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Effects of paclobutrazol concentrations and watering frequencies on the flowering ratio of cucumber plants (*Cucumis sativus* L.)

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Abstract

Generally, cucumber plants have more male flowers than female flowers. The fewer number of female flowers is one of the problems of cucumber production. Flowering regulation can be performed by applying growth regulators and water management. The study aims to determine the effects of paclobutrazol concentrations and watering frequencies on the flowering ratio of cucumber plants. The experiment was arranged in a factorial Randomized Completely Block Design at the Agricultural, Food, and Fishery Extension Center, Seyegan, Yogyakarta. The first factor was the paclobutrazol concentrations consisting of four levels (a control, 0.187 mL.L^{-1}, 0.375 mL.L^{-1}, and 0.562 mL.L^{-1}). Meanwhile, the second factor was the watering frequency consisting of three levels (once a day, once every two days, and once every three days). The observed data were performed using the analysis of variance (ANOVA) and followed with Duncan's Multiple Range Test at α= 5 %. The paclobutrazol concentrations resulted in a significant effect on all of the observed variables. Meanwhile, watering frequencies showed no significant effect on the male flowers, female flowers and ratio of male to female flowers in cucumber. There was an interaction effect of paclobutrazol concentration and watering frequency on the plant height and flowering age of cucumber plants. The treatment of paclobutrazol at a concentration of 0.375 mL.L^{-1}, decreased of male flowers and increased of female flowers, reducing the ratio of male and female flowers of cucumber plants at various watering frequencies.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a vegetable plant of the pumpkin family (*Curcubitaceae*) and is usually consumed in raw form (Zhang et al., 2019). In cucumber cultivation, plants are more dominant in producing male flowers than female flowers so that cucumber plants have an unbalanced ratio of male to female flowers. The flower that will develop into fruits is female flower. Thus, small number of female flowers can be the cause of low cucumber production. Flowering of cucumber depends on the role of growth regulators and environmental conditions.

In the *Cucurbitaceae* plants, gibberellins promote the formation of male flowers. Thus, a modification is necessary to inhibit the formation of gibberellin, one of which is the application of paclobutrazol. Paclobutrazol is a growth inhibitor of the retardant class, which works by inhibiting gibberellin (Watson and Jacobs, 2012). Paclobutrazol works by inhibiting the oxidation of ent-kaurene to ent-kauronoic acid through the inactivation of cytochrome P450 dependent oxygenase (Desta and Amare, 2021). According to Gerdakaneh et al. (2018), paclobutrazol showed a significant effect by suppressing the number of male flowers compared to control. Paclobutrazol

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could increase the number of female flowers and metabolic activity that leads to a higher metabolite translocation from the source to the seed, resulting in the better seed development in pumpkin crop.

Environmental factors such as water deficit might also influence flowering in plants. Plants that experience water stress will accelerate the induction of flowering (Rahayu et al., 2020). Liu et al. (2004) mentioned that an increase in abscisic acid (ABA) concentration occurred in drought conditions. The increased ABA can increase the ethylene hormone. Susilawati et al. (2012) state that the increase of ethylene is due to the amount of oxygen around the roots that can be used by plants to convert ACC (1-amino cyclopropane 1 corboxylic acid), which is the starting material of ethylene. Pan et al. (2018) state that ethylene greatly encourages the formation of female flowers in cucumber plants.

Growth regulators and water management are expected to change the flower ratio of cucumber plants. Budiyanto et al. (2010) showed that the application of paclobutrazol at a concentration of 0.375 $mL.L^{-1}$ on cucumber plants cv. Venus by spraying on the branches and leaves evenly produced more female flowers (19.53) compared to control, which was only 12.64. Sewoong et al. (2020) showed that drought conditions with a water content of 50 % resulted in 12 female flowers and 3 male flowers, while 70 % sufficient water content resulted in 10.4 female flowers and 4.6 male flowers in cucumber plants. So far, there has not been much information about the flowering ratio of the cucumber cv. Roman F1 as affected by combined treatment of paclobutrazol concentration and watering frequency. According to the Ministry of Agriculture Number 3638/Kpts/ SR.120 /10/2009, Roman F1 is superior variety that has a high yield potential. Therefore, this study was conducted to examine the effects of paclobutrazol concentration and watering frequency on the flowering ratio of cucumber plants.

MATERIALS AND METHODS

This research was conducted from October to December 2020 at the screen house of Agricultural, Food, and Fishery Extension Center, Seyegan, Yogyakarta. This location is in the lowlands, which is 165 m ASL, at 7°721'19° south latitude and 110°308' 41° east longitude. The materials used in this study were cucumber seeds cv. Roman F1 and paclobutrazol. This research was conducted using polybags with top soil and manure as planting media.

This research was arranged in a factorial Randomized Completely Block Design (RCBD) consisting of two factors, which were four levels of paclobutrazol concentration (0 (control), 0.187 $mL.L^{-1}$, 0.375 $mL.L^{-1}$, and 0.562 $mL.L^{-1}$) and three levels of watering frequency (once a day, once every two days, and once every three days). Initial fertilization was carried out 7 days before planting with a dose of NPK fertilizer (16:16:16) as much as 600 $kg.ha^{-1}$ and manure as much as 20 $ton.ha^{-1}$ (Balai Penelitian Sayuran, 2013). Pest control was carried out using antracol. Weeding was carried out by cleaning the grass around the plant stems and the edges of the plants in polybags. Volume of watering was 1 L. The application of paclobutrazol was carried out in the morning after watering by spraying it onto the stems and leaves evenly. The spraying was carried out at 21 and 28 days after planting (DAP), which is the active and maximum vegetative growth of cucumber plants, respectively, with the concentration according to the treatment. The watering frequency treatment was carried out during active vegetative growth and stopped when the flowering phase occurred, which was at 21–28 DAP. After flowering, water supply was returned to normal by watering every day until the end of harvest.

The data observed were the soil moisture content observed at the time of watering treatment (21 to 28 DAP), plant height observed at 36 DAP and flowering period observed when the first flower appeared on the plant. Male and female flowers were counted, in which male flowers were characterized through the absence of ovary under the flower crown, while female flowers were through the presence of ovary under the flower crown. Ratio of male to female flowers was determined by comparing the number of male and female flowers of cucumber plants. The number of male and female flowers was determined starting from the appearance of the first flower until 42 DAP. The data were analyzed using analysis of variance (ANOVA) and followed with Duncan's Multiple Range Test (DMRT) at α= 5 %.

RESULTS AND DISCUSSION

The soil moisture-content

The average of soil moisture content is shown in Table 1. The measurement of moisture content was

carried out twice, which were after and before watering. The moisture content before watering is a representation of the condition of the lowest moisture content at a time, while the one after watering is the condition of the highest moisture content at a time. The results showed that the moisture content test before watering showed a lower moisture content than after watering. The lower frequency of watering caused water deficit, thereby causing the soil to become harder and decreasing the ability of the soil to hold water.

The plant height of cucumber

There was an interaction effect of the concentration of paclobutrazol and watering frequency on the plant height of cucumber (Table 2). The application of paclobutrazol significantly decreased the plant height, supported by Tesfahun (2018) stating that paclobutrazol can suppress plant height.

The result of this study showed that the concentration of paclobutrazol and watering frequency had an effect on decreasing the height of cucumber plants. The concentration of paclobutrazol showed significant different results compared to control. The tallest plant was in control treatment with watering frequency of once a day and once every two days (Table 2). Reducing the frequency of watering will lead to drought conditions as shown by Table 1, in which the watering frequency of once every 2 days and 3 days watering had a lower moisture content. The drought conditions resulted in depressed plant growth. The depressed growth was also demonstrated on paclo butrazol applications, in which higher concentration could suppress the growth.

Table 1. Average soil moisture content (%) after and before watering

Watering frequency	Once every 1 day	Once every 2 days	Once every 3 days
Average after watering	46.51 %	41.47 %	38.47 %
Average before watering	37.99 %	29.79 %	23.33 %

Table 2. Effects of paclobutrazol and watering frequency on the plant height of cucumber plants (cm) at 36 DAP

Concentration of paclobutrazol ($mL.L^{-1}$)	Watering frequency			Mean
	Once every 1 day	Once every 2 days	Once every 3 days	
0	104.11 a	102.44 ab	91.44 cd	99.33
0.187	96.22 bc	89.66 cd	86.89 d	90.92
0.375	87.55 d	88.33 d	87.33 d	87.40
0.562	86.67 d	85.67 d	87.00 d	86.44
Mean	93.64	91.52	88.16	91.11
Interaction				(+)
CV %				4.05

Remarks: Means followed by the same letters in the same column and row are not significantly different according to Duncan test at α= 5 %; (+) signifies an interaction; DAP= Days After Planting

The plants given paclobutrazol were shorter compared to control. The higher concentration of paclobutrazol, the shorter the plants. Paclobutrazol can reduce the height of plants because paclobutrazol has an effect in inhibiting gibberellin, which has a role in elongating cells. Lolaei et al. (2013) also mention that the decrease in gibberellin levels in plants, which plays a role in cell division and elongation, will inhibit plant height. Suryana (2012) state that paclobutrazol will inhibit the change from kaurene to kaurenoic acid. Kaurenoic acid is the basic material for the formation of gibberellin, so the inhibition of its formation will result in a decrease in gibberellin, thereby disrupting plant growth. In line with Flores et al. (2018), the application of paclobutrazol at 150 $mg.L^{-1}$ caused a decrease in the height of cucumber, chayote, melon and watermelon plants. Kumar et al. (2012) pointed out that the application of paclobutrazol significantly reduced the height of *Camelia sativa* plants by 47.5 % compared to the control. Furthermore, Hua et al.

(2014) mentioned that paclobutrazol was effective in controlling the height of canola plants. Kamran et al. (2018) also showed that paclobutrazol caused a reduction in internode length and plant height of wheat.

In the control treatment (without paclobutrazol), watering frequency of once every three days resulted in the shorter plants compared to the watering frequency of once a day and once every two days. The decrease in plant height is due to decreased turgor pressure in dry conditions, thus inhibiting cell division and development. This is in line with Nonami (1998), mentioning that in dry condition, cell elongation is inhibited due to interference with the flow of water from the xylem to the surrounding cells, thereby inhibiting the process of cell division and elongation. Furthermore, the decrease in plant height is due to a decrease in cell enlargement.

The flowering period of cucumber

The flowering period of cucumber is showed an interaction effect of the paclobutrazol concentration and watering frequency on the flowering period. The results showed in Table 3 indicated that the application of paclobutrazol and the frequency of watering resulted in the different flowering periods at high concentrations of paclobutrazol and daily watering. The data showed that the application of paclobutrazol at 0.562 $mL.L^{-1}$ combined with watering frequency of once a day delayed the flowering period of cucumber plants. Nugroho (2012) stated that the treatment of growth regulators with inappropriate concentrations will delay the flowering period because the formation of several substances needed by plants for the formation of flower primordia is inhibited. Too high concentration of paclobutrazol will result in pressure in plant growth, resulting in delayed flowering (Yadava, 2012). The optimal limit for the use of paclobutrazol concentrations is 0.187 $mL.L^{-1}$. Stressed plants develop resistance mechanisms, one of which is drought escape by completing their life cycle sooner before experiencing drought. Watering once a day did not cause stress in plants so that they took longer period to start flowering .

The suppression of gibberellin biosynthesis due to the excessive application of paclobutrazol leads to an increase in ABA precursor, namely fornesyl pyrophosphate, thereby increasing the level of endogenous ABA. An increase in ABA level generally leads to slower plant growth. As a result, less assimilates are produced so that the energy source to initiate the formation of flowers is less available, which cause flowering to take longer (Widyanta, 2008).

The watering frequency of once every 2 and 3 days did not affect the flowering period of cucumber plants. This is thought to be due to the short-term drought stress experienced by the plants, as shown by Table 1, so that the plants can still live normally without affecting the flowering period. The drought stress treatment in this study was carried out from 21 to 28 DAP. It was stopped at 28 DAP because the cucumber plants had entered the flowering phase. Maimunnah et al. (2018) stated that fruit formation would fail if the water shortage lasted a long time.

Total male flowers, total female flowers, and male and female flower ratio

The number of male flowers, number of female flowers and ratio of male to female flowers are showed no interaction effect between treatments. But, paclobutrazol itself showed significant effect on the

Table 3. Effects of paclobutrazol and watering frequency on the flowering period (days) of cucumber plants

Concentration of paclobutrazol ($mL.L^{-1}$)	Watering frequency			Mean
	Once every 1 day	Once every 2 days	Once every 3 days	
0	26.77 b	26.33 b	27.11 b	26.74
0.187	27.11 b	27.33 b	27.00 b	27.14
0.375	27.11 b	26.55 b	26.77 b	26.81
0.562	28.78 a	27.11 b	26.89 b	27.59
Mean	27.44	26.83	26.94	27.07
Interaction				(+)
CV %				2.02

Remarks: Means followed by the same letters in the same column and row are not significantly different according to Duncan test at α= 5 %; (+) signifies an interaction.

number of male flowers, number of female flowers and ratio of male to female flowers in cucumber plants. However, there was no significant effect of the watering frequency on the number of male flowers, number of female flowers and ratio of male to female flowers.

Table 4 shows that the paclobutrazol concentrations cause a decrease in the number of male flowers and an increase in the number of female flowers of cucumber plants. This is because concentration of paclobutrazol inhibits gibberellin biosynthesis, in which gibberellin is a hormone that supports male flowers in cucumber plants.

The results showed that the number of male flowers in control treatment was significantly different from that in the paclobutrazol treatment at concentration of 0.187 mL.L^{-1}, 0.375 mL.L^{-1}, and 0.562 mL.L^{-1}. Paclobutrazol concentrations higher than 0.187 mL.L^{-1} could reduce the number of male flowers. The result can be seen in the plants treated with paclobutrazol at concentration of 0.375 mL.L^{-1}, and 0.562 mL.L^{-1}, which produced lower number of male flowers. The treatment of watering frequency did not have a significant effect on the number of male cucumber flowers. This means that the decrease in male flower formation produced by the study was only due to the difference in the concentration of paclobutrazol application.

The application of paclobutrazol increased the number of female flowers. Paclobutrazol concentration of 0.375 mL.L^{-1} and 0.562 mL.L^{-1} produced higher number of female flowers, reaching 27.70 and 27.66, respectively, compared to concentration of 0.187 mL.L^{-1} and control treatment, which produced only 20.48 and 13.22 female flowers, respectively. The treatment of watering frequency did not have a significant effect on the number of female flowers.

The increase in female flowers of cucumber plants due to the application of paclobutrazol was caused by the reduction of gibberellin. Inhibition of gibberellin will suppress the growth of male flowers and can increase the number of female flowers in cucumber plants. Paclobutrazol causes the mitotic process to stop in the shoot meristem, thereby afeecting female flowers (Gerdakaneh et al., 2018).

The ratio of male flowers to female flowers is the ratio between male flowers and female flowers. A high ratio of male to female flowers means that more male flowers are produced, while a low ratio of male to female flowers means that more female flowers are produced (Amalia, 2014). The results showed that the application of paclobutrazol reduced the ratio of male to female flowers in cucumber plants. The application of paclobutrazol at concentration of 0.375 mL.L^{-1} and 0.562 mL.L^{-1} resulted in the lower ratio of male to female flowers, namely 2.94 : 1 and 2.96 : 1, respectively, when compared to control and paclobutrazol application at 0.187 mL.L^{-1} , resulting in a ratio of 8 : 1 and 4.52 : 1, consecutively. Paclobutrazol reduced male flowers and increased female flowers so as to reduce the flowering ratio of cucumber plants. The treatment of watering frequency

Table 4. Effects of paclobutrazol and watering frequency on the number of male flowers, number of female flowers and ratio of male to female flowers

Treatments	Male flowers	Female flowers	Male and female ratio
Concentration of paclobutrazol (mL.L^{-1})			
0	99.07 a	13.22 c	8.00 :1 a
0.187	89.66 b	20.48 b	4.52 :1 b
0.375	79.81 c	27.70 a	2.94 :1 c
0.562	80.14 c	27.66 a	2.96 :1 c
Watering Frequency			
Once every 1 day	88.47 a	21.52 a	4.69 :1 a
Once every 2 days	87.19 a	22.63 a	4.26 :1 a
Once every 3 days	85.86 a	22.64 a	4.85 :1 a
Interaction	(-)	(-)	(-)
CV %	4.23	15.81	29.46

Remarks: Means followed by the same letters in the same column and row are not significantly different according to Duncan test at α= 5 %; (-) no interaction between treatments.

did not show a significant effect on the flowering ratio of cucumber plants.

In cucumber, gibberellins encourage the formation of male flowers. The application of paclobutrazol will suppress gibberellin, which eventually encourages the formation of female flowers. Sudrajat et al. (2021) state that paclobutrazol can reduce the male flowers and increase female flowers in cucumber plants. This is in line with Pokawattna et al. (2018), reporting that the application of paclobutrazol reduced the ratio of male to female flowers (1: 4.8) when compared to control (1:16.9) in *Jatopra* plants.

CONCLUSIONS

There was an interaction effect of the concentration of paclobutrazol and watering frequency on the plant height and flowering period of cucumber. The application of paclobutrazol at a concentration of 0.375 $mL.L^{-1}$ decreased the number of male flowers and increased the number of female flowers, thereby reducing the ratio of male to female flowers in cucumber plants. Meanwhile, watering frequency showed no significant effect on the flowering ratio of cucumber plants.

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