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Study of paclobutrazol application time and different varieties on the growth and production of cucumber plants (*Cucumis sativus* L.)

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ABSTRACT

The decline in cucumber production is mainly due to inefficient cultivation therefore, plant growth regulators and superior varieties are needed to increase productivity. This study aimed to evaluate the effect of paclobutrazol application time and superior cucumber varieties on plant growth and yield. The research was conducted from August to October 2024 at Jalan Galang, Pagar Merbau III Village, Lubuk Pakam District, and at the Biotechnology Laboratory, Faculty of Agriculture, University of North Sumatra. The experiment used a randomized block design with two factors: paclobutrazol application time (7, 14, 21, and 28 DAT) and cucumber varieties (Monas F1, Komanda F1, and Zatavy F1), with three replications. Data were analyzed using ANOVA followed by Duncan's Multiple Range Test at the 5% level. The observed variables included plant height, number of leaves, number of female flowers, male-to-female flower ratio, number of fruits, fruit length, fruit diameter, and fruit weight. The results showed that plants without paclobutrazol showed higher plant height and leaf number, whereas paclobutrazol application at 21 DAT improved yield components, including number of fruits, fruit length, fruit diameter, and fruit weight. Zatavy F1 showed the best growth performance, with an average plant height of 194.67 cm, 76.27 leaves, and fruit weight of 4,149.93 g per plant. Monas F1 produced earlier female flowers, shorter harvest age, and larger fruit size, averaging 14.60 fruits per plant, fruit length 34.53 cm, and fruit diameter 71.9 mm. No significant interaction was observed between the application time of paclobutrazol and variety.

Keywords: application timing, cucumber production, growth regulator, varieties



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1. Introduction

Cucumber (*Cucumis sativus* L.) is a fruit rich in water content, low in calories, a good source of vitamin C, and contains flavonoids that act as antioxidants [1]. Phytochemical tests on cucumber have shown the presence of active compounds such as alkaloids, phenolics, flavonoids, steroids, terpenoids, and saponins [2]. According to data from [3], cucumber production in North Sumatra declined from 285,731 tons in 2023 to 262,529 tons in 2024. This decrease is suspected to be due to less intensive and inefficient cultivation practices. Therefore, improved cultivation technologies, such as the use of plant growth regulators (PGRs) and superior varieties, are needed to increase production yields.

Cucumber plants tend to produce more male flowers than female flowers, leading to an imbalance in the flower ratio. The limited number of female flowers is one of the factors contributing to the low cucumber production. The flowering process in cucumber is influenced by plant growth regulators and environmental factors. One of the plant growth regulators is gibberellin, which plays a role in promoting the formation of male flowers. Therefore, a modification is needed to inhibit gibberellin production, one of which is through the application of paclobutrazol. Paclobutrazol affects the isoprenoid pathway, and alters the levels of plant hormones by inhibiting gibberellin synthesis and increasing cytokinin levels and consequent reduction in stem elongation. When gibberellin synthesis is inhibited, more precursors in the terpenoid pathway accumulate, resulting in the production of abscisic acid [4].

Paclobutrazol is a highly active anti-gibberellin compound, even at low concentrations, and can be absorbed through the leaves, stems, or roots and translocated to the growing sub-apical meristems. It moves acropetally (from the base to the tip) through the xylem, thereby inhibiting the vegetative growth of the plant. This inhibition encourages the diversion of assimilates from vegetative organs to reproductive organs, which in turn stimulates bud break, flower formation, and increased fruit yield. Thus, the use of paclobutrazol can be an effective approach to enhance cucumber productivity [5]. In addition to the use of paclobutrazol, the selection of superior varieties is one of the effective measures to improve cucumber production. Superior varieties are recommended for cultivation as they can enhance both yield and harvest quality. In general, superior varieties possess better traits compared to other varieties [6]. In the results of his research, it is known that the single treatment of two varieties, the best cucumber variety treatment is the Misano Variety, which has the highest average value compared to the Commander Variety. This is thought to be because the Misano variety can adapt to the lowland/swampland environment more quickly and better than the Commander variety, and can absorb nutrients in the soil optimally.

Based on the results of research by [7], it can be seen that the concentration of paclobutrazol application gives an interaction effect between paclobutrazol concentration and watering frequency on plant height and flowering period of cucumber. The application of paclobutrazol at a concentration of 0.375 ml/L reduces the number of male flowers and increases the number of female flowers, thus reducing the ratio of male and female flowers on cucumber plants. The frequency of watering has no significant effect on the ratio of flowering of cucumber plants.

Therefore, research on the timing of paclobutrazol application and the comparison of several cucumber varieties needs to be conducted. This study aims to determine the most appropriate application timing and the best variety to support cucumber plant growth and production. The determination of the optimal application time is expected to significantly increase cucumber production potential.

2. Materials and Methods

2.1. Research sites

This research was conducted on Jalan Galang, Pagar Merbau III Village, Lubuk Pakam Subdistrict, Deli Serdang Regency, and plant analysis was carried out at the Biotechnology Laboratory of the Faculty of Agriculture, University of Sumatera Utara. This research was conducted from August to October 2024.

2.2. Materials and tools

The materials used in this study included cucumber seeds of the Monas F1, Komandan F1, and Zatyvy F1 varieties as planting material, paclobutrazol, and other necessary inputs such as fertilisers, soil media, and water. The field tools employed consisted of mulch, which was used to cover the soil surface to maintain soil moisture and suppress weed growth; bamboo stakes, which served as plant supports to maintain upright growth; a hand sprayer, which was used for the application of paclobutrazol and other liquid treatments; and a measuring tape, which was used to measure plant height and plant spacing. Other supporting field equipment was also used for land preparation, planting, and crop maintenance. Laboratory tools included a digital scale, which was used to measure the weight of harvested cucumber fruits; a digital calliper, which was used to measure fruit diameter accurately; and a spectrophotometer, which was used to determine the chlorophyll content of cucumber leaves.

2.3. Methods

The method used was a Randomized Complete Factorial Design (RCBD) with two factors. The first factor was paclobutrazol application time (7, 14, 21, and 28 days after planting (DAT)). The second factor was cucumber variety (Monas F1, Komandan F1, and Zatyvy F1). There were fifteen treatment combinations, each of which was repeated three times. Each replication consisted of fifteen beds, with each bed containing six plants, and three plants were used as samples.

2.4. Research stages

The research stages are as follows:

2.4.1. Preparation

The planting beds were made with a width of 1.25 meters, a height of 30–50 cm, and a spacing of 80 cm between beds. The soil in the beds was loosened by hoeing and mixed with well-decomposed manure and

dolomite two weeks before planting. Silver-black plastic mulch was installed during hot weather, with the silver side facing up and the black side facing down, then neatly arranged and secured with bamboo stakes. Planting holes with a diameter of 10 cm were made in the mulch in a zigzag pattern or in two opposing rows, according to a planting distance of 50 cm.

2.4.2. Seedling preparation

Cucumber seeds were soaked in water for 12 hours and then wrapped in a moist cloth for 1–2 nights until the plumule and radicle emerged. Once sprouted, the seeds were sown into prepared seedling polybags. To protect the seedlings from pests, Carbofuran in granular form with a 3% concentration was applied around the nursery area. During the seedling stage, routine maintenance such as watering, weeding, and pest and disease control was carried out to ensure healthy growth. After approximately 12 days, or when the seedlings reached a height of about 15 cm with at least five true leaves, they were ready for transplanting into the field. Transplanting was performed in the late afternoon on planting beds that had been watered the previous day to minimize transplant shock.

2.4.3. Planting

Seedlings that already have five leaves and are seven days after planting are ready to be transplanted. Cucumber seedlings were planted on previously prepared beds with a spacing of 80 cm between beds. Each planting hole was planted with one cucumber seedling at a depth of 2 cm with a spacing of 60 x 50 cm between seedlings. Planting was done in the afternoon to prevent wilting due to excessive sun exposure.

2.4.4. Treatment application

Paclobutrazol is sprayed at 7, 14, 21, and 28 days after transplanting. Plants to be treated are marked to prevent the chemical from reaching others. The paclobutrazol solution is sprayed using a hand sprayer until all leaves are thoroughly wet, at a concentration of 0.375 ml per liter of water [7]. Spraying is carried out in the morning at around 08:00.

2.4.5. Plant maintenance

Cucumber maintenance includes regular watering, replanting, staking, pruning, fertilizing, weeding, and pest control. Watering is done twice daily during the first 2–3 weeks, then adjusted to every 2–3 days as needed. Replanting is done within seven days after transplanting for any dead or weak seedlings. Staking uses bamboo poles arranged in a triangle when plants reach 20–30 cm in height. Pruning removes side shoots from nodes 1–5, while shoots from node 6 are maintained; suckers are trimmed every 2–3 days. Basal fertilization is applied one week before transplanting using manure and chemical fertilizers, followed by additional urea three weeks after planting. Weeding is done manually as needed. Pest and disease control includes the use of Mancozeb 80% for leaf spot and Deltamethrin insecticide for fruit flies, applied in the morning or afternoon depending on conditions.

2.4.6. Observed variables

The observed parameters included plant height, number of leaves, number of female flowers, male-to-female flower ratio, number of fruits, fruit length and diameter, and fruit weight.

2.5. Data analysis

This research is purely experimental. The data obtained were analyzed using Analysis of Variance (ANOVA) at 95% significance level. If the treatment has a real effect, then continue with Duncan's Multiple Range Test (DMRT) at 95% significance level with the help of SPSS software version 26.

3. Results and Discussion

3.1. Plant height and number of leaves under the treatment of paclobutrazol application timing and varieties at 7 – 35 days after transplanting (DAT)

The results of statistical analysis showed that the timing of paclobutrazol application had a significant effect on plant height and number of leaves at 21–35 days after transplanting (DAT). The variety treatment significantly affected plant height and the number of leaves at 7–28 DAT. Interaction between the two treatments had no significant effect on plant height and number of leaves at 7–35 DAT. The mean data for plant height and number of cucumber leaves under the paclobutrazol application timing and variety treatments are presented in Table 1.

Table 1. Plant height and number of leaves under the treatment of paclobutrazol application timing and varieties at 7 – 35 days after transplanting

Treatment	Plant height (cm)					Number of leaves (Leaves)				
	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT
Paclobutrazol application timing										
Control	24.19	76.78	164.81 ^a	207.96 ^a	235.74 ^a	6.89	19.70	53.85 ^a	84.30 ^a	99.11 ^a
7 DAT _(w1)	22.93	74.33	142.30 ^c	167.59 ^c	187.78 ^c	6.59	18.30	41.41 ^b	59.78 ^c	73.70 ^c
14 DAT _(w2)	25.26	84.22	153.67 ^b	173.89 ^c	192.78 ^c	7.15	21.52	46.89 ^b	63.70 ^c	76.37 ^c
21 DAT _(w3)	25.15	83.41	173.81 ^a	192.78 ^b	212.04 ^b	6.89	20.70	57.33 ^a	75.19 ^b	86.30 ^b
28 DAT _(w4)	23.30	76.96	168.04 ^a	197.04 ^{ab}	220.19 ^b	6.67	19.74	53.85 ^a	79.26 ^b	91.19 ^b
Variety										
Monas F1	22.46 ^b	72.93 ^b	153.64 ^b	185.00 ^b	206.78	6.51 ^b	18.78 ^b	48.27 ^b	71.42 ^b	84.18
Komandan F1	23.53 ^b	77.20 ^b	157.53 ^b	183.89 ^b	208.44	6.78 ^b	19.60 ^b	49.11 ^b	69.64 ^b	84.82
Zatavy F1	26.31 ^a	87.29 ^a	170.40 ^a	194.67 ^a	213.89	7.22 ^a	21.60 ^a	54.62 ^a	76.27 ^a	87.00
Interaction	tn	tn	tn	tn	tn	tn	tn	tn	tn	tn

Note: The numbers followed by different letters within the same row and column group indicate significant differences based on Duncan's Multiple Range Test at the 5% level; DAT: Days After Planting; tn: no significant at the 5%

The results showed that at the age of 35 days after planting (HST), the treatment without paclobutrazol application (W0) produced a plant height of 207.96 cm and the number of leaves 99.11, which was significantly different from the paclobutrazol application treatment. This indicates that paclobutrazol application inhibits the vegetative growth of cucumber plants. Paclobutrazol, as a plant growth regulator, functions by inhibiting the biosynthesis of gibberellins, which are responsible for vegetative growth processes. Therefore, treated plants tend to have shorter height and fewer leaves. The effectiveness of paclobutrazol between 21 and 35 days after transplanting is associated with the active vegetative phase of cucumber growth, marked by rapid stem elongation and leaf production. During this stage, gibberellin activity is at its peak to support cell elongation, so inhibition of its biosynthesis by paclobutrazol becomes more apparent. This suppression redirects assimilates from excessive vegetative growth toward reproductive development, particularly the initiation of female flowers. Therefore, paclobutrazol application during this period shows stronger effects compared to earlier stages with lower gibberellin activity. According to [8], the application of paclobutrazol inhibits internode elongation, and between 21 and 35 days after planting, it significantly affects growth compared to the initial observation stages. The literature [9] stated that during the first week, paclobutrazol had no significant effect on plant height and number of leaves. Paclobutrazol works by inhibiting the oxidation of kaurene into kaurenoic acid, which reduces cell division and elongation, thereby restricting vegetative growth [10, 11].

The differences in plant height also resulted from the use of different varieties. As shown in Table 1, the highest plant height and number of leaves at 28 DAT were recorded in the Zatavy F1 variety, with an average height of 194,67 cm and 76,27 leaves, significantly higher than the other varieties. The differences in plant height and number of leaves reflect significant genetic variation among the varieties, where the genetic traits of each variety influence its growth. According to [12], plant performance is affected by both genetic and environmental factors. The expression of genetics at specific growth phases results in varied plant characteristics. The Zatavy F1 variety, which showed the best vegetative growth, likely possesses genes that support more active vegetative development, including responses to light, nutrient uptake, and photosynthetic efficiency.

3.2. Number of female flowers in cucumber affected by paclobutrazol application timing and varieties treatment

The results of statistical analysis showed that the timing of paclobutrazol application had a significant effect on the number of female flowers in cucumber plants. However, the variety treatment and the interaction between the two factors had no significant effect on the number of female flowers. The mean data of female flower numbers in cucumber plants under paclobutrazol application timing and variety treatments are presented in Table 2.

Table 2. Number of female flowers in cucumber as affected by paclobutrazol application timing and variety treatment

Paclobutrazol application timing	Variety			
	Monas F1	Komandan F1	Zatavy F1	Mean
Control	20.80	19.98	23.15	21.31 ^b
7 DAT _(W1)	19.24	19.11	19.35	19.23 ^c
14 DAT _(W2)	17.21	17.99	19.78	18.33 ^c
21 DAT _(W3)	24.50	24.26	23.13	23.97 ^a
28 DAT _(W4)	23.30	23.30	23.94	23.51 ^a
Mean	21.01	20.93	21.87	

Note: The numbers followed by different letters within the same row and column group indicate significant differences based on Duncan's Multiple Range Test at the 5% level

The results showed that the average number of female flowers was 23.97 in the paclobutrazol application treatment at 21 days after transplanting (W3), which was not significantly different from the application at 28 days after transplanting (W4). These findings suggest that paclobutrazol, as an inhibitor of gibberellin biosynthesis, reduces vegetative growth and allows greater allocation of energy to the development of generative organs. Application at 21 days after sowing has a more pronounced effect because the plants are in the optimal developmental phase to respond to hormonal regulation, making the action of paclobutrazol more effective. Similarly, the results of [13] showed in cucumber that paclobutrazol application suppresses gibberellin activity, leading to increased female flower formation, higher fruit number, and reduced male flower production. Paclobutrazol increases the number of female flowers by lowering gibberellin levels, thereby suppressing male flower development. By inhibiting cell division in the shoot meristem, paclobutrazol indirectly promotes female flower initiation. The process of female flower formation itself is regulated by a complex interaction between gibberellins, auxins, cytokinins, and environmental factors. Furthermore, [14] also reported that paclobutrazol suppresses gibberellin activity while promoting female flower formation, which in turn contributes to increased fruit yield.

3.3. Male-to-female flower ratio affected by paclobutrazol application timing and variety treatment

The statistical analysis showed that the timing of paclobutrazol application and variety treatments had a significant effect on the male-to-female flower ratio of cucumber plants. The interaction between the two factors was not significant. The average male-to-female flower ratio for the paclobutrazol application timing and varieties is shown in Table 3.

Table 3. Male-to-female flower ratio as affected by paclobutrazol application timing and variety treatment

Paclobutrazol application timing	Variety			
	Monas F1	Komandan F1	Zatavy F1	Mean
Control	0.15 : 1	0.15 : 1	0.19 : 1	0.16 : 1 ^c
7 DAT _(W1)	0.15 : 1	0.16 : 1	0.16 : 1	0.16 : 1 ^c
14 DAT _(W2)	0.14 : 1	0.16 : 1	0.17 : 1	0.15 : 1 ^c
21 DAT _(W3)	0.25 : 1	0.31 : 1	0.26 : 1	0.27 : 1 ^a
28 DAT _(W4)	0.21 : 1	0.26 : 1	0.24 : 1	0.23 : 1 ^b
Mean	0.18 : 1^b	0.21 : 1^a	0.20 : 1^a	

Note: The numbers followed by different letters within the same row and column group indicate significant differences based on Duncan's Multiple Range Test at the 5% level

The results showed that the mean ratio of female to male flowers was 0.27 in the treatment with paclobutrazol application at 21 days after transplanting (W3), which was significantly different from the other treatments. A higher ratio reflects a greater proportion of female flowers relative to male flowers, while a lower ratio indicates the dominance of male flowers. These findings suggest that paclobutrazol application at 21 days after transplanting effectively reduced the formation of male flowers and promoted the formation of female flowers, thereby improving the female-to-male flower ratio. Paclobutrazol application can reduce the number of male flowers and increase the number of female flowers, resulting in a lower flower ratio. According to [13], gibberellin promotes the formation of male flowers, and paclobutrazol application suppresses gibberellin, thereby encouraging the formation of female flowers. Differences in variety affect the male-to-female flower

ratio, which impacts pollination and crop yield. The ratio of female to male flowers was higher in the use of variety Komandan F1, with an average of 0.21, which was not significantly different from the variety Zatavy F1. This ratio is influenced by genetic factors, the environment, and cultivation practices. However, the literature [15] showed that some varieties tend to produce more male flowers, while [16] found that high temperatures could increase the number of male flowers. Furthermore, the literature [17] also stated that proper cultivation techniques can influence the distribution of male and female flowers.

3.4. Fruit observation parameters affected by paclobutrazol application timing and varieties treatment

The results of statistical analysis show that the timing of paclobutrazol application significantly affected the fruit length and diameter in the 2.4 and 8 harvests, as well as the number and weight of the fruits. The variety treatment significantly affected the 6th harvest, while the interaction between both factors had no significant effect on the fruit length, diameter, number, and weight in the 1st through 8th harvests. The mean data for fruit length, diameter, number, and weight of cucumbers with paclobutrazol application timing and variety treatments are shown in Tables 4 and 5.

Table 4. Recapitulation of the average fruit length and diameter under paclobutrazol application timing and varieties treatment

Treatment	Fruit Length (cm)							
	1	2	3	4	5	6	7	8
Paclobutrazol application timing								
Control (w ₀)	27.96	38.19 ^b _c	46.41	48.04 ^{ab}	42.37 ^b	37.56 ^{bc}	33.63 ^b	33.22 ^{bc}
7 DAT (w ₁)	28.33	35.48 ^c	37.96	43.93 ^{bc}	41.15 ^b	36.26 ^c	29.56 ^b	25.70 ^d
14 DAT (w ₂)	30.56	36.00 ^c	39.70	38.56 ^c	37.41 ^b	34.81 ^c	32.07 ^b	29.48 ^{cd}
21 DAT (w ₃)	33.04	50.63 ^a	51.04	53.81 ^a	58.00 ^a	51.93 ^a	49.67 ^a	43.44 ^a
28 DAT (w ₄)	31.85	46.93 ^{ab}	52.11	49.70 ^{ab}	46.26 ^b	43.89 ^b	46.00 ^a	38.67 ^{ab}
Variety								
Monas F1	31.73	42.42	43.82	46.00	44.13	44.98	37.29	33.76
Komandan F1	30.96	45.02	48.22	47.00	44.22	39.56	40.07	34.02
Zatavy F1	28.36	36.89	44.29	47.42	46.76	38.13	37.20	34.53
Interaction	tn	tn	tn	tn	tn	tn	tn	tn
Fruit Diameter (mm)								
Paclobutrazol application timing								
Control (w ₀)	54.6	70.9 ^b	88.9	88.6 ^{abc}	81.3 ^{bc}	74.0 ^c	67.2 ^b	68.8 ^b _c
7 DAT (w ₁)	52.9	67.5 ^b	71.9	83.7 ^{bc}	81.2 ^{bc}	72.1 ^c	61.2 ^b	54.6 ^d
14 DAT (w ₂)	58.1	67.2 ^b	75.5	74.4 ^c	70.9 ^c	69.4 ^c	64.9 ^b	62.5 ^{cd}
21 DAT (w ₃)	63.7	95.5 ^a	95.9	102.7 ^a	111.9 ^a	102.1 ^a	100.6 ^a	87.2 ^a
28 DAT (w ₄)	62.5	90.3 ^a	100.0	96.5 ^{ab}	90.5 ^b	88.4 ^b	93.6 ^a	81.4 ^{ab}
Variety								
Monas F1	61.8	79.8	82.3	85.8	84.7	88.8 ^a	74.3	70.2
Komandan F1	55.9	81.8	88.5	88.2	83.4	77.5 ^b	80.9	70.6
Zatavy F1	57.3	73.4	88.6	93.6	93.4	77.3 ^b	77.3	71.9
Interaction	tn	tn	tn	tn	tn	tn	tn	tn

Note: The numbers followed by different letters within the same row and column group indicate significant differences based on Duncan's Multiple Range Test at the 5% level

The application of paclobutrazol at different timings significantly affected the fruit length and diameter parameters during the second, fourth, and eighth harvests, with the paclobutrazol application at 21 days after planting (W3) resulting in the highest fruit length and diameter during the fifth harvest. This indicates that applying paclobutrazol at the right time can optimize the generative growth of the plants, leading to fruit with larger sizes at specific harvest phases. Paclobutrazol works by inhibiting the biosynthesis of gibberellin, which directs the distribution of energy and photosynthates to generative parts such as fruits. This is supported by the statement of [18], who stated that increased fruit length and width can be caused by paclobutrazol's function in reducing vegetative growth while promoting assimilate partitioning to the fruit, thereby increasing fruit size and weight. The application at 21 DAT allows paclobutrazol to have an optimal effect because the plant is in

the transition phase from vegetative to generative, making it capable of utilizing additional energy for fruit growth.

The study shows that the cucumber variety affects the fruit length and diameter. In the sixth harvest, the Monas F1 variety produced more, longer, and larger fruits compared to the Komandan F1 and Zatyv F1 varieties. This indicates that Monas F1 adapts better to its growing environment. The literature [19] explained that the increase in production is due to the variety's adaptation to the environment, even though other varieties may have higher potential, they have not fully adapted yet. However, the literature [20] stated that some varieties adapt quickly, while others take more time, influenced by genetic factors, temperature, and light. Furthermore, the literature [21] added that genetic factors determine differences in growth components, including the size and shape of the fruit, which are influenced by gene expression in cell division and the cell cycle. This is in accordance with the literature of [22], who stated that genes affecting sugar transport and phloem breakdown also contribute to variations in fruit size, shape, and structure.

Table 5. Recapitulation of the average number and weight of fruit under paclobutrazol application timing and varieties treatment

Treatment	Number of Fruit	Weight of Fruit (gr)
Paclobutrazol application timing		
Control (w ₀)	13.67 ^b	3827.81 ^c
7 DAT (w ₁)	12.67 ^b	3421.77 ^d
14 DAT (w ₂)	12.33 ^b	3544.96 ^{cd}
21 DAT (w ₃)	17.56 ^a	4862.85 ^a
28 DAT (w ₄)	16.00 ^a	4409.44 ^b
Variety		
Monas F1	14.60	3926.88
Komandan F1	14.53	3963.28
Zatyv F1	14.20	4149.93
Interaction	tn	tn

Note: The numbers followed by different letters within the same row and column group indicate significant differences based on Duncan's Multiple Range Test at the 5% level

The research results showed that the highest total number and weight of fruits were observed in the treatment of paclobutrazol application at 21 days after transplanting (W3), with an average of 17,56 fruits and 4862,85 grams. This indicates that paclobutrazol treatment at this time significantly contributed to the increased fruit productivity of the plants. Paclobutrazol, as a growth inhibitor, works to regulate the hormonal balance in plants, which can affect fruit formation and development. By inhibiting gibberellin synthesis, paclobutrazol can encourage the plant to focus more on fruit development rather than excessive vegetative growth by reducing internodal distance, thus improving the translocation of assimilates towards fruit development [23]. The right timing of application can also coincide with the plant's growth phase that is most responsive to the treatment, thereby enhancing production efficiency. However, the literature [24] found that plants treated with paclobutrazol had a higher number of fruits compared to untreated ones. The fruits formed are a result of glucose formation in the dark reaction. The formation of cucumber fruits is aided by the mechanism of parthenocarpy (fruit formation without pollination), a process supported by gibberellin hormones.

Differences in varieties led to differences in the total number and weight of fruits produced. Based on Table 5, the Monas F1 variety showed the highest total number of fruits, while the Zatyv F1 variety had the highest fruit weight. This indicates that the Monas F1 and Zatyv F1 varieties possess genetic advantages that support more optimal fruit development. The high fruit weight in these varieties can be associated with better metabolic efficiency, improved allocation of photosynthates to the fruit, and the plant's ability to absorb and utilize nutrients for generative growth [12]. The advantages of the Zatyv F1 variety also reflect its genetic potential to produce fruits with superior quality and weight. Based on the results of research [24], it is known that the treatment of paklobutrazol application with the use of metavy varieties has a significant effect on the total number of fruits of cucumber plants. Cucumber plants treated with paklobutrazol application showed an average total fruit number of 5.56 per plant, while cucumber plants that were not treated with paklobutrazol application showed an average of 4.16 fruits per plant.

Although in this study the interaction between variety and paclobutrazol application time was not statistically significant, differences in varietal response are also influenced by the timing of application. Each variety may have a different physiological window in which paclobutrazol is most effective, particularly during the transition from vegetative to generative growth. Thus, the observed differences among varieties are not solely due to genetic factors, but also due to the alignment (or mismatch) of paclobutrazol application timing with each variety's growth dynamics.

4. Conclusion

Different application times of paclobutrazol caused significant differences in growth and production. The treatment of paclobutrazol application at 21 days after planting (DAT) showed an increase in production parameters, namely the number of fruits, fruit length, fruit diameter, and fruit weight. Treatment without paclobutrazol application (W0) can increase the growth of plant height and the number of leaves of cucumber plants. Some varieties of cucumber plants show differences in growth and production. Zaty F1 variety gave the best results in plant height, number of leaves, and fruit weight, while Monas F1 variety showed higher fruit size (number of fruits, fruit length, and fruit diameter). The recommendation for this research is that paclobutrazol application at 21 (DAT) and 28 (DAT) and varieties Zaty F1 can increase cucumber production. Application at this age can help control vegetative growth, improve flowering by increasing the ratio of female flowers to male flowers, and increase the number of fruits, fruit length, fruit diameter and fruit weight.

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