JPPIPA 10(9) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

The Effect of Potassium Dosage and Branch-Pruning on the Growth and Yield of Butternut Squash (*Cucurbita moschata Durch*)

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Received: May 03, 2024
Revised: July 13, 2024
Accepted: September 25, 2024
Published: September 30, 2024

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DOI: 10.29303/jppipa.v10i9.7565

Abstract: Butternut squash (*C. moschata*) is a honey squash plant (*Cucurbita moschata Durch*) which is an introduced plant from the lowlands of South America and has adapted to Indonesia. The research was carried out in the planting area of Kampung Labu Madu, Toyoresmi Village, Ngasem District, Kediri Regency from January to June 2021. Potassium is among major nutrients needed by plants in their growth and development. Potassium fertilization can help plants improve the regulation of photosynthetic mechanisms, carbohydrate translocation, protein synthesis This research was a two-factor factorial experiment prepared using a Split Plot Design. The first factor (main plot) was the branch pruning (P) treatment which consisted of 2 levels and the second factor (subplot) was the dose of KCl (K) fertilizer which consisted of 4 levels. The results of the research showed that there was a real influence in the treatment without pruning on the parameters of the number of male flowers and on the parameter of fruit weight with the best treatment being pruning, whereas for the treatment the dose of KCl fertilizer had a real effect on the parameters.

Keywords: Butternut squash; *Cucurbita moschata Durch*; Fruit weight; Male flowers; Pruning

Introduction

Butternut squash (*C. moschata Durch*) was introduced to Indonesia from lowlands area of South America and has adapted well to Indonesian agroclimate (Busthanul et al., 2023). Butternut squash is rich in nutrients including particularly beta-carotene (pigment responsible for flesh orange color) which is beneficial for its anticancer activities (Bieżanowska-Kopeć et al., 2022; Mahmoud & Mehder, 2022). When compared to its nearest relative, pepo and *C. maxima*, butternut squash has higher sweetness level and longer storage duration (Yuan et al., 2022; Lebeda et al., 2024). Yet, butternut squash cultivation and consumption in Indonesia are still lower that the former (Wyatt et al., 2016). Hence, an increase of butternut squash production is important to make it more available in the market for consumption. In this sense, suitable agronomical practices such as potassium fertilization and pruning are among important factors to be studied. Potassium is among major nutrients needed by plants in their growth and development. Discuss on potassium role in plants particularly on squash (Zhang et al., 2023; Adhikari & Kandel, 2015). At the same time, pruning is an important practice to manipulate plant photosynthate management to favor generative phase hence yield can be increased (Paponov et al., 2023). Discuss more on pruning. This paper studied the effect of potassium fertilization and pruning on butternut

How to Cite:
Dewanti, F. D., Augustien, N., Triani, N., Holki, N. I. F., & Sukarjati. (2024). The Effect of Potassium Dosage and Branch-Pruning on the Growth and Yield of Butternut Squash (Cucurbita moschata Durch). *Jurnal Penelitian Pendidikan IPA*, *10*(9), 6902–6909. https://doi.org/10.29303/jppipa.v10i9.7565

squash growth and yield. Even though belongs to the same genus as pumpkin.

Cucurbita, butternut squash cultivation and consumption are still lower than the former. Honey pumpkin (*Cucurbita moschata Durch)* is an introduced plant from the lowlands of South America and has adapted to Indonesia. Honey pumpkin cultivation is very easy, it can be planted directly in the field or in polybags but must use para-para as a place to spread the plant stem. The flesh of the honey pumpkin fruit contains high carbohydrates, vitamins and minerals and has the potential as an alternative food ingredient. In the process of cultivating honey pumpkin requires the availability of adequate nutrients for plants in the form of water, solar intensity and nutrients. One of the nutrients that is very important in improving the quality of pumpkin crops is potassium (Hussain et al., 2022). Potassium fertilization can help plants improve the regulation of photosynthetic mechanisms, carbohydrate translocation, protein synthesis (Shah et al., 2024). The type of potassium fertilizer commonly used is KCl. In addition to fertilization, branch pruning also needs to be done because it is related to sources and sinks that effect the translocation process of photosynthetic products to the entire plant. Pruning can concentrate photosynthate to enlarge the fruit.

Leaf growth that is too dominant will cause photosynthate to be utilised by plants for new vegetative growth, which can be in the form of tendrils, branches or leaves that will later become sinks, so that the source that will be used by the fruit as the main sink will be reduced (Alem et al., 2021; Rosado-Souza et al., 2023). The aims to increase the growth and yield of honey pumpkin (*Cucurbita moschata Durch*) through branch pruning and KCl applicioon.Potassium plays imperative function in upregulation of K+, which reduces ROS production in plants, declines the nicotinamide adenine dinucleotide phosphate (NADPH) oxidases activity, and maintains the photosynthetic electron transport activity that provides assistance in reducing the ROS level (Mandal et al., 2022; Khorobrykh et al., 2020).

The scarcity of K reduces photosynthetic CO_2 fixation as well as the transportation and consumption of photoassimilates followed by membrane and chlorophyll (chl) damage in K-deficit plants (Ray et al., 2022; Cummins et al., 2018). The control of K is allied with the activities of enzymes involved in ROS detoxification (Hasanuzzaman et al., 2020; Dvořák et al., 2021). Potassium activates the adenosine triphosphate (ATP) synthase enzyme (Nesci et al., 2019) which impacts the plasma membrane (PM) linked H^+-ATPase by the K^+ concentration.

Method

Experimental Site and Design

This study was carried out from January to June 2021 at Toyoresmi, Kediri, Jawa Timur Province (add location map and coordinate). The experimental site was as such: grumosol soil type, average temperature 30 ^oC, and humidity 79%. The study was arranged in a split-plot design consisting of 2 factors namely pruning (P) and KCl dose (K) as the whole-plot and sub-plot factors, respectively. The whole- plot factor was devised as without pruning (P0) and with pruning (P1) on the 1st – 7th internode branches. As for the split-plot factor, KCl dose was set at 0, 6, 9, and 12 g/plant coded as K1, K2, K3, and K4, respectively.

Plant Material and Cultivation

Butternut squash variety used was Labu Madu F1 from Panah Merah. The seeds were sown on wet tissue paper for 3-5 days until the radicle emerged. After that, the seeds were carefully transplanted on raised soil beds in 5 cm depth hole at a distance of 1 x 3 m^2. Plant maintenance including proper mulching, watering, pest and disease controlling, and staking. The gourds were harvested after 90 days after transplanting (DAT) upon displaying characteristics as such: pale orange colored gourds skin while also hard and dried stems.

Fertilization Dosage and Application

Manure and NPK were applied as base fertilizer on 7 days before transplanting. Manure, 5 kg, was spread evenly on each bed. Meanwhile NPK (Mutiara brand; ratio 16:16:16) was applied at 40 g/plant dose. Further NPK fertilizations were applied every week on 2 – 10 weeks after transplanting (WAT) at 10 g/plant dose. Such manure and NPK fertilization dosage were applied uniformly to all plants. As for KCl fertilization, the dose was set according to the treatments at 0, 6, 9, and 12 g/plant. Each dosage was divided in two, which each half were applied on 4 and 6 DAT, respectively. Both NPK and KCl fertilizer were applied by diluting the quantity first in sufficient waters before applied directly into the soils.

Branch Pruning

Branch pruning was conducted at 4 WAT in all treatments. The pruning was done at 1st – 7th nodal branches. The pruning was conducted in the morning by using garden scissors. As for control, no pruning was done.

Parameters Observed

The parameters observed were: plant height (cm), stem diameter (cm), flowers emergence (DAT), number of flowers, fruit set (%), number of gourds, gourds

length (cm), gourds weight (g), gourds weight/plant (g), and sugar content (oBrix). Plant height and stem diameter were measured on 1 – 10 WAT. Flowers emergence was observed by counting the days taken by both first male and female flowers to merge. Number of gourds was obtained by counting all gourds harvested. Gourd length and gourds weight were measured immediately after harvest. Sugar content was measured using a refractometer immediately after harvest. The last, fruitset was calculated using the following formula:

$$\% \text{ Fruit set} = \frac{\text{Total number of fruits}}{\text{Total number of flower g/plant}} \quad (1)$$

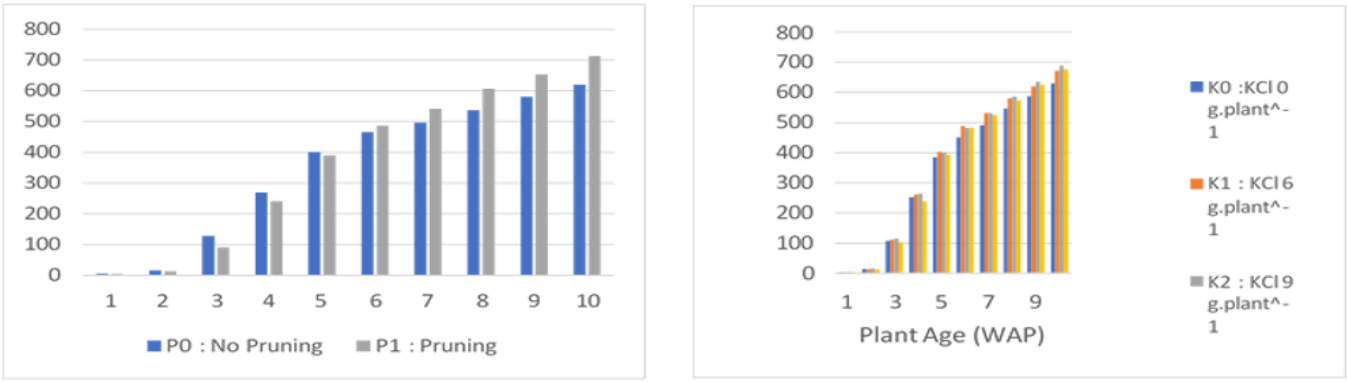
Data Analysis

Each parameters data was displayed as mean value. Significancy of the treatments were analyzed using ANOVA. If there was any significance, post-hoc tests were carried out using Least Significant Difference (LSD) test at 5% significance level (α = 0.05).

Result and Discussion

Phenotype Honey Pumpkin on Pruning Treatment and KCl Dosage

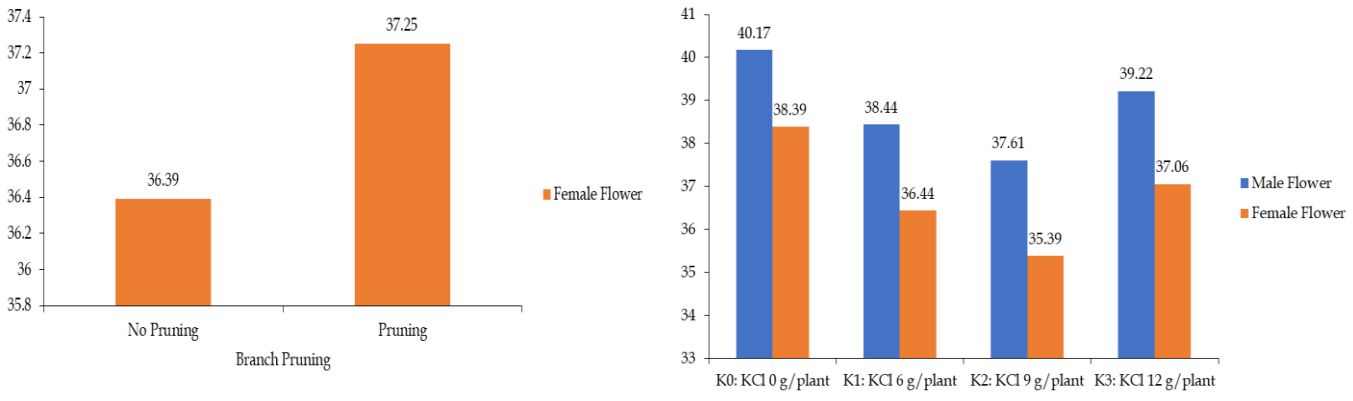
The growth process of honey pumpkin (*Cucurbita moschata Durch*) plants formed a plant length reaching 679 – 719 cm. The pruning treatment increased the length of the plant by 13.03% compared to no pruning (Figure 1), while the KCl treatment (6, 9, and 12 g/plant) increased the length of the plant by 8.62% compared to no KCl (Figure 1.) The results of data analysis of longitudinal growth of honey pumpkin plants due to pruning and not pruned from the age of 2 weeks to 10 weeks were not significantly different, as well as the treatment of KCl doses of 0, 3, 6 and 9 g/plant did not occur significantly different (Figure 1).



(a) (b)

Figure 1. (a) Pruning and (b) dose of KCl treatments on Honey Pumpkin Plant Length (cm)

The results of the analysis of variance showed that pruning treatment and KCl dose treatment had no effect on the appearance of flowers, the formation of male flowers in the KCl dose treatment occurred at the age of 37.61 to 40.17 DAT, while the formation of female flowers occurred at 35.39 to 38.39 DAT, presented in Figure 2.



(a) (b)

Figure 2. (a) Pruning and (b) dose of KCl treatments on Honey Pumpkin Appearing Flowers (days)

Number of Male and Female Flowers

The growth process of flower appearance in the unpruned treatment increased the number of male flowers higher than the pruning of honey pumpkin branches. Pruning treatment on honey pumpkin reduced the number of male flowers by 39.77% compared to no pruning while the number of female flowers was not significantly different. KCl treatment at a dose of 12 g/plant was able to increase the formation of female flowers by 26.45% compared to no KCl treatment, while the KCl dose treatment (0-12 g/plant) on the formation of the number of male flowers was not significantly different as presented in Table 1.

Table 1. Average Number of Male and Female Flowers of Honey Pumpkin Plants due to Branch Pruning Treatment and Doses of KCl Fertilizer

	Male Flower	Female Flower
Branch Pruning		
No Pruning	100.86 b	5
Pruning	60.75 a	5.25
LSD 5%	10.75	Ns
Dose KCl		
KCl 0 g.plant^{-1}	73.67	4.17a
KCl 6 g.plant^{-1}	85	5.33 b
KCl 9 g.plant^{-1}	79.44	5.33 b
KCl 12 g.plant^{-1}	85.11	5.67 b
LSD 5%	ns	0.99

Notes: Numbers accompanied by the same letter in the same column indicate no significant difference in the LSD test at the 5% level; ns = no significant.

Table 2. Average Number of Fruit/Plant, Fruit Length/Fruit and Percentage of Fruit Set of Honey Pumpkin Plants due to Branch Pruning Treatment and Doses of KCl Fertilizer

Treatment	Number Fruit.Plant^{-1}	Fruit Length (cm)	Fruit Set (%)
Branch Pruning			
No Pruning	3.14	22.61	67.01
Pruning	2.89	23.64	57.13
LSD 5% Dose of KCl		ns	Ns
KCl 0 g plant^{-1}	2.50	21.26	65.66
KCl 6 g plant^{-1}	3.11	22.99	61.55
KCl 9 g plant^{-1}	3.06	24.06	58.81

Notes: ns = no significant

Fruit Weight per Fruit (g), Fruit Weight per Plant (g) and Fruit sugar content (Brix) The average data analysis showed that the pruning treatment of honey pumpkin plants was able to increase the weight of fruit/fruit by 8.97%, compared to without pruning. Fruit weight/plant was not significantly different as well as fruit sugar content (Brix). The treatment of KCl dose of 12 g. Plant^{-1} was able to increase fruit weight. Fruit^{-1} by 15.89%; fruit weight. plant^{-1} by 35.65% and fruit sugar content (Brix) by 16.43%. The treatment of pruning and dosing of KCl 12 g plant^{-1} was able to increase the number of female flowers and fruit weight. plant^{-1}, presented in Table 3.

Table 3. Average Weight of Fruit per Fruit, Weight of Fruit.Plant^{-1} and Fruit Sugar Content (Brix) of Honey Pumpkin Plants due to Pruning Treatment Branch Pruning and KCl dosage

Treatment	Weight Fruit. Fruit-1 (g)	Weight Fruit Plant-1 (g)	Fruit Sugar Content (Brix)
Branch Pruning No Pruning	2391.16 a	7611.28	10.89
Pruning	2626.81 b	7701.89	11.28
LSD 5%	118.95	Ns	Ns
Dose of KCl KCl 0 g.plant^{-1}	2233.88 a	5693.50 a	9.61 a
KCl 6 g.plant^{-1}	2523.89 b	7908.17 b	11.50 b
KCl 9 g.plant^{-1}	2622.14 b	8176.33 b	11.72 b
KCl 12 g.plant^{-1}	2656.04 b	8848.33 b	11.50 b
LSD 5%	271.68	1803. 81	0.80

Notes: Numbers accompanied by the same letter in the same column indicate no significant difference in the LSD test at the 5% level; ns = no significant

Discussion

The result of pruning branches the photosynthetic process is increased, photosynthate is diverted to the apical stem, so that the stem is more elongated (Figure 1). Pruning tends to generate a healthier condition of the plant; sunlight enters the entire plant more effectively, enhancing light interception for photosynthesis (Jung & Arar, 2023). The increasing demand for food is in line with the increase in population. Honey pumpkin or Butternut squash (*Cucurbita moschata Durch*) is an introduced plant that is able to adapt in Indonesia. Honey pumpkin has the potential as an alternative food ingredient that has great benefits to meet food needs, Honey Pumpkin contains carbohydrates, vitamin A, Vitamin E, vitamin C, Vitamin B Complex, Thiamin, Vitamin B-6 (phiridoxcine), patotenic acid.

The ability of plants to grow and develop requires some support during the production process. Proper fertilization, proper regulation of organ supply and photosynthate transfer will obtain maximum product

yield and productivity. Plants need macro elements such as (N, P, K. Mg, Ca) and micro elements such as (Fe, Mn, Cu and Zn). The process of plant growth and development is inseparable from the process of forming proteins, fats, hormones, DNA, enzymes, and ATP. The results of the pruning treatment tended to lengthen the honey pumpkin plants by 13.03% than without pruning (Figure 1). The results showed that the pruning treatment of honey pumpkin branches significantly affected the parameters of the number of male flowers and fruit weight per fruit.

Pruning aims to reduce unproductive plant parts so that the assimilate from the photosynthesis process will be translocated for the growth of other plant parts (Suchocka et al., 2021). Pruning also aims to increase the efficiency of nutrient use and streamline plant growth and development in a more productive direction (Fuentes-Peñailillo et al., 2024). Pruning of lateral branches is pruning that aims to maintain and increase plant production. Pruning must be done at the right age to provide optimal results on plant growth and yield because it is closely related to the process of photosynthesis and metabolic rate (Firdaus et al., 2023; Xiong, 2024). Branch pruning treatment significantly affected the parameters of fruit weight per fruit. Pruning treatment (P1) has a higher average value of fruit weight per fruit than other treatments (Table 3). This is in accordance with the statement of Nie et al. (2021) and Matias et al. (2023) that plants are pruned by leaving fewer branches will use most of their photosynthetic products not only for stem development, but for fruit growth and development.

Pruning by leaving fewer primary branches produces a better average fruit weight, this is thought to be that the fewer organ parts of the plant that utilize photosynthate, the more effective the photosynthate for plant growth. The more photosynthate, the greater the food reserves used for fruit formation, thus affecting the weight of the plant fruit (Garrido et al., 2023). The results showed that the dose of KCl fertilizer treatment significantly affected the parameters of the number of female flowers, fruit weight per fruit, fruit weight per plant, and fruit sugar content. KCl is a type of potassium fertilizer that is widely used in plant cultivation. KCl fertilizer is easy to obtain, easily soluble in water and easily available to plants. KCl fertilizer contains 60% K_2O in the form of flour or crystalline granules. The anion that follows it (Cl) has little negative effect on the soil (Wang et al., 2023; Rosales et al., 2020). Potassium element is most widely used in the vegetative phase. Potassium as an activator of various enzymes so that protein synthesis, starch, transpiration can run smoothly in the process of photosynthesis (Baslam et al., 2020).

Plants that absorb enough K elements can maintain the water content in their tissues because they are better able to absorb water and soil moisture. In addition, if K uptake is sufficient, plants will increase the production of phenol compounds that can protect plants. Potassium is extremely important for flower formation and water regulation (Bulawa et al., 2022; Kołton et al., 2022). The oxidation ability of plant root cells decreases if the K element is deficient so that the root environment becomes reductive which causes an increase in Fe solubility because the insoluble ferric ions (Fe^{3+}) turn into ferrous ions (Fe^{2+}) which are easily soluble (Molnár et al., 2023; Ning et al., 2023). The treatment of KCl fertilizer dose showed a significant effect on the parameter of the number of female flowers with the highest average value found in the treatment of 12 g/plant KCl dose (K3) of 5.67 flowers, the lowest at 0 g/plant KCl. Some doses of KCl 6, 9, and 12 g/plant tend to form female flowers earlier (35-37 DAP) than male flowers take 37- 39 HST (Figure 3.) It is suspected that the provision of KCl spurs the formation of female flowers and the process of fertilization is faster, compared to without KCl (Figure 2).

The presence of a real effect on the parameter of the number of female flowers is in accordance with the statement of Xu et al. (2020) and Sardans et al. (2021) that potassium functions as a catalyst for the formation of carbohydrates in the process of photosynthesis, protein formation, translocation of sugar and protein, helps in the process of opening and closing stomata, and strengthens tissues and plant organs so that they do not fall off easily. The highest fruit weight per fruit was obtained from the treatment of KCl fertilizer dose of 12 g/plant with an average of 2656.04g. While the highest fruit weight per plant was also obtained from the treatment of KCl fertilizer dose of 12 g/plant with an average of 8848.33 g. The provision of K fertilizer will increase the yield of fruit. This is in accordance with the opinion of Hidaka et al. (2019) which states that the translocation of photosynthate to the fruit of the plant is influenced by potassium, where potassium increases the movement of photosynthate out of the leaves to the roots, and this will increase the provision of energy for root growth, development of size, and fruit quality so that the weight of the fruit increases.

The treatment of KCl fertilizer dose showed a significant effect on the parameter of fruit sugar content. The highest fruit sugar content was obtained from the treatment of KCl fertilizer dose of 9 g/plant with an average of 11.72 %Brix. Measurement of sugar content or the level of sweetness of fruit expressed as a measurement of soluble solids content is conventionally done by damaging the product being measured. The fruit to be measured for sugar content is then cut and the liquid extracted, then measured using a refractometer and expressed in units of %Brix. The higher the value, the higher the sugar content and the sweeter the flavour.

If the plant lacks potassium element, the sugar translocation process will be disrupted because one of the functions of potassium element is to help the translocation process of photosynthetic products to all parts of the plant including the honey pumpkin fruit. Fruit sweetness is also one of the indicators of fruit quality. The high sugar content in the fruit occurs due to the adequacy of K nutrients absorbed by plants from the soil (Xie et al., 2021; Wang et al., 2024).

The results showed that there was no significant interaction between the treatment of branch pruning and the dose of KCl fertilizer on all observed observation parameters. This is probably because there is no mutual relationship between the treatment of branch pruning and the dose of KCl fertilizer on the growth and yield of honey pumpkin plants.

Conclusion

Pruning treatment reduces the formation of male flowers of honey gourd, KCl treatment at a dose of 12 g. Plant-1 was able to form 5.67 flowers, fruit weight, fruit-1 of 2656.04 g, fruit weight, plant-1 of 8848.33 g, and sugar content of 11.72% Brix. The potential of KCl fertilizer is able to increase fruit weight. fruit-1. Plant -1 and fruit sugar content Potassium fertilization can help plants improve the regulation of photosynthetic mechanisms, carbohydrate translocation, protein synthesis. The type of potassium fertilizer commonly used is KCl. In addition to fertilization, branch pruning also needs to be done because it is related to sources and sinks that effect the translocation process of photosynthetic products to the entire plant. Pruning can concentrate photosynthate to enlarge the fruit. Leaf growth that is too dominant will cause photosynthate to be utilised by plants for new vegetative growth, which can be in the form of tendrils, branches or leaves that will later become sinks, so that the source that will be used by the fruit as the main sink will be reduced.

Acknowledgments
Thanks to all parties who have supported the implementation of this research. I hope this research can be useful.

Author Contributions
Conceptualization, N. A.; methodology, N. T.; validation, N. I. F.; formal analysis, S. R.; investigation, S.; resources, N. A.; data curation, N. T.: writing—original draft preparation, N. I. F.; writing—review and editing, S. R.; visualization, S. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

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