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Effect of Paclobutrazol Concentration and Urea Fertilizer Dosage on Plant Growth and Yield Long Beans (*Vigna sinensis* L.)

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ABSTRACT

Long bean is a well-known horticultural commodity in people's lives with quite high nutritional value. This study aims to determine the effect of paclobutrazol concentrations and doses of Urea fertilizer on the growth and yield of long bean plants. Long bean plants were planted on private cultivation land in Werungotok Village, Nganjuk District, Nganjuk Regency, East Java in January 2023 – April 2023. The study was structured using a Split Plot Design with 2 factors, including concentration of paclobutrazol and the dose of Urea fertilizer. Each factor consisted of 4 levels and was repeated 3 times. The results revealed that the concentration of paclobutrazol and the dose of urea fertilizer had an effect on plant length, number of leaves, age of flower emergence, number of flowers, number of fruits, fruit weight per plant, fruit weight per plot, fruit weight per hectare, fruit length and fruit set. The best results were obtained from the treatment with a concentration of 150 ppm paclobutrazol and a dose of 100 kg/ha of urea.

1. INTRODUCTION

Long bean (*Vigna sinensis* L.) is a type of vegetable plant rich in nutrients, including vitamins A, B, and C, and minerals found in the pods, especially young pods, as well as protein, fat, and carbohydrates in the seeds. Long beans are promoted as a source of plant-based protein for the community to improve nutritional intake, making the increase in long bean production a vital effort. Long bean seeds contain plant-based protein with 70% carbohydrates, 17.3% protein, 1.5% fat, and 12.2% water (Haryanto *et al*., 2013).

Long bean plants require loose soil with sufficient tillage depth and easy binding of soil nutrients. Loose soil can increase plant root growth so that nutrients can be absorbed properly, this can increase overall growth (Anwar, 2013). The yield of long beans in Indonesia is relatively low compared to other countries. According to the statistic data (BPS, 2022), the production of long bean plants in Indonesia has decreased year by year from 488,499 tons in 2017 to 458,307 tons (2018), 455,615 tons (2019), 450,859 tons (2020), and 440,870 tons (2021). This decline is attributed to several factors, including the use of local varieties with low yield potential, suboptimal planting methods, and imbalanced fertilization. One solution to enhance long bean production is the application of plant growth regulator (PGR). Plant growth regulators can be categorized into two types based on their properties, namely to stimulate growth and to inhibit growth. Growth-inhibiting regulators can be used to increase long bean yield. One such growth regulator is paclobutrazol.

Achieving optimal production in cultivation is the desired solution in agriculture, especially in long bean farming, to ensure a stable supply of horticultural products. The current issue faced by the community is the lack of information on the use and application of growth regulators. Many Indonesian farmers are still hesitant to use hormones or growth

regulators and often misuse them, such as applying incorrect concentrations due to limited information on the effectiveness of different concentrations. This needs to be validated through data or significant yield differences.

Inorganic fertilizers like urea are crucial for plant growth, especially in increasing long bean production. According to Ariyanto (2020), the application of paclobutrazol at concentrations of 150 and 175 ppm with three applications at 20, 30, and 40 days after planting (DAP) significantly affected flower and fruit formation, and fruit weight per plant and per hectare. Economically, the best concentration was 150 ppm, yielding 35.68 tons/ha, an 18.38% increase compared to the control treatment of 0 ppm, which yielded 29.12 tons/ha. Soelaksini *et al*. (2022) found that applying urea fertilizer at 45 kg/ha (P4) in mung bean plants resulted in the highest average number of pods per sample (54.24), the highest average weight of wet pods per sample (58.58 grams), and the highest average weight of dry seeds per sample (34.82 grams). The lowest values were found in treatments without urea fertilizer (P1).

Based on the above explanation, it is hypothesized that the application of paclobutrazol and urea fertilizer at various concentrations influences long bean production. This study aims to determine the best concentration and provide comprehensive information on the appropriate use of growth regulators and fertilizer doses, expecting a positive impact on long bean production.

2. MATERIALS AND METHODS

2.1. Time and Place of Research

This research was performed from January to April 2023 on a private field in Werungotok Village, Nganjuk District, Nganjuk Regency, East Java.

2.2. Materials and Tools

The materials used in this study included long bean seeds of the Parade Tavi variety, urea fertilizer applied twice (half at 2 weeks after planting and the other half at 5 weeks after planting) by watering, paclobutrazol (Gobest) applied three times at 20, 30, and 40 days after planting based on the indeterminate plant type, and NPK Phonska fertilizer applied at 2 g/plant at planting and 1 g/plant from 14 to 49 days after planting by spreading on the soil. Manure, SP 36, and KCl were used as base fertilizers, applied by spreading on the soil. Sankill insecticide and Antracol fungicide were used to control whiteflies, armyworms, and *cercospora* leaf spot disease in the field. Petromax adhesive was used to help the fertilizer solution stick and spread evenly on the long bean plants. Other tools included a hoe, trowel, analytical balance, knife, sprayer, calculator, bucket, hand sprayer, and meter tapes.

2.3. Research Method

The experiment was structured using a Split Plot Design with two treatment factors: the frequency of urea fertilizer application as subplots and paclobutrazol as the main plots, resulting in two factors. The first factor was the paclobutrazol concentration (P) with four levels: 0 ppm (P0), 150 ppm (P1), 175 ppm (P2), and 200 ppm (P3). The second factor was the dose of urea fertilizer (N) with four levels: 8 g/plant NPK control (N0), 3 g/plant urea (N1), 4 g/plant urea (N2), and 5 g/plant urea (N3). These two factors with the specified levels resulted in 16 treatment combinations, repeated three times to yield 48 experimental units with three sample plants per unit. Figure 1 depicted the layout of experimental plots.

The long bean cultivation began with soil preparation by forming beds 1 meter wide and 30 cm high, with a plot size of 1.6 m x 1 m, 0.3 m between plots, and 0.5 m between blocks. After forming the beds, silver plastic mulch was installed. Planting was done by making holes 3 cm deep, with 2 seeds per hole spaced 40 x 60 cm apart, resulting in 8 plants per plot with border plants. When the plants grew, stakes made of 2-meter-high wood were installed for plant support. Fertilization was done either once at the start (manure, SP 36, and KCl) or in stages (urea twice, paclobutrazol three times, NPK twice). Irrigation was performed by flooding every 10 days or as needed based on weather conditions. Pest control was done using Sankill insecticide and Antracol fungicide. Harvesting began at 43 DAP and continued thrice weekly, selecting firm, fresh green pods.

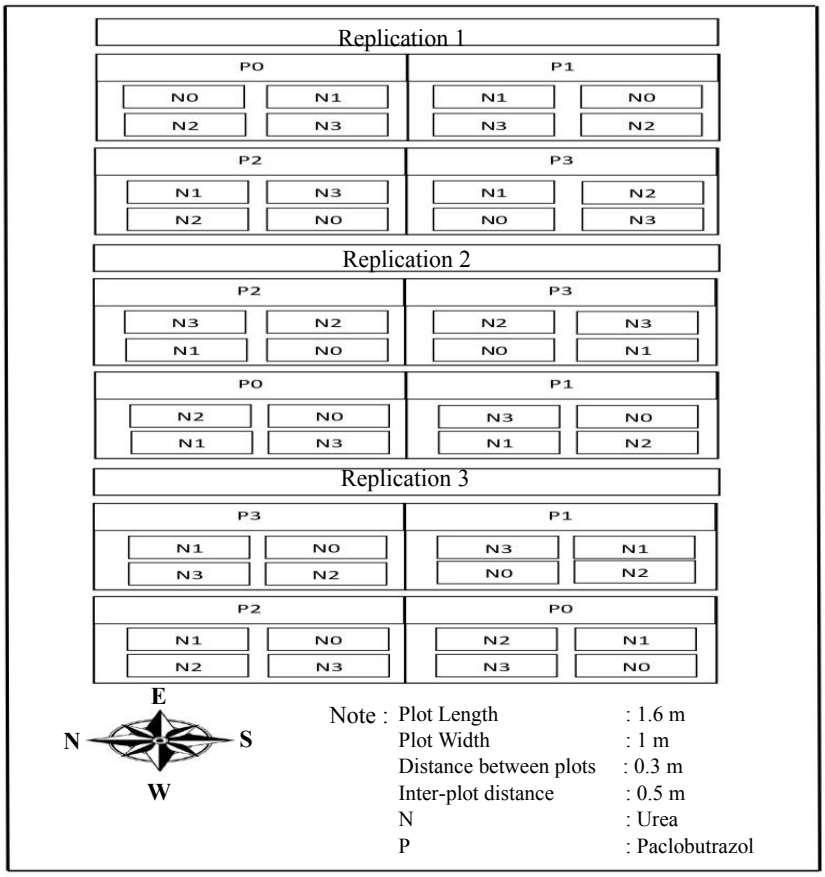

Figure 1. Layout of experiment plots.

2.4. Measurement Method

The observation of the growth parameters of long bean plants was conducted periodically and incidentally. Periodic observations were made at 14, 21, 28, 35, 42, 49, 56, 63, 70, and 77 days after planting (DAP), including plant length and number of leaves. Incidental observations included the age of flowering (days), number of flowers, number of fruits per plant, fruit length, fruit weight per plant (grams), fruit weight per plot (m²), fruit weight per hectare (tons), and fruit set percentage. Long beans can be harvested two weeks after flowering according to predetermined criteria. The fruit set parameter was calculated by determining the percentage of flowers that successfully became long bean fruits in one plant using the formula:

$$Fruit\ Set\% = \frac{Number\ of\ flowers\ that\ become\ fruits}{Total\ number\ of\ flowers} \times 100\% \quad (1)$$

2.5. Analysis Method

The observational data were analyzed using ANOVA. The research data were analyzed with variance analysis using a linear model according to Gomez & Gomez (1995) as follows:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \delta_{ik} + (\alpha\beta)_{ij} + \varepsilon_{ijk} \quad (2)$$

where Y_{ijk} is observation value at the i^{th} level treated with paclobutrazol, j^{th} level treated with urea fertilizer, and k^{th} replication, μ is the general mean value, α_i is the effect of the i^{th} level of the main plot, β_j is the effect of the j^{th} level of the subplot, $(\alpha\beta)_{ij}$ is the effect of interaction between the i^{th} level treated with urea fertilizer and the j^{th} level treated with paclobutrazol, δ_{ik} is random effect for the main plot, and ε_{ijk} is random effect for the subplot (Kusriningrum, 2008). If a significant effect is found, the analysis continues with the LSD (Least Significant Difference) test at the 5% level.

3. RESULTS AND DISCUSSION

3.1. Plant Length (cm)

The variance analysis show that the interaction of paclobutrazol concentration and urea fertilizer dose significantly affected the length of long bean plants from 21 to 77 DAP. The individual treatments of paclobutrazol concentration and urea fertilizer dose significantly affected the plant length at all observation ages except 14 and 70 DAP. This is because, at 14 DAP the plants had not reached their maximum growth, and at 70 DAP the plants started to decline in vegetative growth. The average plant length due to interaction of paclobutrazol concentration and urea fertilizer dose is presented in Tables 1, while the effect of individual treatments is presented in Table 2.

Table 1. Effect of treatment combinations of paclobutrazol concentration and urea dose on the average plant length of long beans at 21 to 77 DAP except 70 DAP

Age	Urea fertilizer dose (g/plant)	Plant length (cm)			
		PC 0	PC 150	PC 175	PC 200
21 DAP	8 (NPK-Control)	62.56 d	59.67 ab	60.44 bc	60.33 bc
	3	62.17 d	60.11 abc	60.78 c	60.67c
	4	62.50 d	61.83d	60.50 c	60.33 bc
	5	62.17 d	60.33 bc	60.44 bc	59.50a
	LSD 5%		0.78		
28 DAP	8 (NPK-Control)	92.67 h	90.33 abcd	90.17 ab	90.28 abc
	3	92.39 gh	90.83 de	90.67 bcde	90.17 ab
	4	92.39 gh	92.06 g	91.39 f	90.39 abcd
	5	92.39 gh	90.72 cde	90.94 ef	89.94 a
	LSD 5%		0.52		
35 DAP	8 (NPK-Control)	121.71 i	118.11 a	118.94 bc	118.00 a
	3	121.44 hi	120.00 fg	119.33bcd	118.83 b
	4	121.44 hi	121.11 h	120.11 g	119.39 cde
	5	121.44 hi	119.89 efg	119.56 def	119.33bcd
	LSD 5%		0.53		
42 DAP	8 (NPK-Control)	162. 11 h	158.17 a	158.94 bc	158.11 a
	3	161.78 h	160.00 f	159.33bcd	158.83 b
	4	161.78 h	161.11 g	160.11 f	159.39cde
	5	161.67 h	159.89 ef	159.61def	159.33bcd
	LSD 5%		0.51		
49 DAP	8 (NPK-Control)	192.06 h	188.22 a	188.94 bc	188.06 a
	3	191.67 h	190.00 f	188.33 cd	188.78 b
	4	191.67 h	191.11 g	190.11 f	189.39cde
	5	191.61gh	189.89 ef	189.61 def	189.33 cd
	LSD 5%		0.52		
56 DAP	8 (NPK-Control)	232.11 h	228.45 ab	228.94 abc	228.17 a
	3	231.78gh	230.00 de	229.33 cd	228.44 ab
	4	231.78gh	231.11 fg	230.11 de	229.28bcd
	5	231.67gh	229.89 de	229.50 cd	230.39 ef
	LSD 5%		0.24		
63 DAP	8 (NPK-Control)	252.06 g	248.17 a	248.94 bc	248.11 a
	3	251.72 g	250.00 de	249.11 bc	248.56 ab
	4	251. 72 g	251.11 f	250.11 e	249.28 c
	5	251.72 g	249.89 de	249.50 cd	249.28 c
	LSD 5%		0.58		
77 DAP	8 (NPK-Control)	272.72 i	268.22 a	268.94 bc	268.22 a
	3	272.06 h	270.00 ef	269.11 cd	268.56 ab
	4	272.22 hi	271.11 g	270.11 g	269.28 cd
	5	272.06 h	269.89 ef	269.50 de	268.94 bc
	LSD 5%		0.54		

Note: The same letter accompanying average numbers at the same age indicate not significant at 5%. (PC = paclobutrazol concentration in ppm)

Table 2. Average plant length of long beans due to paclobutrazol concentration and urea fertilizer dose treatment at 14 and 70 DAP

Treatment	Plant length (cm)	
	14 DAP	70 DAP
Paclobutrazol concentration (ppm)		
0	30.43 a	261.93 a
150	30.11 a	259.68 a
175	29.83 a	253.86 a
200	29.89 a	258.84 a
LSD 5%	ns	ns
Urea fertilizer dose (g/plant)		
8 (NPK)	29.89 a	259.35 a
3	30.00 a	259.88 a
4	30.21 a	260.58 a
5	30.17a	254.51 a
LSD 5%	ns	ns

Note: The same letter accompanying average numbers at the same age and treatment indicate no significant difference in the LSD test at 5%.

The combination treatment that resulted in the longest plants was the treatment with 0 ppm paclobutrazol and 8 g/plant of NPK fertilizer at the ages of 21, 28, 35, 42, 49, 56, and 63 DAP. This is because the NPK fertilizer dose of 8 g/plant at these ages provided the most optimal amount of nutrients needed by the plants to support their growth in length. Additionally, the absence of paclobutrazol allowed the plants to grow longer without hindrance, as paclobutrazol works by inhibiting cell division and elongation in the sub-apical meristem of the stem.

Conversely, the treatment with 200 ppm paclobutrazol and 8 g/plant of NPK fertilizer resulted in less optimal nutrient availability for the plants' growth in length, compounded by the highest concentration of paclobutrazol, which inhibited the growth of plant length. This aligns with Sandra (2007), who stated that one function of paclobutrazol is to inhibit stem elongation and can shorten internodes, thus inhibiting plant height growth, increasing stem diameter, and enhancing photosynthesis within the plant. Additionally, paclobutrazol inhibits gibberellin production, leading to a decreased rate of cell division. Reduced cell division results in inhibited vegetative growth and indirectly causes the transfer of assimilates to reproductive growth needed for the formation and development of flowers and fruits. According to Salisbury & Ross (1995), paclobutrazol is a substance that inhibits stem elongation and causes dwarfing by inhibiting gibberellin synthesis, thereby slowing down the elongation of meristem cells.

3.2. Number of Leaves

The variance analysis results show that the interaction of paclobutrazol concentration and urea fertilizer dose significantly impacted the number of leaves of long bean plants from 21 to 77 DAP. The individual treatments of paclobutrazol concentration and urea fertilizer dose significantly affected the number of leaves at all observation ages except 14 DAP. At 14 DAP the plants were in the early stage with few number of leaves (in average 3.53 to 3.60 strands) and were not significantly impacted by the treatments. The average number of leaves of long bean plants due to the combination treatment of paclobutrazol concentration and urea fertilizer dose is presented in Tables 3.

The long bean plants treated with a combination of 0 ppm paclobutrazol concentration and 8 g/plant of NPK fertilizer produced the highest results in terms of leaf count. The lowest leaf count was observed in the treatment with concentration of paclobutrazol 200 ppm and 8 g/plant of NPK fertilizer, as well as the treatment with 200 ppm paclobutrazol and 5 g/plant of urea fertilizer. The treatment with 200 ppm paclobutrazol Gobest resulted in a reduced leaf count compared to the control treatment. This is consistent with the study by Nazibah *et al*. (2018), which showed an 8% reduction in leaf count in long bean plants treated with high doses of paclobutrazol compared to the control. This finding also aligns with the author's research, indicating that high doses of paclobutrazol decrease vegetative growth (plant length and leaf count) but can increase the number of flowers and fruits.

Table 3. Average number of leaves of long bean due to the interaction treatment of paclobutrazol and urea dose at 21 to 77 DAP

Age	Urea Fertilizer Dose (g/plant)	Number of Leaves (leaves)			
		PC 0	PC 150	PC 175	PC 200
21 DAP	8 (NPK-Control)	13.00 i	11.33 b	10.56 a	10.44 a
	3	12.78 hi	12.00 def	12.44 gh	12.11 efg
	4	12.78 hi	12.33 fg	11.89 cde	11.56 bc
	5	12.78 hi	11.56 bc	11.67 bcd	11.56 bc
	LSD 5%			0.39	
28 DAP	8 (NPK-Control)	19.00 f	16.33 ab	16.67 bcd	16.67 ab
	3	18.78 f	17.78 e	17.33 cde	17.44 de
	4	18.89 f	18.87 f	17.56 e	16.56 ab
	5	18.78 f	16.89 bcd	16.78 abc	16.22 a
	LSD 5%			0.61	
35 DAP	8 (NPK-Control)	27.78 f	24.33 a	24.67 abc	24.78 abc
	3	27.22 ef	26.22 d	26.22 d	25.33 c
	4	27.22 ef	26.89 de	26.44 d	24.56 ab
	5	27.22 ef	25.11 bc	24.78 abc	24.22 a
	LSD 5%			0.75	
42 DAP	8 (NPK-Control)	37.78 h	34.00 ab	34.67 bc	34.67 bc
	3	37.22 gh	36.00 def	35.78 def	35.44 cde
	4	37.22 gh	36.56 fg	36.33 efg	34.56 bc
	5	37.22 gh	35.11 cd	34.67 bc	33.44 a
	LSD 5%			1.03	
49 DAP	8 (NPK-Control)	47.22 g	44.45 ab	44.67 ab	44.67 ab
	3	46.56 fg	45.89 de	45.78 de	45.56 cd
	4	46.56 fg	46.44 ef	46.44 ef	44.67 ab
	5	46.56 fg	45.11 bc	44.67 ab	44.22 a
	LSD 5%			0.66	
56 DAP	8 (NPK-Control)	55,78 g	52,78 cde	52,67 ab	52,55 ab
	3	55,44 g	54,11 def	53,78 cde	53,56 cd
	4	55,44 g	54,56 f	54,44 ef	52,56 ab
	5	55,44 g	53,11 bc	52,56 ab	52,33 a
	LSD 5%			0.71	
63 DAP	8 (NPK-Control)	62,00 g	58,22 ab	58,67 bc	57,33 a
	3	61,44 fg	60,33 def	59,78 cde	59,56 cde
	4	61,44 fg	60,56 ef	60,11 de	58,22 ab
	5	61,44 fg	59,11 bcd	59,22 bcd	58,67 bc
	LSD 5%			1.28	
70 DAP	8 (NPK-Control)	67,44 g	64,22 a	64,78 abc	64,00 a
	3	66,78 fg	66,33 ef	65,67 de	65,44 cd
	4	66,78 fg	65,67 de	65,78 de	64,11 a
	5	66,78 fg	65,11 bcd	64,78 abc	64,56 ab
	LSD 5%			0.79	
77 DAP	8 (NPK-Control)	75,67 i	72,33 ab	72,78 abcd	72,11 a
	3	74,89 h	73,44 def	73,56 ef	73,00 bcd
	4	75,11 hi	74,44 gh	73,78 fg	72,56 abc
	5	74,89 h	73,11 cdef	72,78 abcd	72,56 abc
	LSD 5%			0.74	

Note: The same letter accompanying average numbers at the same age indicate not significant at 5%. (PC = paclobutrazol concentration in ppm)

3.3. Flowering Time (days)

The analysis of variance results showed that the interaction treatment of paclobutrazol concentration and urea fertilizer dose significantly affected the flowering time of long bean. Both the paclobutrazol concentration and the urea fertilizer dose individually had a significant impact on the flowering time of long bean. Table 4 shows the average flowering time of long bean plants due to the interaction of paclobutrazol concentration and urea dose.

Table 4. Average flowering time of long bean due to the interaction treatment of paclobutrazol and urea fertilizer

Urea fertilizer dose (g/plant)	Flowering time (days)			
	PC 0	PC 150	PC 175	PC 200
8 (NPK-Control)	32.22 d	28.33 abc	28.44 bc	28.78 c
3	32.56 d	28.00 ab	28.22 ab	28.44 bc
4	32.44 d	27.89 a	28.00 ab	28.33 abc
5	33.56 e	28.00 ab	28.44 bc	28.33 abc
LSD 5%		0.49		

Note: The same letter accompanying average numbers indicate no significant difference in the LSD test at 5%.

The interaction between the two treatments showed a positive response to flowering time. The combination of 150 ppm paclobutrazol and 3, 4, 5 g/plant of urea fertilizer and 8 g/plant of NPK fertilizer resulted in earlier flowering at 27 to 28 DAP compared to the control (32 to 33 DAP with 0 ppm paclobutrazol and 8 g/plant NPK Phonska). The application of paclobutrazol significantly accelerated flowering, with higher concentrations leading to earlier flowering. According to Wattimena (2018), the use of growth regulators to influence flowering generally follows three principles: the plant genotype determines the flowering pattern, the plant must reach maturity before responding to flowering treatments, and certain growth regulators govern the flowering process.

3.4. Number of Flowers

The analysis of variance results showed that the interaction treatment of paclobutrazol concentration and urea fertilizer dose significantly impacted the number of flowers in long bean. Both the paclobutrazol concentration and the urea fertilizer dose individually had a significant impact on the number of flowers in long bean. The average number of flowers per long bean due to the combination treatment of paclobutrazol concentration and urea fertilizer dose is presented in Table 5. The highest number of flowers was obtained from the combination treatment of 150 ppm paclobutrazol with 4 g/plant of urea fertilizer. This is because paclobutrazol can suppress the influence of gibberellins, ultimately promoting flower formation. According to Wattimena (2018), growth inhibitors like uniconazole and paclobutrazol increase the tendency to form female flowers, affecting the number of fruits. The best combination of 150 ppm paclobutrazol concentration with 4 g/plant of urea fertilizer is due to optimal nitrogen (urea) nutrition, enhancing plant growth, protein synthesis, chlorophyll formation, and improving the shoot-to-root ratio. Therefore, optimal nitrogen application can enhance the growth rate of long bean plants (Hafiz *et al*., 2020). According to Adiningsih & Supartini (1995), excessive use of urea results in a decrease in soil pH so that micro flora and fauna die, the soil becomes compacted and soil aeration becomes poor, which ultimately can inhibit root development and plant growth.

Table 5. Average number of flowers per long bean due to the interaction treatment of paclobutrazol and urea fertilizer

Urea Fertilizer Dose (g/plant)	Number of Flowers			
	PC 0	PC 150	PC 175	PC 200
8 (NPK-Control)	43.33 a	49.42 e	57.00 k	55.25 h
3	44.08 b	53.33 f	57.50 l	54.92 h
4	44.38 c	59.83 n	58.67 m	55.67 i
5	45.46 d	56.66 j	55.83 ij	54.00 g
LSD 5%		0.39		

Note: The same letter accompanying average numbers the same column indicate no significant difference in the LSD test at 5%.

3.5. Number of Fruits per Plant

The analysis of variance results revealed that the interaction treatment of paclobutrazol concentration and urea fertilizer dose significantly affected the number of fruits per long bean. Both the paclobutrazol concentration and the urea fertilizer dose individually had a significant impact on the number of fruits per plant from the first to the fifth harvest and the total number of fruits per plant. The average total number of fruits per long bean plant due to the

interaction treatment of paclobutrazol concentration and urea fertilizer dose is presented in Table 6. The combination treatment of paclobutrazol concentration and urea fertilizer dose significantly impacted the total number of fruits per long bean plant. The highest average total number of fruits per plant (45.00) was obtained with the combination of 150 ppm paclobutrazol and 4 g/plant of urea fertilizer. The lowest average total number of fruits per plant (35.44) was observed with the combination of 0 ppm paclobutrazol and 8 g/plant of NPK Phonska fertilizer. Decreasing the urea fertilizer dose actually increased the number of fruits per plant, likely because long bean, being leguminous, can fix nitrogen directly in the soil and rhizosphere, thereby increasing the soil's total nitrogen content. This is consistent with Firmansyah & Sumani (2013), who found that increasing nitrogen fertilizer doses raised the soil's total nitrogen content. High nitrogen fertilizer doses can lead to higher total nitrogen availability in the soil, but excessive nitrogen uptake can inhibit growth. Nitrogen absorption by plants is influenced by the availability of nitrogen in the soil. The availability of nitrogen is affected by chemical and biological processes. In the reduction state, nitrogen is absorbed in the form of ammonium (NH), while in the oxidation state it is in the form of nitrate (NO_3) (Cassman *et al*., 2002).

Table 6. Average total number of fruits per long bean due to the interaction treatment of paclobutrazol and urea fertilizer

Urea Fertilizer Dose (g/plant)	Total Number of Fruits per Plant			
	PC 0	PC 150	PC 175	PC 200
8 (NPK-Control)	35.44 a	39.00 c	39.00 c	39.00 c
3	37.00 b	40.33 de	40.33 de	39.00 c
4	37.33 b	45.00 g	42.33 f	39.78cd
5	37.00 b	40.67 e	40.00 de	39.00 c
LSD 5%		0.82		

Note: The same letter accompanying average numbers indicate no significant difference in the LSD test at 5%.

Table 7: Average total fruit weight per long bean for interaction treatments of paclobutrazol and urea fertilizer

Urea Fertilizer Dose (g/plant)	Total Fruit Weight per Plant (g)			
	PC 0	PC 150	PC 175	PC 200
8 (NPK-Control)	730.86 a	786.28 c	825.72 e	819.14 de
3	752.47 b	839.39 f	843.64 f	814.47 d
4	756.00 b	920.92 h	878.56 g	811.44 d
5	757.92 b	845.08 f	839.75 f	809.36 d
LSD 5%		9.90		

Note: The same letter accompanying average numbers the same column indicate no significant difference in the LSD test at 5%.

3.6. Fruit Weight per Plant (g)

Analysis of variance results revealed that the interaction treatment of paclobutrazol and urea fertilizer dosage significantly affected the fruit weight per plant. The paclobutrazol concentration and urea fertilizer dosage each also had a significant impact on the fruit weight per plant from the first to the fifth week and the total fruit weight per plant. The average total fruit weight per plant over the five-week harvest period for the combination treatments of paclobutrazol and urea fertilizer dosage is presented in Table 7. The combination of paclobutrazol concentration and urea fertilizer significantly affected the number of fruits per plant, fruit length, fruit weight per plant, fruit weight per plot, fruit weight per hectare, and fruit set. The formation of amino acids, proteins, and fats essential for pod formation is thought to contribute to the complete filling of seeds. The availability of urea provides sufficient raw material for protein synthesis, leading to better seed filling and pod formation. These photosynthetic products are translocated throughout the plant via the phloem, particularly for pod filling and seed formation, resulting in a higher number of filled pods per plant (Prihmantoro, 2007).

3.7. Fruit Weight per Plot

The analysis of variance showed that the interaction treatment of paclobutrazol concentration and urea fertilizer dosage significantly impacted the fruit weight per plot from the first to the fifth week of harvest. The paclobutrazol concentration and urea fertilizer dosage each also significantly impacted the fruit weight per plot from the first to the fifth week and the total fruit weight per plot. The average total fruit weight per plot of long beans over the five-week harvest period for the combination treatments of paclobutrazol concentration and urea fertilizer dosage is presented in Table 8. The combination of paclobutrazol concentration and urea fertilizer dosage significantly affected the total fruit weight per plant of long beans. The highest average total fruit weight per plant was 920.92 g for the combination of 150 ppm paclobutrazol and 4 g/plant urea fertilizer. The lowest average total fruit weight per plant was 730.86 g for the treatment of no paclobutrazol and 8 g/plant NPK fertilizer.

Table 8. Average total fruit weight per plot of long bean for interaction treatments of paclobutrazol and urea fertilizer over 5 weeks of harvest

Urea fertilizer dose (g/plant)	Total Fruit Weight (kg/plot)			
	PC 0	PC 150	PC 175	PC 200
8 (NPK-Control)	5.68 a	6.15 abc	6.49 abcd	6.45 abcd
3	5.85 ab	6.53 bcd	6.58 bcd	6.42 abcd
4	5.84 ab	7.71 d	6.87 cd	6.41 abcd
5	5.88 ab	6.59 bcd	6.58 bcd	6.39 abcd
LSD 5%		0.82		

Note: The same letter accompanying average numbers indicate no significant difference in the LSD test at 5%.

Table 9: Average fruit weight per hectare of long bean for interaction treatments of paclobutrazol and urea fertilizer

Urea fertilizer dose (g/plant)	Total Fruit Weight (ton/ha)			
	PC 0	PC 150	PC 175	PC 200
8 (NPK-Control)	28.38 a	30.74 c	32.47 ef	32.26 def
3	29.18 b	32.63 fg	32.89 g	32.10 d
4	29.24 b	35.84 i	34.36 h	32.05 d
5	29.39 b	32.96 g	32.89 g	31.97 d
LSD 5%		0.40		

Note: The same letter accompanying average numbers indicate no significant difference in the LSD test at 5%.

3.8. Fruit Weight per Hectare (tons)

The analysis of variance showed that the combination treatment of paclobutrazol concentration and urea fertilizer dosage significantly affected the fruit weight per hectare of long bean plants. The paclobutrazol concentration and urea fertilizer dosage each also significantly affected the fruit weight per hectare. The average fruit weight per hectare for the combination treatments of paclobutrazol concentration and urea fertilizer dosage is presented in Table 9. The combination of paclobutrazol concentration and urea fertilizer dosage significantly affected the fruit weight per hectare. The highest average fruit weight per hectare of long bean plants was 35.84 tons/h (150 ppm paclobutrazol + 4 g/plant urea fertilizer), while the lowest was 28.38 tons/ha (0 ppm paclobutrazol + 8 g/plant NPK fertilizer). Our results are in line with Hadzafi & Sugito (2020), where application of Urea fertilizer at a dose of 100 kg/ha has a very significant effect on the growth and yield of long bean plants (leaf area per plant, fresh weight of long beans, and dry weight per plant and yield).

3.9. Fruit Length

The analysis of variance showed that the interaction treatment of paclobutrazol concentration and urea fertilizer dosage significantly affected the fruit length of long bean plants. The paclobutrazol concentration and urea fertilizer

dosage each significantly impacted the fruit length of long bean plants. The average fruit length for the combination treatments of paclobutrazol concentration and urea fertilizer dosage is presented in Table 10. The combination of paclobutrazol concentration and urea fertilizer dosage significantly affected the fruit length of long bean plants. The longest average fruit length was 74.06 cm for the combination of 0 ppm paclobutrazol and 8 g/plant NPK fertilizer, while the shortest was 64.79 cm for the combination of 200 ppm paclobutrazol and 3 g/plant urea fertilizer. Increasing the paclobutrazol dosage negatively impacted the fruit length of long bean plants. According to Lolaei *et al*. (2013), higher paclobutrazol dosages inhibit gibberellin biosynthesis, thereby restricting vegetative growth such as shoot elongation, plant height, and fruit length. Sakhidin & Suparto (2011) also noted that growth inhibitors containing paclobutrazol can hinder stem elongation, increase stem diameter, and prevent lodging in plants.

Table 10. Average fruit length of long bean plants for combination treatments of paclobutrazol concentration and urea dosage

Urea Fertilizer Dose (g/plant)	Fruit Length (cm)			
	PC 0	PC 150	PC 175	PC 200
8 (NPK-Control)	74.06 i	67.56 b	70.00 d	64.85 a
3	73.83 h	70.21 e	70.02 d	64.79 a
4	73.88 h	73.38 g	70.71 f	64.94 a
5	73.77 h	70.56 f	69.17 c	64.88 a
LSD 5%		0.39		

Note: The same letter accompanying average numbers indicate no significant difference in the LSD test at 5%.

Table 11. Average percentage of flowers developing into fruits (fruit set) in long bean due to combination treatments of paclobutrazol and urea fertilizer

Urea Fertilizer Dose (g/plant)	Fruit Set (%)			
	PC 0	PC 150	PC 175	PC 200
8 (NPK-Control)	81.33 fg	79.33 e	68.00 a	70.67 bc
3	83.33 h	75.00 d	69.67 ab	71.00 bc
4	82.67 gh	75.00d	71.67 c	71.00 bc
5	80.67 ef	72.00 c	71.33bc	71.33 bc
LSD 5%		1.75		

Note: The same letter accompanying average numbers indicate no significant difference in the LSD test at 5%.

3.10. Fruit Set (%)

Fruit set refers to the percentage of flowers that develop into fully formed fruits on a plant. The analysis of variance results showed that the combination treatment of paclobutrazol concentration and urea fertilizer dosage significantly affected the fruit set of long bean plants. Both paclobutrazol concentration and urea fertilizer dosage individually also had a significant effect on the fruit set of long bean plants. The average fruit set values for long bean plants due to the combination treatments of paclobutrazol concentration and urea fertilizer dosage are presented in Table 11. The combination of paclobutrazol concentration and urea fertilizer dosage significantly affected the percentage of flowers developing into fruits (fruit set). The highest average fruit set was 83.33% (0 ppm paclobutrazol and 3 g/plant urea fertilizer), while the lowest was 68.00% (175 ppm paclobutrazol and 8 g/plant NPK fertilizer). The fruit set percentage in plants treated with paclobutrazol was generally lower than in untreated plants, but under the research conditions, it was observed that during the rainy season, untreated plants had a higher rate of fruit and flower drop compared to paclobutrazol-treated plants. This is supported by Sakhidin & Suparto (2011), who found that paclobutrazol can also reduce gibberellin synthesis, accelerate flowering, increase the number of flowers and fruits, but decrease the fruit set in durian plants. All plants have their own response to fruit set so that in this long bean plant not 100 percent of the flowers form fruit. This is in accordance with the opinions and statements of Gardner *et al*. (2008) that failure to set fruit can be caused by a lack of pollination.

4. CONCLUSION

Based on the discussions presented, the following conclusions can be drawn:

1. The paclobutrazol concentration and urea fertilizer dosage treatments significantly affected the parameters of plant length, number of leaves, flowering time, number of flowers, number of fruits per plant, fruit length, fruit weight per plant, fruit weight per plot, fruit weight per hectare, and fruit set.
2. The application of 150 ppm paclobutrazol Gobest 250 SC is effective in inhibiting vegetative growth while enhancing generative phase outcomes, such as flower formation, fruit formation, and fruit weight per plant and per hectare. The 150 ppm concentration is the most effective, producing 35.84 tons/ha compared to the control treatment (0 ppm), which produced 28.38 tons/ha.
3. The application of 4 g/plant or 100 kg/ha of urea fertilizer yielded the best results in terms of plant length, number of leaves, number of fruits per plant from weeks 1 to 5, number of fruits per plot from weeks 1 to 5, fruit weight per plant from weeks 1 to 5, fruit weight per plot from weeks 1 to 5, and fruit weight per hectare.

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REFERENCES

Adiningsih, S.J., & Soepartini, M. (1995). Pengelolaan pupuk pada sistem usahatani lahan sawah. Paper presented at *Apresiasi Metodologi Pengkajian Usahatani Berbasis Padi dengan Wawasan Agribisnis*, PSE, Bogor, 7-9 September 1995.

Anwar, C. (2013). Analisis ekonomi komoditi kacang panjang di Kabupaten Banyuasin Sumatera Selatan. *Jurnal Ilmiah Agriba*, ***4***(2), 198–204.

Ariyanto, M. (2020). Pengaruh konsentrasi paklobutrazol terhadap pertumbuhan dan hasil tanaman kacang panjang (*Vigna sinensis* L.). [*Undergraduate thesis*]. Universitas Pembangunan Nasional Jawa Timur. 86 pp.

Badan Pusat Statistik [BPS]. (2022). *Statistik Tanaman Hortikultura Indonesia*. Retrieved January 5, 2023, from http://www.bps.go.id

Cassman, K.G., Dobermann, A., & Walters, D.T. (2002). Agroecosystems, nitrogen-use efficiency, and nitrogen management. *Ambio*, ***31***(2),132-40. https://doi.org/10.1579/0044-7447-31.2.132

Firmansyah, I., & Sumarni, N. (2013).Pengaruh dosis pupuk N dan varietas terhadap pH tanah, N-total tanah, serapan N, dan hasil umbi bawang merah (*Allium ascalonicum* L.) pada tanah entisols-Brebes Jawa Tengah. *Jurnal Hortikulutra*, ***23***(4), 358-364

Gardner, F.P., Brent, P.R, & Mitchell, R.L. (2008). *Fotosintesis dan Fisiologi Tumbuhan* (Translation by Herawati Susilo). Jakarta: UI Press: 428 pp.

Gomez, K.A., & Gomez, A.A. (1995). *Prosedur Statistik untuk Penelitian Pertanian* (Syamsudin, E., & Baharsjah, J.S., Trans.). Jakarta: UI Press.

Hadzafi, M.M., & Sugito, Y. (2020). Pertumbuhan dan hasil tanaman kacang panjang terhadap pemberian pupuk daun Gandasil D dan zat pengatur tumbuh Harmonik. *Jurnal Ilmu Pertanian Tropika dan Subtropika*, ***1***(1), 12-22.

Hafiz, A., Sari, S.G., Nisa, C. (2020). Efisiensi serapan nitrogen pada pertumbuhan kacang panjang (*Vigna sinensis* L.) setelah pemberian sludge industri karet remah. *Bioscientiae*, 17(1), 1-14.

Hammel, A.I. (1989). Effect of paclobutrazol on growht, chloroplast phigments and sterol biosynthesis of maize (*Zea mays* L.). *Plant Science*. 105 hal

Haryanto, E., Suhartini, T., & Rahayu, E. (2013). *Budidaya Kacang Panjang*. Jakarta: Penebar Swadaya. 69 pp.

Kusriningrum, K. (2008). *Perancangan Percobaan*. Airlangga University Press, Surabaya.

Lolaei, A., Mobasheri, S., Bemana, R., & Teymori, N. (2013). Role of paclobutrazol on vegetative and sexual growth of plants. *International Journal of Agriculture and Crop Sciences*, ***5***(9), 958-961.

Nazibah, M.S.S., Karno, K., & Lukiwati, D.R. (2018). Tanggap pertumbuhan dan perkembangan tanaman tomat (*Solanum lycopersicum*) terhadap paklobutrazol dan komposisi media tanam. *Agro Complex, **2***(3), 199-205.

Prihmantoro, H. (2007). *Memupuk Tanaman Buah*. Penebar Swadaya, Jakarta.

Sakhidin, & Suparto, S.R. (2011). Kandungan giberelin, kinetin dan asam absisat pada tanaman durian yang diberi paclobutrazol dan etepon. *Jurnal Hortikultura Indonesia*, ***2***(1), 21-26. https://doi.org/10.29244/jhi.2.1.21-26

Salisbury, F.B. & Ross, C.W. (1995). *Fisiologi Tumbuhan Jilid 2* (Translation by Diah R. Lukman and Sumaryono). Bandung: ITB Press: 141 pp.

Sandra, E. (2007). *Membuat Anggrek Rajin Berbunga*. Agro Media, Jakarta.

Soelaksini, L.D., Irawan, T.B., & Nuraisyah, A. (2022). Peningkatan produksi kacang hijau (*Vigna radiate* L) menggunakan pupuk azolla pinnata dan pupuk urea. *Jurnal Ilmiah Inovasi*, ***22***(1), 73–83. https://doi.org/10.25047/jii.v22i1.3139

Wattimena, G.A. (2018). *Zat Pengatur Tumbuh Tanaman*. Bogor: PAU Bioteknologi IPB. 36 pp.