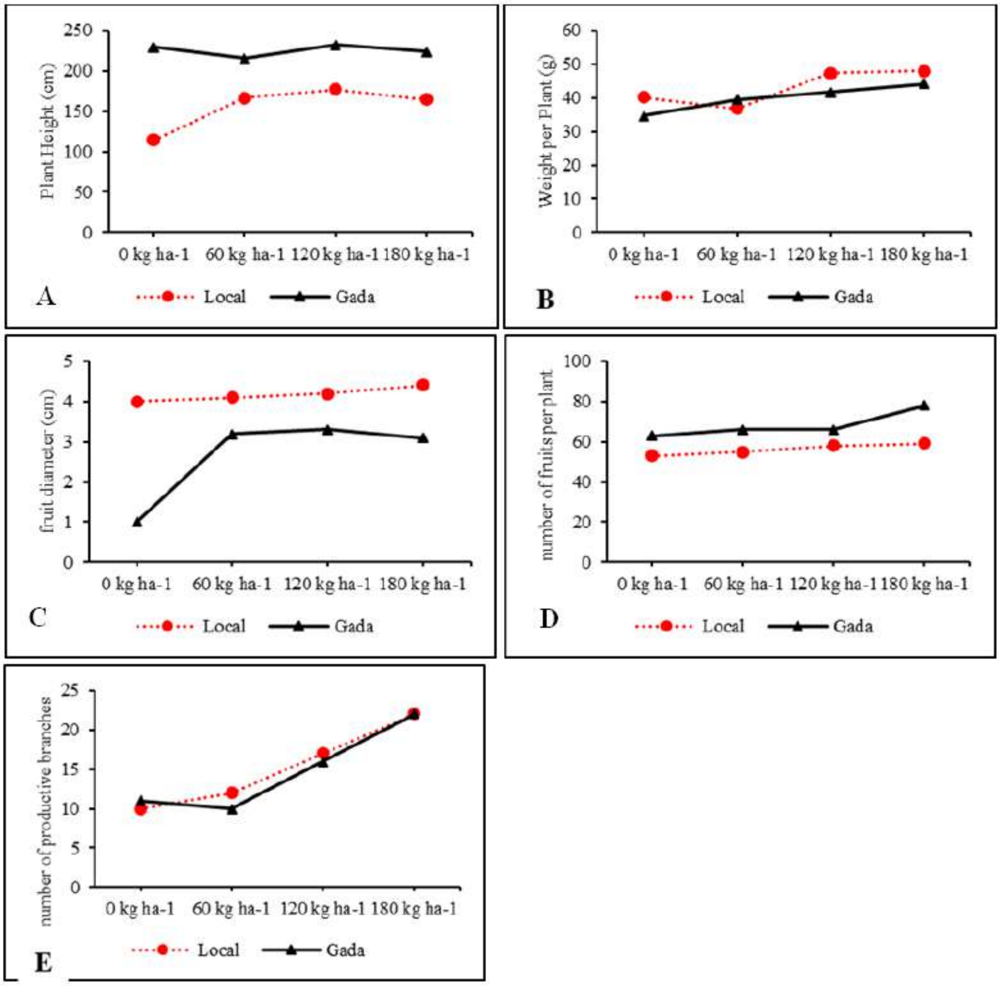

Fig. 1. The influence of different potassium doses and chili varieties on A) plant height, B) weight per plant, C) fruit diameter, D) number of fruits per plant, E) number of productive branches

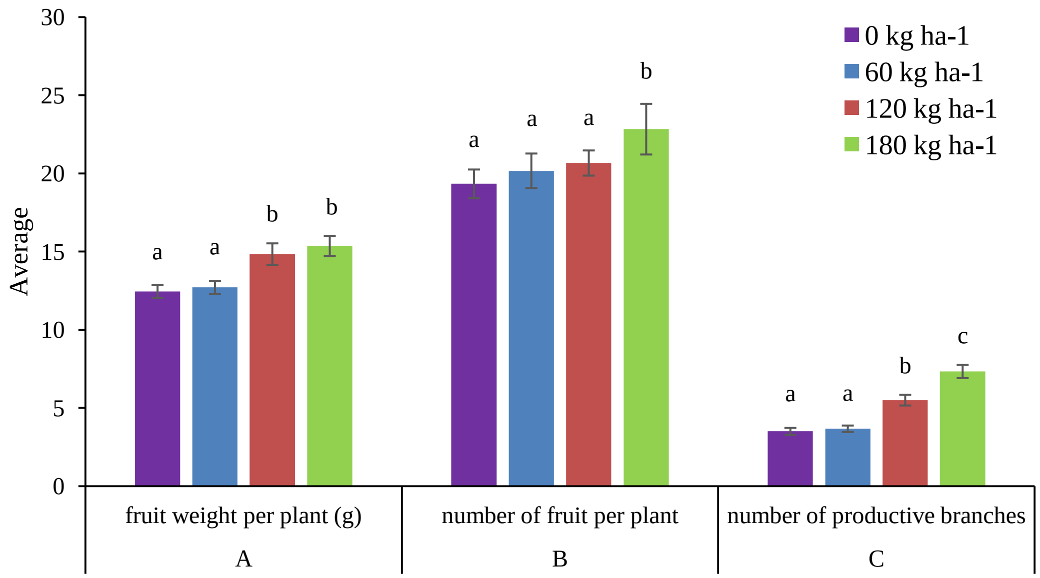

Fig. 2. Effect of different potassium doses on fruit weight per plant (A), number of fruits per plant (B), and number of productive branches (C). Error bars show the standard error (SE) of the means of three replicates. The different lower cases represent a significant difference (p-value < 0.05) among four potassium doses treatments within the same chili variety

The potassium fertilizer used in this experiment was KCl. [3] found that at a lower nitrogen (250 mg) and potassium (300 mg) fertilization, the highest total yield of fruits in red pepper was obtained from combination with KNO_3 to 1.90 kg m^{-2} and 2.48 kg m^{-2}. When nitrogen and potassium doses were increased to 350 mg N and 400 mg K, the highest total yield of fruits was obtained from combination with KCl or KNO_3 (2.25 and 2.29 kg m^{-2}, respectively) in 2005. Meanwhile, in 2006, the highest total yield of fruits was obtained from combination with KCl to 2.66 kg m^{-2}. [14] stated that better yield production of chili under KCl than NaCl treatment due to better leaf water status and photosynthesis, more leaf number, and less chlorotic leaves.

In conclusion, the application of 120 kg K ha^{-1} was enough to increase the weight of fruit per plant, the number of fruits per plant, and the number of productive branches in chili. [15] reported that maximum plant height (110.2 cm), plant spread (108.2 cm), 100 pod weight (54.5 g), number of fruit per plant (228.4), and maximum yield (48.85 q ha^{-1}) in chili variety LCA 353 were obtained from the application of 300 kg N ha^{-1}, was given as 50% urea and remaining 50% as CAN (calcium ammonium nitrate), 120 kg K ha^{-1} as 50% MOP (muriate of potash) and 50% as SOP (sulphate of potash). [11] resumed that potassium plays an imperative role in plant photosynthesis process and the subsequent carbohydrate translocation and metabolism which increase the crop yield and grain quality. Potassium also regulates the biosynthesis, conversion, and allocation of metabolites that ultimately increases the yield.

Capsaicin Content in Fruit

The capsaicin content of ripe local and Gada variety did not differ (p-value =0.277) in various treatments of potassium fertilizer. Otherwise, the unripe chilies indicated the statistical difference between local and Gada varieties (p-value = 0.009) (Fig. 3). The highest capsaicin content on ripe chili fruit was resulted by application of 180 kg K ha^{-1}, both in local and Gada variety, respectively 0.87 and 0.9 mg/100g. Capsaicin content in the ripe local variety was higher than Gada variety, which means the local variety was spicier (Fig. 3A). In the local variety, there was no capsaicin content in unripe fruits, but it differed from the unripe Gada variety. The highest capsaicin content on unripe Gada fruit was shown in 120 kg K ha^{-1} to 0.48 mg/100g (Fig. 3B). [6] found that a combination of 200 kg P ha^{-1} + 120 kg K ha^{-1} and 100 kg P ha^{-1} resulted in the highest capsaicin content 129.17 mg/100g and 128.17 mg/100 g respectively.

The higher potassium doses were given to the plant, the capsaicin level on ripe fruit also increased (Fig. 3A). [11] resumed that potassium plays role in plant reproductive development, especially in flowering, pollen germination, and physiological maturity. Phenological development was delayed due to the lower application of K. Meanwhile [16] resumed that capsaicin content in plants increases gradually during fruit development and reaches maximum levels at 40 to 50 days, then it tends to degrade into secondary compounds due to peroxidase action. This result showed that potassium fertilization triggered the formation of capsaicin during fruit development.

Ascorbic Acid in Fruit

Ascorbic acid content (%) in chili fruit showed different results on varieties for each potassium dose. Gada variety which was applied with 60 kg K ha^{-1} resulted in the highest ascorbic acid content to 4.15%. In contrast with Gada variety, the highest content of ascorbic acid in the local variety was 3.44% when it was applied with 120 kg K ha^{-1}. The lowest ascorbic acid content was obtained from the Gada variety without potassium application to 27.17% (Fig. 4).

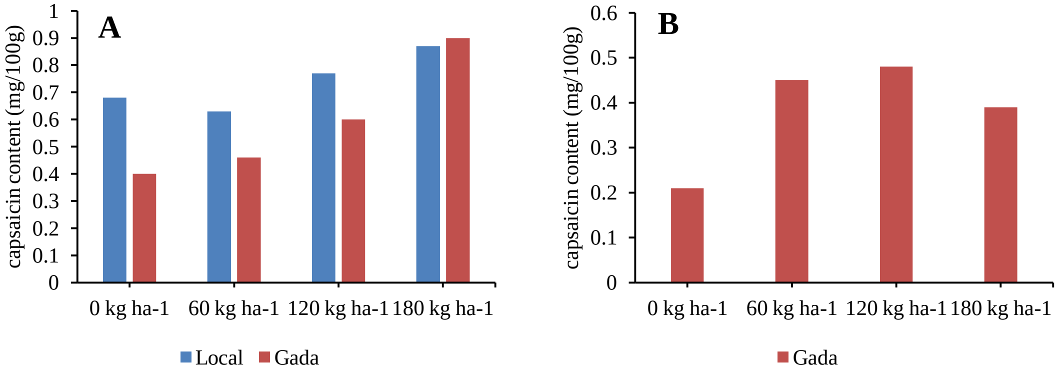

Fig. 3. Capsaicin content on different potassium doses and chili variety in ripe fruit (A) and unripe fruit (B)

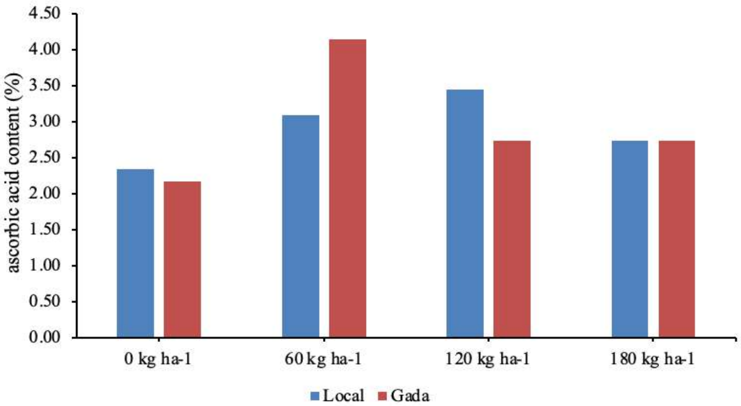

Fig. 4. Ascorbic acid content (%) in different potassium doses and chili variety

Akram et al. [6] found that application of 200 kg P ha^{-1} and 120 kg K ha^{-1} produced the highest ascorbic acid content to 176.66 mg/100 g. The lowest ascorbic acid content was recorded in chili plants without fertilizer (148.37 mg/100 g). [9] observed that potassium fertilizer increased ascorbic acid in pepper fruits from 30 days after anthesis until the end of the experiment (60 DAA). The highest ascorbic acid content in pepper fruit was obtained from nutrient solution up to 14-10 mM K^+ to 269 mg/100 g of juice. Meanwhile, the lowest ascorbic acid content was shown by the lowest level of K^+ (0.5-0 mM K^+), i.e. 122 mg/100 g of juice. Higher potassium nutrient solution to 14 mM, reduced ascorbic acid content in pepper fruit. Ascorbic acid plays an important role as an antioxidant in plants. Ascorbic acid content is affected by the composition of the nutrient solution. Although the mechanisms of ascorbic acid improvement due to the increased plant K^+ status are uncertain, it could be related to increase photosynthesis, sugar production, and photoassimilate transport from leaves to fruit.

CONCLUSIONS

Chili varieties and potassium doses did not have any interaction with the five observed parameters of the chili plant. Plant height (cm), fruit diameter (cm), fruit weight per plant (g), and the number of fruits per plant were influenced by chili varieties. The number of productive branches did not differ between local variety and Gada. The application of potassium doses did not significantly differ on plant height and fruit diameter. Meanwhile, fruit weight per plant, number of fruits per plant, and number of productive branches were significantly affected by potassium doses. Gada variety is taller than local variety, also produced the higher number of fruits per plant. The local variety produced bigger chili fruit and higher productive branches than the Gada variety. It can be assumed that Gada variety had better genotype characteristics in yield than the local variety.

Application of 120 kg K ha^{-1} was enough to increase the weight of fruit per plant, the number of fruits per plant, and the number of productive branches in chili. The highest capsaicin content on ripe chili fruit was resulted by application of 180 kg K ha^{-1}, both in local and Gada variety. Unripe fruits of local variety did not produce capsaicin, whereas the highest capsaicin content on unripe Gada fruit was shown in 120 kg K ha^{-1}. The highest ascorbic acid content in Gada variety resulted from 60 kg K ha^{-1}, meanwhile in local variety, the highest content of ascorbic acid was obtained from 120 kg K ha^{-1}.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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