

Effect of Concentration and Frequency of Paclobutrazol Application on Growth and Yield of Shallot

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Article History:

Received : 16 July 2024
Revised : 06 October 2024
Accepted : 19 October 2024

Keywords:

Bulbs,
Harvest,
Paclobutrazol,
Shallot,
Vegetative.

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ABSTRACT

Shallot is a horticultural commodity that is always needed for consumption and has high economic value. However, shallot production in East Java has decreased due to the low quality and quantity of shallot seeds. This study aims to determine the effect of concentration and frequency of paclobutrazol application on the growth and yield of shallot. This research was conducted in Sambigede Village, Sumber Pucung Subdistrict, Malang Regency in January-May 2024. The research was arranged using a Split Plot Design with 3 replication. The main plots were paclobutrazol concentrations: 50 ppm, 100 ppm, 150 ppm, and 200 ppm. The subplots were the frequency of paclobutrazol application: 1 time, 2 times, and 3 times. The combination of paclobutrazol concentration of 100 ppm and application frequency of 1 time gave the best results in inhibiting the vegetative phase, increasing tuber dry weight per clump, harvest index, and chlorophyll content. The frequency of paclobutrazol application did not significantly affect the fresh weight of tubers per clump, fresh weight of tubers per plot and dry weight of tubers per plot, but paclobutrazol concentration of 100 ppm affected the fresh weight of tubers per clump.

1. INTRODUCTION

Shallot (*Allium ascolonicum* L.) is a horticultural commodity that has high economic value. Demand for shallots has increased along with population growth. According to statistical data (BPS, 2023), shallot production in East Java has decreased, which in 2021 amounted to 5,009,921 quintals to 4,739,890 quintals in 2022. The decline in shallot production is caused by the use of poor quality seeds, poor planting media, and relatively narrow agricultural land resulting in small shallot production (Susanti *et al.*, 2018).

Shallots can be grown easily in the lowlands and highlands with a good planting time is in dry season. However, shallot production in rainy season is rarely done because of obstacles in form of photosynthesis process disruption and disease attacks causing decreased production (Purba & Astuti, 2013). Shallots can grow optimally in soil that has a crumbly structure with a balanced ratio of solid material and pores (Syawal, 2019).

Growth regulators provision will be effective on growth at certain concentrations. Growth regulators will have a good effect if given in the right amount, otherwise if the growth regulator is given in excess of what the plant needs, it will interfere with the growth process in the plant (Darlina *et al.*, 2016).

Paclobutrazol works on the meristem by inhibiting gibberellin biosynthesis, thus inhibiting cell elongation. Paclobutrazol has working principle of inhibiting oxidation reaction between kaurene and kaurenoic acid in the synthesis of gibberellin, so there is a suppression of the plant stem, increasing the green color of the leaves and will indirectly affect flowering by inhibiting division and enlargement of meristematic cells without causing abnormal growth (Suhadi *et al.*, 2017).

Paclobutrazol applications must be made at correct frequency to get maximum results. If paclobutrazol is not given at right time, the plant will not show its response. The application of paclobutrazol with a frequency of 3 times, namely at the age of 50 DAP, 60 DAP and 70 DAP, has an effect on growth and yield of potato plants, which can increase potato seeds amount and potato seeds weight (Hamdani *et al.*, 2021).

Application of paclobutrazol at different concentrations and frequencies to specific crops will also produce different responses. The application of paclobutrazol must be adjusted to the correct concentration and frequency to achieve optimal results (Nugroho & Elonard, 2019). Referring to this, it is necessary to research right paclobutrazol concentration and application frequency to increase growth and yield in shallot plants (*Allium ascalonicum* L.).

2. MATERIALS AND METHODS

2.1. Time and place of research

The research was conducted from February to May 2024 on privately owned farmland in Sambigede village, Sumber Pucung subdistrict, Malang district.

2.2. Tools and Materials

The tools used were hand tractor, hoe, hand sprayer, ruler, meter, analytical balance, measuring cup. The materials used were Tajuk variety shallot bulbs, SP 36 fertilizer, KCl fertilizer, Urea fertilizer, ZA fertilizer, Paclobutrazol GoBest 250 SC, Antracol 70 WP fungicide, Delta 25 EC insecticide, Glumax adhesive.

2.3. Research Methods

The experiment was organized using a split-plot design (RPT). The experiment consisted of main and sub plots. The main plot was paclobutrazol concentration (K), which consisted of four levels: 50 ppm (K1), 100 ppm (K2), 150 ppm (K3), and 200 ppm (K4). The subplot was paclobutrazol application frequency (F), which consisted of three levels: 1 time application (F1), 2 times application (F2), and 3 times application (F3). This experiment obtained 12 treatment combinations that were repeated three times to obtain 36 experimental units, as shown in the experimental design in Figure 1.

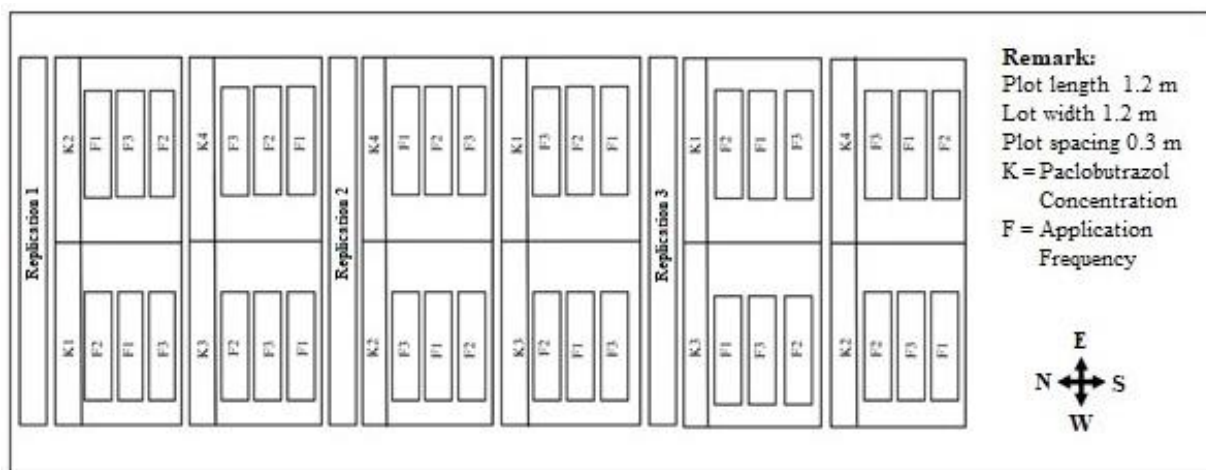


Figure 1. Experimental design of treatment combination

2.4. Research Implementation

Preparation of planting material were done by selecting seeds that are not deformed, nutritious and not infected with diseases. The seeds used were Tajuk variety shallot. Soil preparations is carried out with sanitation activities, making

beds with size of 1.2 m x 1.2 m (1.44 m²), a trench 40 cm width and 40-50 cm depth. Then liming was done to increasing soil's pH. This was done because the experimental field soil had pH of 5.6. Then basic fertilization was done with SP 36, KCl and Urea. Supplemental fertilization was done twice, when the plants were 15 days after planting (urea, ZA and KCl) and 25 days after planting (ZA and KCl). The tip of the tuber was cut $\pm$ 1 cm before planting, then $\frac{3}{4}$ of it was planted into the soil and $\frac{1}{4}$ of it was still visible. The planting space used was 15 cm x 15 cm.

Paclobutrazol was applied according to the treatment combination. Paclobutrazol was applied by spraying the plants leaves evenly with a hand sprayer in morning when the plants were aged 25 DAP, 35 DAP and 45 DAP. Shallots were watered every morning unless it rains. Hilling was done when the plants were aged 25 DAP. For pest control, the insecticide Dangke 40 WP and the fungicides Topsindo 70 WP, Great-Nil 78 WP, Folirfos 400 SL were used. Shallot plants with flowers were removed by manual cutting aiming for maximizing bulb formation so as not to focused on seed formation in the flowers.

Harvesting takes place simultaneously when the shallots are 60 days old, according to its characteristics, i.e. when 80% of plants have collapsed. Post-harvest activities that carried out were direct sunlight drying until completely dry for 7-10 days or until the bulb outermost skin had peeled off (Dinas Pertanian Daerah Istimewa Yogyakarta, 2012).

Observed parameters consisted of vegetative parameters (growth parameters) and generative parameters (yield parameters). Vegetative parameters were observed every 7 days, including plant length (cm) and leaf number per clump (blade). Generative parameters included fresh tuber weight per clump (g), fresh tuber weight per plot (kg), dry tuber weight per clump (g), dry tuber weight per plot (kg), harvest index, and chlorophyll. Harvest index parameters were calculated using formula bellow

$$\text{Harvest Index} = \frac{\text{Dry weight of shallot bulbs}}{\text{Total dry weight of shallots}} \times 100\% \quad (1)$$

Chlorophyll parameters were carried out by analyzing the chlorophyll contained in shallot leaves by weighing shallot plants leaves as much as 5 g, then mashed them with a mortar and added 10 mL of 80% acetone. The solution was then filtered, placed in a phalcon and centrifuged. Then supernatant was put into a cuvette and placed in the spectrophotometer. Absorbance was measured at wavelengths of 646 nm and 663 nm. The chlorophyll content was calculated according to the Harbourn method (1987). The formula used to calculate chlorophyll a, b and total chlorophyll was as follows.

$$\text{Total chlorophyll} = 17.3 \lambda_{646} + 7.18 \lambda_{663} \text{ mg/L} \quad (2)$$

$$\text{Chlorophyll } a = 12.21 \lambda_{663} - 2.81 \lambda_{646} \text{ mg/L} \quad (3)$$

$$\text{Chlorophyll } b = 20.13 \lambda_{646} - 5.03 \lambda_{663} \text{ mg/L} \quad (4)$$

The data obtained were analyzed by variance analysis. If the results show a significant effect, the Honestly Significant Difference (HSD) test at the 5% level.

3. RESULTS AND DISCUSSION

3.1. Plant Length (cm)

The variance analysis result showed that combined concentration treatment with paclobutrazol frequency had a significant effect on shallot plants length at 28-56 DAP (day after planting). Single paclobutrazol concentration treatment significantly affects plants length at all observation ages except at 7-21 DAP, but single paclobutrazol frequency treatment significantly affects shallot plants length aged 28-49 DAP. The average shallot plants length due to each treatment is presented in Table 1. Then, the average shallot plants length due to combination treatment between concentration and frequency of paclobutrazol is presented in Table 2.

Table 1 shows that single paclobutrazol concentration treatment has no significant effect on plant length aged 7-21 DAP. Single paclobutrazol frequency treatment also has no significant effect on plants length at age of 7-21 DAP. This is because the paclobutrazol concentration and frequency treatment begins when the plants were 25 DAP, so it did not affect shallot plants length.

Table 1. Paclobutrazol concentration and frequency effect on average plant length at 7–21 DAP

Treatment	Plant Length (cm)		
	7 DAP	14 DAP	21 DAP
Control	11.30	15.10	20.17
Paclobutrazol Concentrations (ppm)			
50	11.87	15.69	20.23
100	10.72	15.84	20.37
150	11.22	15.44	20.14
200	11.51	15.04	19.71
BNJ 5%	ns	ns	ns
Paclobutrazol Frequency (times)			
1	11.87	15.32	20.53
2	11.33	15.69	19.88
3	10.80	15.51	19.92
HSD 5%	ns	ns	ns

Note: ns = not significantly.

Table 2. Combined treatment between concentration and frequency of paclobutrazol on average plant length at 28–56 DAP

Age	Treatment		Plant Length (cm)			
	Paclobutrazol Frequency (times)		Paclobutrazol Concentrations (ppm)			
			50	100	150	200
28 DAP	Control		31.10			
	1		27.87 b	22.57 a	26.53 ab	25.93 ab
	2		30.83 b	25.33 ab	26.50 ab	23.33 ab
	3		30.00 b	30.50 b	27.58 b	27.73 b
	HSD 5%		4.37			
35 DAP	Control		33.97			
	1		29.90 b	24.50 a	30.17 b	29.07 b
	2		31.73 b	27.23 ab	28.40 b	25.17 ab
	3		30.57 b	31.58 b	31.13 a	28.50 b
	HSD 5%		3.66			
42 DAP	Control		36.77			
	1		30.57 b	24.97 a	30.50 b	29.79 ab
	2		33.63 b	27.40 ab	29.17 ab	25.53 ab
	3		31.70 b	32.00 b	31.73 a	30.00 ab
	HSD 5%		5.03			
49 DAP	Control		38.33			
	1		31.03 ab	26.15 a	30.85 ab	30.30 ab
	2		34.67 b	28.50 ab	30.43 ab	29.77 ab
	3		31.88 b	32.50 b	31.83 b	30.77 ab
	HSD 5%		5.22			
56 DAP	Control		39.07			
	1		32.10 ab	28.33 a	31.93 ab	32.33 ab
	2		35.83 b	29.17 a	31.33 ab	30.50 a
	3		32.60 ab	32.83 ab	32.43 ab	31.20 a
	HSD 5%		4.52			

Note: Numbers followed by the same letter at the same age do not differ significantly in the 5% HSD test.

Highest average shallot plants length aged 28 DAP to 56 DAP was obtained in 50 ppm paclobutrazol treatment combination + application frequency at twice, namely 30.83 cm, 31.73 cm, 33.63 cm, 34.67 cm and 35.83 cm, respectively. The lowest average shallot plants length aged 28 DAP to 56 DAP was obtained in 100 ppm paclobutrazol treatment combination + application frequency 1 time, namely 22.57 cm, 24.50 cm, 24.97 cm, 26.15 cm and 28.33 cm

respectively. 100 ppm paclobutrazol treatment combination + application frequency at once decreased the plant length by 26.47% compared to 50 ppm paclobutrazol treatment combination + application frequency at twice and 37.91% compared to the control plants.

Application of higher concentrations of paclobutrazol to plants can cause greater inhibition of vegetative growth. This is in accord with the research from (Marshel *et al.*, 2015), that giving different concentrations of paclobutrazol causes different responses, namely the higher concentration given, the lower height of the resulting plant. Furthermore, according to research results of (Kamran *et al.*, 2018), paclobutrazol inhibits plant growth which will then affect yield by expanding root system and increasing water absorption from deeper plant layers. This is also compatible with (Pulungan *et al.*, 2018) statement that paclobutrazol has working mechanism by inhibiting gibberellin production, which in turn can cause reduction in cell division rate and reduction in vegetative growth.

3.2. Leaf Number (Blade)

Variance analysis result showed that paclobutrazol concentration with frequency combined treatment had a significant effect on leaf number per clump at 28- 56 DAP. The single treatment of paclobutrazol concentration significantly affects leaf number per clump at all observation ages except 7-21 DAP. The single treatment of paclobutrazol frequency significantly affect leaf number per clump at 28 DAP and 35 DAP. Leaf number average per clump due to each treatment is presented in Table 3. Then, leaf number average per clump due to the combination treatment between concentration and frequency of paclobutrazol is presented in Table 4.

Table 3. Paclobutrazol concentration and frequency effect on average leaf number per clump at 7 - 21 DAP

Treatment	Number of Leaves Per Clump (Blade)		
	7 DAP	14 DAP	21 DAP
Control	7.67	12.33	17.00
Paclobutrazol Concentrations (ppm)			
50	7.78	13.67	16.44
100	7.67	12.33	17.00
150	6.59	12.56	16.00
200	7.11	12.44	16.33
HSD 5%	ns	ns	ns
Paclobutrazol Frequency (times)			
1	7.50	12.33	16.67
2	6.67	12.83	16.42
3	7.69	13.08	16.25
HSD 5%	ns	ns	ns

Note: ns = not significantly.

Table 3. shows that single paclobutrazol concentration treatment had no significant effect on the length of plants aged 7-21 DAP. Single treatment paclobutrazol frequency treatment also had no significant effect on leaf number per clump at of 7-21 DAP. This is because the paclobutrazol concentration and frequency treatment starts when the plants are 25 DAP, so it did not affect the length of the shallot plants.

Highest average leaf number per clump of shallot plants aged 28 DAP to 56 DAP was obtained in 50 ppm concentration combination treatment + twice application frequency, namely 32.00 strands, 33.67 strands, 34.67 strands, 35.67 strands and 37.33 strands, respectively. Lowest average leaf number per clump of shallot plants aged 28 DAP to 56 DAP was obtained in 100 ppm paclobutrazol combination treatment + once application frequency, namely 18.50 strands, 20.33 strands, 26.33 strands, 27.67 strands and 29.00 strands, respectively. 100 ppm paclobutrazol treatment + once application frequency reduced leaf number per clump by 28.72% compared to 50 ppm paclobutrazol treatment + twice application frequency and by 50.58% compared to the control plants. Giving higher paclobutrazol concentrations to plants causes a smaller leaf number on plants. This is in accordance with research from (Harpitaningrum *et al.*, 2014) that paclobutrazol application can inhibit plant growth by suppressing plant's height and leaf number.

According to (Cahyani *et al.*, 2022) Paclobutrazol is a growth regulator that can inhibit gibberellin biosynthesis, so that plant vegetative growth is inhibited. However, results showed that concentrations of 150 ppm and 200 ppm produced a higher leaf number compared to 100 ppm concentration. It is suspected that giving too excessive paclobutrazol concentration can inhibit its effectiveness in regulating plant growth. Paclobutrazol retardant application at high concentrations may interfere with metabolic processes in plant cells (Trisnaningtyas *et al.*, 2024).

Table 4. Effect of treatment combination (concentration and frequency of paclobutrazol) on leaf number per clump at 28–56 DAP

Age	Treatment		Number of Leaves Per Clump (Blade)			
	Paclobutrazol Frequency (times)		Paclobutrazol Concentrations (ppm)			
			50	100	150	200
28 DAP	Control		34.33			
	1		26.67 bc	18.50 a	25.17 b	25.33 b
	2		32.00 c	22.50 ab	30.33 c	26.00 bc
	3		29.97 bc	27.17 bc	26.67 bc	29.67 bc
	HSD 5%		4.86			
35 DAP	Control		38.67			
	1		27.67 bc	20.33 a	32.67 c	32.00 c
	2		33.67 c	24.00 ab	32.00 c	26.50 b
	3		30.00 bc	28.67 bc	30.00 bc	33.67 c
	HSD 5%		5.08			
42 DAP	Control		41.00			
	1		29.33 ab	26.33 a	34.00 b	33.00 b
	2		34.67 b	27.33 a	34.33 b	27.33 a
	3		31.00 ab	29.00 ab	30.67 ab	34.33 b
	HSD 5%		5.17			
49 DAP	Control		42.00			
	1		29.67 ab	27.67 a	34.67 ab	33.33 ab
	2		35.67 b	29.00 ab	34.33 ab	30.00 ab
	3		31.67 ab	29.33 ab	31.00 ab	35.00 ab
	HSD 5%		7.71			
56 DAP	Control		43.67			
	1		30.67 ab	29.00 a	35.67 b	33.67 ab
	2		37.33 b	29.67 ab	36.00 b	31.33 ab
	3		32.00 ab	30.33 ab	31.67 ab	35.33 ab
	HSD 5%		6.56			

Note: Numbers followed by the same letter at the same age do not differ significantly in the 5% HSD test.

3.3. Fresh Weight per Clump (g)

Variance analysis result showed that paclobutrazol concentration with frequency combined treatment did not give a real interaction on fresh bulb's weigh per clump of shallot plants. Single paclobutrazol concentration treatment factor has a significant effect on fresh bulb's weigh per clump, but single paclobutrazol frequency treatment does not give a significant effect on fresh weight of bulbs per clump. Fresh bulb's weight average value per clump of shallot plants due to paclobutrazol concentration and frequency treatment are presented in Table 5. Single 100 ppm paclobutrazol concentration treatment obtains highest average fresh bulb's weight per clump, which is 35.91g. While lowest average fresh bulb's weight per clump is obtained in the 150 ppm paclobutrazol treatment, which is 31.47g. The 100 ppm concentration treatment increased fresh bulb's weigh per clump by 14.10% compared to the 150 ppm concentration treatment and 56.13% compared to control plants. According to (Novianto, 2018), growth regulators are effective at certain concentrations, when deficit and excessive growth regulators concentration application causes disruption of plant growth at certain times. Single factor of paclobutrazol frequency treatment did not have a significant effect on fresh weigh of bulb per clump of shallot plants. This may be due to the fact that paclobutrazol application once can inhibit gibberellin synthesis. According to (Winardiantika *et al.*, 2012), paclobutrazol application once has been able to inhibit

gibberellin synthesis so as to inhibit plant growth and when the application is done twice and thrice, paclobutrazol effect becomes less effective because synthesis inhibition has occurred at the beginning of the application and the plant becomes more immune to paclobutrazol.

Table 5. Concentration and frequency effect of paclobutrazol on average fresh bulb's weight per clump

Treatment	Fresh Yield (g/clump)	Treatment	Fresh Yield (g/clump)
Control	23,00	Paclobutrazol Concentration (ppm)	
Paclobutrazol Frequency (times)		50	34.20 bc
1	33.53	100	35.91 c
2	34.60	150	31.47 a
3	33.22	200	33.40 b
HSD 5%	ns	HSD 5%	1.72

Note: Numbers followed by the same letter at the same age do not differ significantly in the 5% HSD test.; ns = not significantly

Table 6. Paclobutrazol concentration and frequency effect on average fresh weight (kg) of bulb per plot (1.44 m²)

Treatment	Fresh Yield (kg/plot)	Treatment	Fresh Yield (kg/plot)
Control	1.13	Paclobutrazol Concentration (ppm)	
Paclobutrazol Frequency (times)		50	1.27
1	1.33	100	1.45
2	1.32	150	1.34
3	1.46	200	1.42
HSD 5%	ns	HSD 5%	ns

Note: ns = not significantly.

3.4. Bulb Fresh Weight per 1.44 m² (kg)

Variance analysis result showed that combined paclobutrazol concentration with frequency treatment did not give a significant interaction on fresh bulb's weigh per 1.44 m². Single paclobutrazol concentration and frequency factor did not give a significant effect on fresh bulb's weigh per 1.44 m². Average weight of fresh bulbs per 1.44 m² of shallot plants due to paclobutrazol concentration and frequency treatment are presented in Table 6.

Paclobutrazol concentration and frequency treatment did not give significantly different results on the parameter of fresh weight of bulbs per 1.44 m². According to (Rubiyaniti & Rochayat, 2015) result on batik roses research, paclobutrazol provision does not give significant different results, presumably because paclobutrazol does not provide auxin biosynthesis inhibition, which functions is to stimulating for root formation, but works on inhibit gibberellin biosynthesis by inhibiting kaurene formation into kaurenoic acid.

3.5. Bulb Dry Weight per Clump (g)

Variance analysis results showed that combined paclobutrazol concentration with frequency treatment gave a significant interaction on dry bulb's weight per clump of shallot plants. The single factor of concentration and frequency of paclobutrazol treatment gave a significant effect on dry bulb's weight per clump. The average value of dry weight of bulbs per clump of shallot plants due to the combination treatment between concentration and frequency of paclobutrazol is presented in Table 7.

The highest average dry bulb's weight of per clump of shallot plants was 33.60 g in combined 100 ppm paclobutrazol concentration treatment + paclobutrazol frequency at once. The lowest average dry bulb's weight per clump of shallot plants was 22.93 g in combined 50 ppm paclobutrazol concentration treatment + paclobutrazol frequency at twice. The 100 ppm concentration treatment + paclobutrazol frequency at once increased dry bulb's weight per clump by 46.53% compared to the 50 ppm concentration treatment + paclobutrazol frequency at twice and 57.52% compared to the control plant. This is in accordance with a statement that paclobutrazol affects bulb's weight because it has a function to

maximize the generative growth process which results in maximum bulb's filling so that plants treated with paclobutrazol have a heavier weight (Suud *et al.*, 2023).

Table 7. Paclobutrazol concentration and frequency combined treatment effect on average bulb's dry weight (g) per clump

Paclobutrazol Frequency (times)	Paclobutrazol Concentrations (ppm)			
	50	100	150	200
Control	21.33			
1	29.40 ab	33.60 b	31.93 b	30.20 ab
2	22.93 a	31.83 b	25.00 ab	31.80 b
3	28.40 ab	27.60 ab	27.93 ab	28.20 ab
HSD 5%	8.03			

Note: Numbers followed by the same letter at the same age do not differ significantly in the 5% HSD test.

3.7. Bulb Dry Weight per 1.44 m² (kg)

Variance analysis results showed that combined paclobutrazol concentration with frequency treatment did not give a significant interaction on dry bulb's weight per 1.44 m² of shallot plants. Single paclobutrazol concentration treatment and frequency factor did not give a significant effect on dry bulb's weight per 1.44 m² of shallot plants. The average value of dry weight of bulbs per 1.44 m² of shallot plants by the treatment of concentration and frequency of paclobutrazol are presented in Table 8. Paclobutrazol concentration and frequency application treatment singularly did not give a significant effect in this research. Differences in ability to respond to each shallot variety, application time, and non-optimal environmental conditions are thought to be factors that cause dry bulb's weight per 1.44 m² not significantly different. In accord with the statement of Frommer and Sonnewald (1995) in (Tsegaw, 2006) in their research on potato plants that competition for tuber initiation will reduce number of tubers formed, but this will not happen depending on paclobutrazol application time and planting site condition. Paclobutrazol use will give different responses to different plants (Syahid, 2007).

Table 8. Paclobutrazol concentration and frequency effect on average dry bulb's weight per 1.44 m²

Treatment	Bulb Yield (kg/1.44 m ²)	Treatment	Bulb Yield (kg/1.44 m ²)
Control	1.02	Paclobutrazol Concentration (ppm)	
Paclobutrazol Frequency (times)		50	1.12
1	1.15	100	1.30
2	1.14	150	1.15
3	1.30	200	1.21
HSD 5%	ns	HSD 5%	ns

Note: ns = not significant.

3.8. Harvest Index

Variance analysis results showed that combined paclobutrazol concentration with frequency treatment gave a significant interaction on shallot harvest index. Single paclobutrazol concentration treatment and frequency factor did not give a significant effect, Paclobutrazol frequency gave a significant effect on shallot harvest index. The average value of harvest index of shallot plants due to the combination treatment between concentration and frequency of paclobutrazol is presented in Table 9. The highest average value of harvest index of shallot plants is 0.97% in the combined paclobutrazol concentration of 100 ppm treatment + paclobutrazol frequency at once. The lowest average value of harvest index of shallot plants is 0.75% in the combined paclobutrazol concentration of 150 ppm treatment + paclobutrazol frequency at twice. The 100 ppm paclobutrazol treatment + administration frequency at once increased the harvest index by 29.33% compared to the 150-ppm paclobutrazol treatment + administration frequency at twice and 46.96% compared to the control plant. This is because paclobutrazol application can increase photosynthetic products utilization efficiency, resulting in a higher harvest index. In accordance with (Tesfahun, 2017) research that paclobutrazol application to Tef (*Eragrostis Tef* (Zucc.) Trotter) plants can increase harvest index, which is considered

to be caused by growth regulators that can increase photo assimilates distribution and change distribution pattern of assimilates toward reproductive part to increase the absorption capacity, leading to better results.

Table 9. Paclobutrazol concentration and frequency combination effect on average harvest index (%) of shallot plants

Paclobutrazol Frequency (times)	Paclobutrazol Concentrations (ppm)			
	50	100	150	200
Control			0.66	
1	0.78 ab	0.97 b	0.95 ab	0.85 ab
2	0.78 ab	0.94 ab	0.75 a	0.81 ab
3	0.96 ab	0.82 ab	0.96 ab	0.88 ab
HSD 5%			0.21	

Note: Numbers followed by the same letter at the same age do not differ significantly in the 5% HSD test.

Table 10. Shallot chlorophyll analysis

Treatment	Absorbance		Absorbance Average		Total Chlorophylls (mg/L)
	λ 646 nm	λ 663 nm	λ 646 nm	λ 663nm	
K ₁ F ₁	0.322	0.459	0.32	0.45	8.78
	0.317	0.446			
K ₁ F ₂	0.224	0.309	0.23	0.31	6.09
	0.227	0.301			
K ₁ F ₃	1.202	1.668	1.20	1.67	32.81
	1.205	1.672			
K ₂ F ₁	1.390	1.724	1.41	1.73	36.74
	1.423	1.731			
K ₂ F ₂	0.355	0.450	0.37	0.49	9.92
	0.382	0.538			
K ₂ F ₃	0.626	0.878	0.64	0.90	17.59
	0.657	0.929			
K ₃ F ₁	1.278	1.688	1.29	1.70	34.48
	1.299	1.707			
K ₃ F ₂	1.308	1.701	1.31	1.70	34.87
	1.310	1.705			
K ₃ F ₃	1.153	1.611	1.16	1.61	31.56
	1.159	1.610			
K ₄ F ₁	1.235	1.684	1.24	1.68	33.48
	1.238	1.683			
K ₄ F ₂	1.176	1.654	1.18	1.65	32.22
	1.177	1.652			
K ₄ F ₃	1.085	1.615	1.09	1.62	30.40
	1.089	1.615			

3.9. Chlorophyll Analysis

Chlorophyll observation data of shallot leaves (Table 10) showed that the highest total chlorophyll in shallot plants was obtained in 100 ppm paclobutrazol treatment + application frequency at once, which was 36.74 mg/L. While the lowest total chlorophyll was obtained in 50 ppm paclobutrazol treatment + application frequency at twice, which was 6.09 mg/L. Paclobutrazol can shut the growing point so that cells stop dividing. This results in increased photosynthesis. Higher chlorophyll content is indicated by greener leaf color. Greener leaf color will be more efficient in capturing light that is useful for the photosynthesis process, so photosynthetic activities can run well. Plants with higher chlorophyll levels can conduct a more efficient photosynthetic process and produce more energy. The energy produced is later used for bulbs formation, thus increasing yields. Paclobutrazol treatment increases chlorophyll content, which increases photosynthetic activity, so plant yields will increase (Runtunuwu *et al.*, 2016).

The results shallot plants photosynthesis that are used efficiently will increase the harvest index. This is in accordance with the opinion of (Sakanti *et al.*, 2024) which states that the provision of retardant growth regulators can increase the yield of harvest index in plants. However, if paclobutrazol is applied at too low a concentration, it is not effective enough to inhibit the enzymes involved in gibberellin synthesis. In addition, if paclobutrazol is applied at too low a concentration, photosynthesis is not allocated effectively. Conversely, applying paclobutrazol at too high a concentration can interfere with plant physiological processes. The application of growth regulators by paying attention to the right concentration will give a positive response, if the concentration is too high it will damage plant organs so that it affects the growth and development of plants, on the contrary, concentrations below the optimum will not be effective (Rosalina, 2016 in Novianto & Wartono, 2023). Growth hormones in high concentration levels can cause a bad reaction or response biochemically, physiologically or morphologically (Niagara *et al.*, 2018).

4. CONCLUSION

The results showed that paclobutrazol application can increase shallot plants yield. Giving combined treatment of 100-ppm paclobutrazol concentration with a frequency at once can give the best results on dry weight of bulbs per clump of 33.60 g, harvest index of 0.97%, and the amount of chlorophyll in leaves of 36.74 mg/L. It is recommended to use 100 ppm paclobutrazol concentration combination treatment with one time frequency to increase shallot plants production. Furthermore, further research of bulb diameter parameters needs to be done.

ACKNOWLEDGMENTS

Thanks to the Agrotechnology Study Program of UPN "Veteran" East Java for providing the facilities for this research.

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