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RESEARCH ARTICLE

Growth, yield, and fruit quality responses of three cucumber (*Cucumis sativus* L.) varieties to different ethephon concentrations

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ABSTRACT

The decline in cucumber (*Cucumis sativus* L.) production in Indonesia was correlated with sex ratio imbalance. Therefore, ethephon could be used to retard vegetative growth and modify the sex ratio of the cucumber plant towards femaleness to increase yield. This regulator also has the ability to increase fruit quality. The objective of this research was to investigate the growth, yield, and fruit quality responses of three cucumber varieties to different ethephon concentrations. A factorial randomized block design was used and consisted of cucumber variety (Vanesa, Mars, and Roberto) and ethephon concentration (no ethephon, 150 ppm, and 300 ppm). Each treatment was replicated three times. The results revealed that 150 ppm of ethephon reduced vegetative growth and increased the number of female flowers, sex ratio, fruit diameter, and marketable fruits. Roberto variety had the highest sex ratio, fruit length, total carotenoid, flavonoid, and phenolic content. The interaction effect showed that Roberto with 150 ppm of ethephon exhibited the best in male flower number and fruit weight per plant. Overall, the ethephon treatment at 150 ppm and Roberto variety were recommended to increase the yield and quality of cucumber.

Keywords: Cucumber; Ethephon; Growth; Fruit quality; Yield

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a horticultural crop and a member of the Cucurbitaceae family. Its fruit is one of the sources of fiber and foods for humans (Schmidt et al., 2020). It could be consumed as salad, pickle, or utilized for medicine and cosmetics. Additionally, fruits are rich in nutrients such as protein, carbohydrate, calcium, iron, phosphor, vitamin B, ascorbic acid, phenolic compounds, flavonoid, and more (Mukherjee et al., 2013). Cucumber plants have male, female, and bisexual flowers, and could be classified by their flower position and appearance on the stem as gynoecious, monoecious, andromonoecious, trimonoecious, hermaphroditic, or androecious (Pawełkowicz et al., 2019).

FAO (2020) reported that there was a decline in cucumber yield in Indonesia. In 2014, the average yield was 477.976 ton ha^{-1} and decreased to 435.973 ton ha^{-1} in 2019. The decline of cucumber yield may be attributed to the sex ratio imbalance of the plant, where the number of its male flowers was lower than that of the female flowers. According to Ahmed et al. (2004), male and female flower proportion in cucumber affected fruit yield, as more female flowers would cause a higher yield. Cucumber's sex expression was determined by environmental, hormonal, and genetic factors (Adhikari et al., 2012). Plant growth regulator (PGR) contributes to improving earlier flowering time and modifies sex expression towards femaleness on cucumber plant (Baruah and Sarma, 2013).

Ethephon (2-chloroethyl phosphonic acid) is an ethylene-releasing compound and a regulator that is involved in many processes in plant and cellular levels (Khan et al., 2008). Furthermore, as a PGR, it promotes the development of female flowers in cucumber plants (Wang et al., 2010). Mir et al., (2019) revealed that 300 ppm of ethephon induced the highest fruit number and fruit set of cucumber. Previous research also established that the foliar application of ethephon increased the number of fruits per plant

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and fruit weight of *Cucurbita pepo* L. (Sure et al., 2012). In contrast to growth and yield, there is much less information about the effects of ethephon on fruit quality of cucumber. Previous study indicated that ethephon enhanced fruit size of apple (Cline & Bakker, 2015) and bitter gourd (Imamsaheb and Hanchinmani, 2014), also flavonoids of apple (Shafiq et al., 2014)

The use of a proper cucumber variety is also needed to improve plant yield. Genetic improvement along with more precise agronomic management practices is necessary to obtain a higher yield of the plant (Bailey-Serres et al., 2019). However, there was a lack of research conducted about ethephon concentration especially in several cucumber varieties. Therefore, the objective of this research was to investigate the growth, yield, and fruit quality responses of three cucumber varieties to different ethephon concentrations.

MATERIALS AND METHODS

Experimental site and design

This experiment was conducted in July-September 2020 under screenhouse condition in Faculty of Agriculture, Universitas Padjadjaran, Indonesia (752 m asl). The minimum and maximum daily temperatures were 12.39 ^{0}C and 31.82 ^{0}C respectively, while the average daily temperature was 23.86 ^{0}C. The average relative humidity (RH) was 83.58%. A factorial randomized block design, including three *Cucumis sativus* L. varieties namely Vanesa, Mars, and Roberto, and three ethephon concentrations as follows, no ethephon, 150 ppm, and 300 ppm were used in the study. Moreover, each treatment was replicated three times.

Field experiment

Tillage and fumigant sterilization of Inceptisols soil were carried out before planting. Afterwards, 5 kg of soil, manure, and husk charcoal in the ratio of 2:1:1 were mixed and put into a 40 cm x 40 cm polybag. Before planting, the cucumber seeds were submerged in water for 24 hours. The seeds that sunk in the water were then selected to be planted in the polybag. The recommended dose of NPK (16:16:16) fertilizer was 600 kg/ha applied at planting and 28 days after planting (DAP), in which 9.8 g per plant of each application. The plant spacing used was 40 cm x 70 cm. Foliar synthetic ethephon (Santrel 500 SL) was applied at vegetative stages (21 DAP). Around 21 DAP, cucumber plant usually have very dense leaves and branch leading to decrease the formation of flowers and fruits (Mardhiana et al., 2017). Thus, ethephon was applied to inhibit and modify generative stage The spraying volume was 10 mL per plant determined through calibration.

Growth and yield measurements

Plant height was measured from the surface of growing media to the meristem tip at 28 DAP and 35 DAP, then the increment between that period was obtained. Total leaf number (the number of fully expanded leaves) and leaf area through gravimetric methods (Daughtry, 1990) were observed at 35 DAP. Floral characteristics such as first flowering date (days to first flower appearance after planting), male and female flower number (total opened male and female flower in whole plant), and sex ratio (the ratio of female to male flower) were also calculated. Finally, yield components such as fruit number and fruit weight were analyzed after harvesting, characterized based on the description of weight and fruit color uniformity of each variety. The fruits harvested were weighted and counted, then the average of each variable was obtained.

Fruit quality measurements

Marketable fruit was analyzed according to Indonesian National Standard (2013), characterized by fresh appearance, proper shape, and color, also no mechanical damage, pest and disease. Moreover, fruit length and diameter, colour analysis (L*, a*, b*), carotenoid, flavonoid, and phenolic content were measured. Fruit length and diameter were calculated using vernier calipers (Mitutoyo, Germany), while the reflectance spectrophotometer (Konica Minolta CR-400, Tokyo, Japan) was used for the color analysis. According to Pathare et al. (2013), L*, a*, b* values were varied and could be defined as; L* (0 is black; 100 is white), a* (positive value is red; negative value is green; 0 is neutral), and b* (positive value is yellow; negative value is blue; 0 is neutral).

Determination of carotenoid, flavonoid, and phenolic content

For assessments of total flavonoid and phenolic content, ethanolic extracts from dried leaves were used, while carotenoid used the acetone extract. Measurement of total carotenoid has followed the method described by Biswas et al. (2011). Flavonoid content was analyzed using the aluminum chloride colorimetric method explained by Sytar et al. (2018). Phenolic content was analyzed according to Singleton and Rossi (1965), which determined by FolinCiocalteu method, using gallic acid as standard. The absorbance was measured at 449 nm, 415 nm, and 765 nm wavelength for carotenoid, flavonoid, and phenolic analysis respectively, performed with UV-Vis spectrophotometer (UVmini-1240 mini, Shimadzu Corporation, Kyoto, Japan).

Statistical analysis

Data were subjected to ANOVA at 5% probability performed with SPSS v21, and when the data was significant, the Duncan multiple range (DMRT) test was conducted.

RESULTS

Effects of ethephon and variety on plant growth

Fig. 1 showed the growth of each cucumber variety at 35 DAP. According to Table 1, no significant interaction effect was found between ethephon application and different cucumber varieties on plant height increment and leaf area. As shown in Table 2, ethephon significantly reduced plant height increment and leaf area at 150 ppm (47.73 cm and 4946.54 cm^2 respectively) and 300 ppm (41.32 cm and 4353.56 cm^2 respectively) concentrations. Meanwhile, variety had no significant effect on those parameters. Moreover, the ethephon and variety showed a significant interaction on leaf number per plant (Table 1). As shown in Fig. 2A, Roberto variety without ethephon application (13.50) exhibited lower number of leaves that was significantly different from the Mars without ethephon (19.43) and at 150 ppm (20.67), also Vanesa at 300 ppm of ethephon (17.41). At Vanesa, higher ethephon concentration tend to increase leaf number.

No significant interaction effect was recorded between ethephon concentration and cucumber variety on the first flowering date, the number of female flowers, and sex ratio (Table 1). As shown in Table 2, the main effect of ethephon caused no significant difference on first flowering date, while it increased the number of female flowers and sex ratio at 150 ppm (11.69 and 1.10 respectively) and 300 ppm (11.97 and 1.25 respectively) concentrations. Furthermore, among the floral parameters, the variety treatment only affected first flowering date and sex ratio. Vanesa showed the earliest flowering time (28.59 DAP), while Roberto provided the maximum sex ratio (1.50). The interaction of the ethephon and variety had a significant effect on the number of male flowers per plant. The lowest male flower number was recorded on Roberto with 150 ppm of ethephon (6.45) and significantly different from others except for Roberto without ethephon (11.33), Vanesa at 150 ppm of ethephon (14.56), and all varieties at 300 ppm concentration of ethephon (Fig. 2B).

Effects of ethephon and variety on plant yield

There was a significant interaction effect between ethephon concentration and cucumber variety with regards to fruit weight and fruit number per plant (Table 1). Additionally, Fig. 3A showed that Mars treated with 150 ppm of ethephon (1141.23 g) significantly provided heavier fruit compared to other treatments except for Roberto at 150 ppm (1102.45 g) and all varieties combined with 300 ppm of ethephon. Similarly, Mars combined with ethephon at 150 ppm (9.72) significantly exhibited a greater fruit number than other treatments except for when this regulator was applied at 300 ppm (9.11) and in Vanesa at the same concentration (9.23) (Fig. 3B). The lowest fruit weight was noted on Vanesa and Mars without ethephon application (495.48 g and 534.83 g respectively), as well as fruit number (4.67 and 4.50 respectively).

Effects of ethephon and variety on fruit quality

Significant interaction between ethephon concentration and cucumber variety on several fruit quality parameters, such as marketable fruit, fruit length and diameter were not found in this study (Table 1). According to Table 3, 150 ppm and 300 ppm of ethephon showed the highest marketable fruit (83.56% and 86.00% respectively). Those treatments also significantly increased fruit diameter. However, the maximum fruit length only was noted on 300 ppm of ethephon (17.70 cm). Furthermore, the variety did not show a significant effect on marketable fruit. The highest fruit length, which was also significantly different from the other varieties occurred on Roberto (22.90 cm), although it had the lowest fruit diameter (2.85 cm). On the other hand, the highest fruit diameter was recorded on Mars (3.61 cm).

According to Table 1, there was no significant interaction between the treatments on a* and b*. The main effect of ethephon did not impact both a* and b* values. As shown

Fig 1. Vanesa (A), Mars (B), and Roberto (C) variety at 35 DAP.

in Table 3, the range of a* value on this treatment was from -8.14 to -7.73, indicating that cucumber fruit skin exhibited greenness in colour. On the other hand, the range of b* value was from 24.22 to 25.07, suggesting a slightly yellow colour. However, Roberto variety presented the greatest a* (-5.89). Additionally, the highest b* value was noted on Vanesa (34.77). Conversely, the interaction between the treatments was significantly different on L*. As shown in Fig 4, Vanesa untreated by ethephon (62.28) significantly obtained a higher L* value than others except for Vanesa at other concentrations. The lowest L* value was showed on Roberto at 150 ppm (29.81), while it was not significantly different from this same variety at other ethephon concentrations.

Table 1: The probability of growth, yield, and fruit quality responses of three cucumber varieties due to different ethephon concentration

Parameters	Ethephon Concentration (E)	Variety (V)	Interaction (E*V)
Growth			
Plant height increment	0.001*	0.853^{ns}	0.803^{ns}
Leaf number	0.280^{ns}	0.000*	0.032*
Leaf area	0.006*	0.112^{ns}	0.722^{ns}
First flowering date	0.435^{ns}	0.000*	0.729^{ns}
Male flower number	0.000*	0.001*	0.010*
Female flower number	0.002*	0.445^{ns}	0.073^{ns}
Sex ratio	0.001*	0.000*	0.351^{ns}
Yield			
Fruit weight	0.000*	0.000*	0.000*
Fruit number	0.000*	0.073^{ns}	0.001*
Fruit Quality			
Marketable fruit	0.000*	0.176^{ns}	0.419^{ns}
Fruit length	0.000*	0.000*	0.588^{ns}
Fruit diameter	0.036*	0.000*	0.376^{ns}
L*	0.884^{ns}	0.000*	0.004*
a*	0.095^{ns}	0.000*	0.886^{ns}
b*	0.643^{ns}	0.000*	0.498^{ns}
Carotenoid content	0.792^{ns}	0.000*	0.721^{ns}
Phenolic content	0.746^{ns}	0.020*	0.077^{ns}
Flavonoid content	0.406^{ns}	0.000*	0.515^{ns}

* = significant ($p<0.05$), ^{ns}=not significant ($p \geq 0.05$)

Interaction between ethephon concentration and cucumber variety did not significantly affect the carotenoid, flavonoid, and phenolic content (Table 1). The main effect of ethephon treatment showed insignificant effect on those parameters, while significantly affected by variety. According to Table 3, Roberto exhibited the highest carotenoid (282.98 mg BCE/100 g DW) and flavonoid (218.15 mg QE/100 g DW). The highest phenolic content also recorded on Roberto (445.14 mg GAE/100 g DW) while did not significantly differ with Vanesa (403.08 mg GAE/100 g DW).

DISCUSSION

Effects of ethephon and variety on plant growth

The results indicated that ethephon retard stem elongation in the plant. Dranski et al. (2013) revealed that seedling height increment of *Pachystroma longifolium* was reduced by up to 50% when ethephon was applied. Moreover, the addition of this regulator resulted in a shorter plant height of *Narcissus tazetta* L. compared to the control (Demir and Çelikel, 2019). Another finding showed that ethephon also reduced the height of maize plants (Spitzer et al., 2015). The anti-gibberellin trait of ethylene alters plant height and leads to reduce stem elongation (Miller and Olberg, 2016)

The reduction of growth parameter also was found on leaf area. Yadava (2001) confirmed that reduction of cape gooseberry leaf area occurred with the ethephon application. This reduction may be attributed to the decline of spongy mesophyll cell and intercellular space near leaf margin after ethephon application. A significant decrease in leaf area was also noted by ethephon application on maize (Gong et al., 2021).

The interactions between the treatments showed different results. Interestingly, at Vanesa, higher ethephon concentration was followed by the increase in leaf number. However, on the Mars, the used of this regulator slightly

Table 2: Plant height increment, leaf area, first flowering date, female flower number, and sex ratio of three cucumber varieties due to different ethephon concentration

Treatments	Plant Height Increment (cm)	Leaf Area (cm^2)	First Flowering Date (DAP)	Female Flower Number	Sex Ratio
Ethephon concentration					
No ethephon	59.42 b	6384.59 b	31.93 a	8.06 a	0.45 a
150 ppm	47.73 a	4946.54 a	32.26 a	11.69 b	1.10 b
300 ppm	41.32 a	4353.56 a	32.37 a	11.97 b	1.25 b
Variety					
Vanesa	48.15 a	4828.64 a	28.59 a	9.72 a	0.70 a
Mars	50.17 a	4915.15 a	32.37 b	10.47 a	0.53 a
Roberto	48.15 a	5940.90 a	35.59 c	11.27 a	1.50 b

Mean value followed by the same letter on the same column was not significant ($p \geq 0.05$) according to Duncan's multiple range test.

Table 3: Marketable fruit, fruit length and diameter, a*, b*, carotenoid, flavonoid, and phenolic content of three *Cucumis sativus* L. varieties to ethephon concentration

Treatments	Marketable Fruit (%)	Fruit Length (cm)	Fruit Diameter (cm)	a*	b*	Carotenoid Content (mg BCE/100 g DW)	Flavonoid Content (mg QE/100 g DW)	Phenolic Content (mg GAE/100 g DW)
Ethephon concentration								
No ethephon	75.00 a	16.63 a	3.17 a	-7.73 a	24.50 a	120.25 a	117.12 a	404.01 a
150 ppm	83.56 b	17.02 a	3.26 b	-7.65 a	24.22 a	130.58 a	126.77 a	414.84 a
300 ppm	86.00 b	17.70 b	3.28 b	-8.14 a	25.07 a	127.47 a	139.53 a	395.75 a
Variety								
Vanesa	82.67 a	15.32 b	3.26 b	-9.12 a	34.77 c	26.23 a	86.50 a	403.08 ab
Mars	82.89 a	13.14 a	3.61 c	-8.51 b	28.03 b	69.09 b	78.78 a	366.37 a
Roberto	79.00 a	22.90 c	2.85 a	-5.89 c	11.00 a	282.98 c	218.15 b	445.14 b

Mean value followed by the same letter on the same column was not significant (p≥0.05) according to Duncan's multiple range test.
BCE: Betacarotene equivalents, QE: Qatechin equivalent, GAE: Gallic acid equivalent, DW: dried weight.

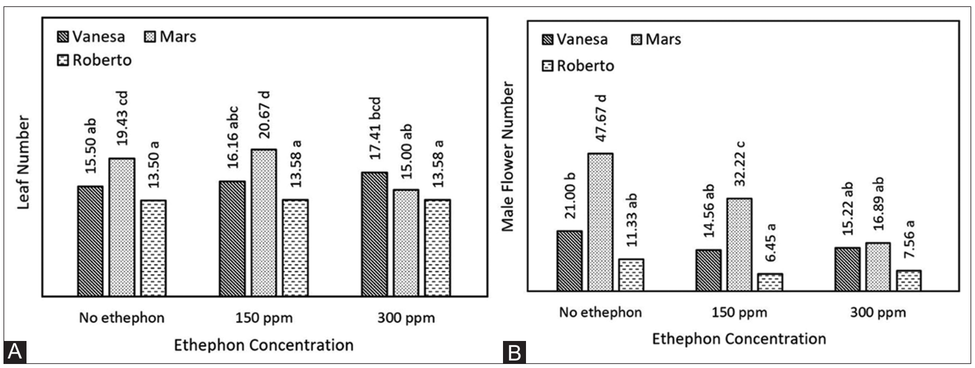

Fig 2. Effect of ethephon concentration in different cucumber varieties on leaf number (A) and male flower number (B). Mean value followed by the same letter was not significant (p≥0.05) according to Duncan's multiple range test.

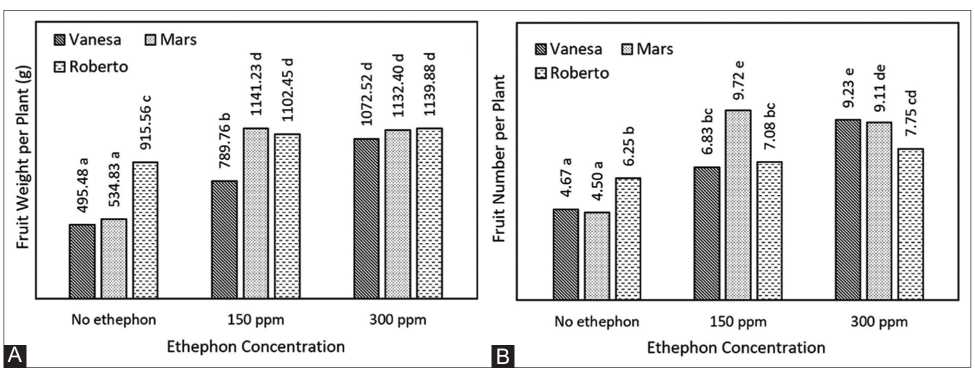

Fig 3. Effect of ethephon concentration in different cucumber varieties on fruit weight per plant (A) and fruit number per plant (B). Mean value followed by the same letter was not significant (p≥0.05) according to Duncan's multiple range test.

decreased leaf number. This might be due to the genetic factors that resulted in the different growth responses of each variety to ethephon. Shiono et al., (2019) revealed that this regulator decreased the total leaf number of barley.

Ethephon had positive effect on floral characteristics such as increasing the number of female flowers and sex ratio, also decreased male flowers number. These results seem to be consistent with other research which found that treatment with a low or high concentration of ethephon increased cucumber plant femaleness (Papadopoulou and Grumet, 2005). A similar result was revealed by Girek et al. (2013) that *Cucumis melo* L. treated with this regulator experienced a reduction in the male flower number. Colombo and Galmarini (2017) stated that ethephon is effective in disrupting the development of pollen without influencing the female functionally, which leads to male sterility. Male sterility could be defined as the failure of a plant to form functional pollens, anthers, and/or male gametes at reproductive stage (Wei et al., 2012).

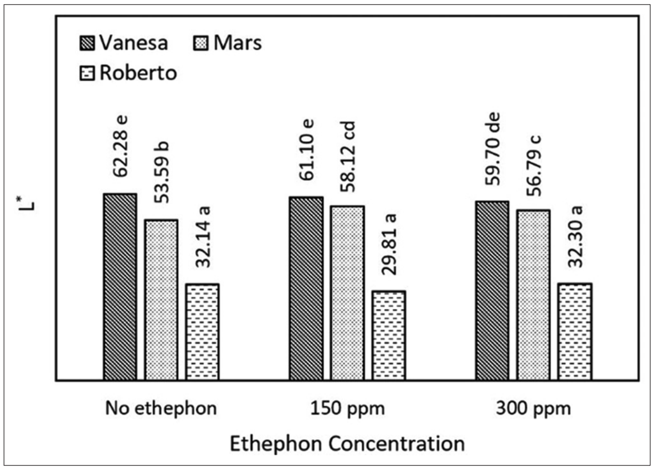

Fig 4. Effect of ethephon concentration in different cucumber varieties on L*. Mean value followed by the same letter was not significant (p ≥ 0.05) according to Duncan's multiple range test.

A significant increase in the floral sex ratio of *Cucumis melo* L. (female to male) was noted with ethephon (Chaurasiya et al., 2016). These results may be attributed to ethylene role as a promoter of female flowers, either directly or by decreasing endogenous levels of auxin and gibberellic acid, or even by enhancing abscisic acid production. Therefore, ethephon could promote cucumber sex expression towards femaleness by causing an increase in the number of female flowers.

However, ethephon did not alter first flowering date which was in agreement with Miller et al. (2012) that ethephon at up to 200 ppm concentration did not influence flowering time in several floriculture crops. Its application at lower concentration did not also alter the flowering time of *Narcissus tazetta* (Çelikel and Demir, 2019).

Effects of ethephon and variety on plant yield

According to the results, the plants treated by ethephon could experience higher fruit weight per plant. Devi and Madhanakumari (2015) confirmed that this regulator alone or combined with other plant growth regulators resulted in higher fruit yield per plant compared to control treatment. A possible explanation for the increase might be due to less amount of gibberellins while receiving more photosynthates, as a results of ethephon application (Yadava, 2001). At the same time, less energy was observed during vegetative stage, leading to saving more energy for generative stage, including flower bud initiation, fruit set, and fruit growth.

Ethephon also was able to increase the total fruit number of the cucumbers. Furthermore, it provided the best positive effect on fruit number of several melon cultivars (Girek et al., 2013). Yadava (2001) reported that ethephon provided a higher fruit number of cape gooseberry and this might be due to the higher fruit set.

Effects of ethephon and variety on fruit quality

The results indicated that each variety had various fruit size. Moreover, both concentrations of ethephon were effective in increasing marketable fruit and fruit size. Previous study have demonstrated that tomato plants treated by this regulator showed greater marketable fruit than control (Jędrszczyk et al., 2017). These results also are in line with data obtained by Imamsaheb and Hanchinmani (2014) that ethephon enhanced fruit length and diameter. The application of ethephon on cucumber plant affected the auxin level causing an increase in fruit size (Mir et al., 2019). Auxin is hormone which involved in cell differentiation, elongation, and division (Tantasawat et al., 2015). Moreover, they also revealed that cell enlargement greatly determined fruit size and it was controlled by auxins. The increase in fruit size also may be attributed to the acceleration in the rate of cell enlargement and cell division and more intercellular space after being treated by growth substances (Sharma and Tiwari, 2015).

Fruit color is one of the important external factors in determining fruit quality, as the appearance of the fruit greatly influences consumer interest. The results indicated that ethephon slightly influenced color parameters as a significant difference only achieved by L*. Buhrig et al. (2015) reported that ethephon significantly altered L* of potatoes skin. Variety treatment had different in fruit skin colour. Vanesa had the brightest green fruit skin, while Mars had a little bit dark and yellowish. On the other hand, Roberto had the darkest green colour.

The application of ethephon did not alter carotenoid in our study. Furthermore, Roberto positively had high result of this parameter. Carotenoid appears as a natural pigment which reflects the colour of horticultural plants; the bright red, orange, and yellow colors, and also the flavor and aroma (Hermanns et al., 2020). Song et al. (2010) stated that common cucumbers (*Cucumis sativus* L.) produced white fruit as the result of lower carotenoid content, while several varieties also develop orange fruits that are rich in carotenoid.

Furthermore, flavonoid and phenolic content were not affected by ethephon. The insignificant effect on ethephon application was in accordance with the earlier studies. Previous research showed that ethephon application did not influence flavonoid and phenolic content of *Echinodorus grandiflorus* in different seasons (Joaquim et al., 2008). However, an increase in its concentration tended to enhance flavonoid content in our study, although it was not notably different. Shafiq et al. (2014) stated that the initial biosynthetic steps for flavonoid formation might require the ethylene presence.

On the other hand, variety affected total flavonoid and phenolic content, which the best results were obtained on Roberto. Environmental and plant genetic factors interact with each other resulting in different gene expressions and changing of secondary metabolites composition (Ismail et al., 2017). Most of phenolic compounds, particularly flavonoids, act as antioxidants and ROS scavengers (Bautista et al., 2016).

CONCLUSION

Ethephon application at 150 ppm decreased plant height increment and leaf area. It was sufficient for increasing female flower number, sex ratio, fruit diameter, and marketable fruit. The colour parameters of the fruit skin were slightly affected by this regulator. Furthermore, Roberto variety had the highest sex ratio, fruit length, also total carotenoid, flavonoid, and phenolic content.

The interaction showed that Mars combined with 150 ppm of ethephon showed the best fruit number and fruit weight per plant. However, the difference in fruit weight was not significance different from that of Roberto at 150 ppm. Overall, the Roberto variety and ethephon treatment at 150 ppm were recommended to increase cucumber yield and fruit quality.

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Author's Contribution

Kusumiyati designed the entire research project including writing and crosschecked the final manuscript. Sarah Nurul Fajri conducted laboratory and field research, and also analyzed the data. Jajang Sauman Hamdani and Wawan Sutari supervised the results and discussions of this manuscript.

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