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The Effect of Paclobutrazol and Types of Nitrogen (N) Fertilizer on The Growth and Yield of Long Bean (*Vigna sinensis* L.)

Nirmala Aulia Sari[1], Ida Retno Moeldjani[1,✉], Agus Sulistyono[1]

[1] Program Studi Agroteknologi, Fakultas Pertanian, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya, INDONESIA

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Corresponding Author:
✉ ida_retno@upnjatim.ac.id
(Ida Retno Moeldjani)

ABSTRACT

Long bean is the one of the most widely consumed vegetables both fresh and processed. The market demand for long beans is rising, but their production remains limited. This study aims to investigate how different concentrations of paclobutrazol and various types of nitrogen fertilizers affect the growth and yield of long bean plants. The research was conducted in Dander Village, Dander District, Bojonegoro Regency, East Java. The study employed a factorial Randomized Block Design (RBD) with two factors: the concentration of paclobutrazol (P0 = control, P1 = 150 ppm, P2 = 200 ppm, P3 = 250 ppm) and the type of nitrogen fertilizer (N0 = NPK control, N1 = Urea, N2 = ZA, N3 = KNO3). Variables to observed included plant length, number of leaves, flowering age, number of pods, pod weight, number of seeds, and fruit set. The results showed that the combination of 150 ppm paclobutrazol and KNO_3 nitrogen fertilizer produced the best results in terms of the fastest flower emergence at 29 days after planting (HST) and the highest pod weight of long beans at 43.00 grams per plant.

1. INTRODUCTION

Long bean (*Vigna sinensis* L.) is one of the horticultural commodities favored by the Indonesian people. This plant has economic value because it produces a large number of fruits. Long beans are used as a mixture for vegetables or sautéed and can also be served as fresh vegetables in daily meals. Long beans have several beneficial nutrients, including being a source of vitamins and minerals that play a role in regulating metabolism, increasing intelligence and body resistance, and facilitating the digestive process due to their high fiber content.

The production of long beans in Indonesia is quite lower than those of other countries. Based on data from the Statistical Research Center (BPS, 2021), the production of long beans decreased from 2021 to 2022, with 383,685 tons in 2021 and 360,674 tons in 2022. The Bojonegoro Regency area in East Java is one of the regions with low long bean production. The causes include the insufficient availability of superior seeds or seedlings. Production decline can also occur due to other factors, including variety, imbalanced fertilization, and pest and disease attacks. Therefore, a solution is needed to increase the yield of long beans by using superior long bean varieties and the application of the growth regulator (PGR) Paclobutrazol, which inhibits vegetative growth but stimulates maximum production yield.

Paclobutrazol is a type of growth regulator that inhibits gibberellin biosynthesis, thus hindering vegetative plant growth. Paclobutrazol basically inhibit the oxidation reaction between kaurene and kaurenoic acid in gibberellin synthesis, resulting in the suppression of plant stems. Research by Ariyanto (2020) showed that using paclobutrazol at a concentration of 175 ppm could inhibit the vegetative phase of long beans and enhance the generative phase, with a production yield of 35.68 tons/ha. This yield is quite high; therefore, the use of paclobutrazol as a PGR in long bean cultivation needs to be implemented but must be balanced with soil fertilization (Herawati, 2012).

Urea is a nitrogen fertilizer source containing essential elements supporting high plant productivity with low production costs and high nitrogen content. ZA fertilizer provides readily available N elements for plants quickly (Petrokimia Gresik, 2004). The sulfur content in ZA fertilizer is used in the formation of green leaves for long beans. Potassium nitrate (KNO_3) fertilizer is a chemical fertilizer containing potassium and nitrogen. The potassium in KNO_3 acts as a balance when plants have excess nitrogen. The K element can also increase carbohydrate synthesis and translocation, enhancing cell wall thickness, stem strength, and sugar content (Syaifuddin & Baherah, 2013).

The application of PGR Paclobutrazol and various nitrogen fertilizers is expected to address various issues related to the decline in long bean yields. Using superior varieties is the initial step to achieve maximum production yield. Paclobutrazol as a PGR can inhibit gibberellin production, limiting vegetative growth and increasing chlorophyll content in leaves, thus optimizing photosynthesis and enhancing flowering and fruiting processes. The nutrients contained in nitrogen fertilizers play a crucial role in the growth of long beans. The availability of nutrients during the growth period will influence the reproduction, growth, and yield of long beans. Combining PGR Paclobutrazol and various nitrogen fertilizers can identify the best concentration and provide information on the best influence to increase long bean yields.

2. RESEARCH METHOD

This research was conducted from December 2023 to March 2024 in Dander Village, Dander District, Bojonegoro Regency, East Java. The land is located at an altitude of 25 - 500 meters above sea level, with grumusol soil type, an average temperature ranging from 27°C to 38°C, rainfall of 1500 – 2500 mm/year, and humidity between 65% - 90%.

The tools used in this research included mulch, hoes, trowels, measuring cups, watering cans, buckets, meters, rulers, wool threads, raffia strings, stakes, knives, scales, sieves, calipers, and stationery. The materials used in this research included long bean seeds of Pertiwi variety, Urea fertilizer, SP 36, KNO_3, ZA, NPK Phonska fertilizer, manure, Regent insecticide, Antracol fungicide, labels, and Paclobutrazol Gobest 250 SC.

This study was a factorial experiment arranged in a Randomized Block Design (RBD) consisted of 2 factors. The first factor was the concentration of Paclobutrazol Gobest (P) with 4 treatment levels. Paclobutrazol concentrations (P) are: P_0 = 0 ppm (control); P_1 = 150 ppm; P_2 = 200 ppm; P_3 = 250 ppm. The second factor was nitrogen fertilizer type (N) with 4 treatment levels: N_0 = NPK (control); N_1 = Urea; N_2 = ZA; N_3 = KNO_3. There were 16 treatment combinations with 3 replications, resulting in 48 experimental units with 3 sample plants per unit.

Land preparation began with soil tillage on the long bean cultivation area by turning the soil with a hoe to loosen it. Then, 3 replications of beds were made, totaling 48 plots with a width of 1 meter, a height of 30 cm, and a distance of 1 meter between beds. Next, silver plastic mulch was installed on the beds. Holes in the mulch were made according to the specified planting distance using a heated used milk can and then pressed onto the plastic mulch.

The seeds used were of the Pertiwi variety. Manure at 1.6 kg/m^2 was evenly spread 7 days before planting, then mixed and raked to integrate the fertilizer with the soil. At the initial planting, basal fertilizers KCl 4.75 g/plant, SP 36 4.75 g/plant, and NPK 5 g/plant were applied using the drilling method. Planting long bean seeds was done by drilling holes in the soil 3 cm deep, placing 2 seeds per hole, and then covering them thinly with soil in the morning. The planting distance for long bean seeds was 40x60 cm^2, with 8 plants per plot and border plants. At 7 days after planting (DAP), thinning was done, leaving the best plant per hole by cutting above the soil surface. Watering was done after planting if the soil was too dry.

The Urea fertilizer treatment at 4.75 g/plant, ZA at 10 g/plant, and KNO_3 at 16 g/plant were applied to the plants 4 times, at 14, 28, 42, and 56 DAP. Fertilization was done by dissolving the fertilizers in 200 cc of water per treatment and applying it around the plants according to their respective treatments. NPK Phonska fertilizer was applied to long bean plants for the N0 level or as a control treatment. NPK fertilizer was applied as a follow-up fertilizer at 13.5 g/plant at 14, 28, and 42 DAP with a dose of 2 g/plant and at 56 DAP with a dose of 2.5 g/plant.

Paclobutrazol was applied to the plants 3 times when long bean plants were 20, 30, and 40 DAP. Paclobutrazol was applied by giving the concentration according to the treatment levels: 0 ppm, 150 ppm, 200 ppm, and 250 ppm. The application was done by dissolving it in water and directly applying it to the planting medium, 50 cc per application at

20 DAP, and 100 cc per application at 30 and 40 DAP. Paclobutrazol application was done in the morning from 07:00 – 09:00 WIB.

Maintenance included watering, replanting, weeding, staking, pruning, and controlling pests and diseases. Harvesting long beans was done by cutting the base of the pods with hands. The first harvest was done when the long bean plants were 14-15 days after flowering. Subsequent harvesting was done 2-3 times a week. The harvest criteria for long beans were when the pods were firm and green.

Observation parameters for long bean plants included vegetative and generative phases. Vegetative parameters consisted of plant length and number of leaves. Generative parameters included the age of flower appearance, number of pods per plant, weight per pod, and fruit set (%).

Data analysis from the experiment was conducted using variance analysis according to the design used, namely the Randomized Block Design (RBD). If the F test showed significant effects, further testing would be conducted using the Honest Significant Difference (HSD) test at a 5% significance level (0.05).

Table 1. Effect of treatment (paclobutrazol concentration and N fertilizer type) on plant length of long bean from 28 to 77 DAP

Age (DAP)	Paclobutrazol Conc. (ppm)	Plant length (cm)			
		NPK (Control)	Urea	ZA	$KN0_3$
28	0	258.33 c	228.33 abc	248.33 bc	218.33 ab
	150	220.67 ab	252.00 bc	227.33 abc	227.33 abc
	200	240.00 abc	225.67 abc	211.00 a	226.00 abc
	250	220.00 ab	243.33 abc	229.00 abc	228.00 abc
	HSD 5%		35.46		
42	0	301.33 d	283.33 abcd	291.00 bcd	279.33 abc
	150	280.33 abc	292.33 bcd	298.00 cd	284.00 abcd
	200	288.67 abcd	273.00 ab	269.33 a	273.33 ab
	250	276.33 ab	288.33 abcd	282.67 abcd	284.00 abcd
	HSD 5%		20.28		
56	0	322.33 e	315.67 cde	318.33 de	308.33 abcd
	150	312.33 bcde	315.00 bcde	318.00 de	310.67 abcd
	200	315.67 cde	317.00 de	301.33 a	305.33 abc
	250	305.00 ab	305.67 abc	309.67 abcd	308.33 abcd
	HSD 5%		10.48		
70	0	339.00 c	337.00 c	336.67 c	335.67 c
	150	337.33 c	333.67 abc	337.33 c	334.00 abc
	200	334.67 abc	337.33 c	327.33 a	335.33 c
	250	333.67 abc	336.00 c	327.67 ab	335.00 bc
	HSD 5%		7.37		

Note: same lowercases after average numbers in the same column and age imply that they are not statistically different at $\alpha = 5\%$.

3. RESULTS AND DISCUSSION

3.1. Plant Length

The analysis results show that the combination treatment of paclobutrazol concentration and N fertilizer type significantly affects the plant length of long beans from 28 to 77 days after planting (DAP). Table 1 shows that the combination of 0 ppm paclobutrazol concentration and NPK fertilizer resulted in the best plant length parameters. This is because NPK fertilizer can provide the most optimal amount of nutrients needed by the plants to support their growth. Additionally, the absence of paclobutrazol allows the plants to grow longer without inhibition, facilitating sub-apical cell division and elongation in the stems. According to Pramitasari *et al*. (2016), NPK fertilizer provides the most optimal amount of nutrients needed by plants, and the nitrogen element in NPK fertilizer is crucial in the photosynthesis process to support the growth in plant height. This is in line with the statement by Dini *et al*. (2022), which mentions that one function of paclobutrazol is to inhibit stem elongation, thereby shortening the plants. It also

causes a decrease in cell division rates. The reduction in cell division slows vegetative growth, causing the transfer of assimilates to the reproductive growth needed for flower, fruit, and fruit development. Paclobutrazol is a substance capable to inhibit stem elongation and cause dwarfing by inhibiting gibberellin synthesis (Lienargo *et al*., 2014).

3.2. Number of Leaves

The analysis results show that the combination of paclobutrazol concentration and N fertilizer type significantly affects the number of leaves of long beans from 56 to 77 DAP. Table 2 shows that the combination treatment of 150 ppm paclobutrazol concentration and urea fertilizer resulted in the best number of leaves parameters. The 150 ppm paclobutrazol treatment increased the number of leaves of long bean plants compared to the control treatment. This is consistent with the research by Rachmadani (2023), which showed that increasing the concentration of paclobutrazol significantly affects the number of leaves. The addition of urea fertilizer gave the highest results. This is in line with statement of Saraswati (2023) that urea fertilizer contains essential elements needed by plants in large quantities, which are very beneficial for the growth and development process. The proper application of urea fertilizer can increase the number of leaves, thus supporting the growth of long bean plants. Urea fertilizer, which contains 46% nitrogen (N), is highly beneficial for plant growth and development. It helps make plant leaves greener, denser, and fresher. The abundant chlorophyll content in the leaves allows the plant to perform photosynthesis more efficiently. Urea fertilizer can accelerate plant growth (increasing size, number of tillers, and branches) and also enhance the protein content within the plant (Hadzafi et al. 2020).

Table 2. Effect of treatment (paclobutrazol concentration and N fertilizer type) on the number of leaves of long bean at 49–77 DAP

Age (DAP)	Paclobutrazol Conc. (ppm)	Number of leaves			
		NPK (Control)	Urea	ZA	$KN0_3$
56	0	70.00 cd	70.33 cd	57.67 a	58.67 ab
	150	67.67 bcd	72.00 d	59.67 ab	59.33 ab
	200	67.33 bcd	58.67 ab	61.67 abc	60.67 ab
	250	58.00 a	59.00 ab	59.33 ab	61.67 abc
	HSD 5%		9.13		
63	0	76.67 cd	73.33 cd	61.00 a	70.67 abcd
	150	78.00 d	79.00 d	66.00 abcd	61.67 abcd
	200	76.67 cd	75.00 cd	72.33 abcd	75.00 cd
	250	75.00 cd	72.67 bcd	69.00 abcd	69.67 abcd
	HSD 5%		11.50		
70	0	79.33 bc	82.67 c	66.00 a	70.00 ab
	150	81.00 bc	83.33 c	77.67 abc	77.67 abc
	200	80.00 bc	76.33 abc	72.67 abc	70.00 ab
	250	72.00 abc	79.00 bc	69.67 ab	79.67 bc
	HSD 5%		11.93		
77	0	83.33 bc	82.67 bc	65.33 a	73.33 abc
	150	83.33 bc	86.67 c	81.67 bc	84.00 c
	200	77.67 abc	82.67 bc	76.67 abc	75.33 abc
	250	79.33 abc	80.33 bc	69.00 ab	80.00 bc
	HSD 5%		14.56		

Note: same lowercases after average numbers in the same column and age imply that they are not statistically different at α = 5%.

3.3. Flowering Age

The analysis results show that the combination of paclobutrazol concentration and N fertilizer type significantly affects the flowering age of long bean. The treatment of paclobutrazol concentration significantly affects the flowering age of long bean, as does the type of N fertilizer. Table 3 shows that the interaction between the two treatments significantly affects the flowering age. The combination treatment of 150 ppm paclobutrazol concentration and KNO_3 fertilizer resulted in the earliest flowering age, causing the long bean to flower earlier than the control treatment, at 29 DAP. Additionally, this combination treatment significantly affected the weight per pod of long bean plants, which

was 43.0 grams. Research by Iman *et al.* (2014) showed the concentration of paclobutrazol applied to the plant was too high, which can delay the time of flower bud emergence and reduce the number of flowers produced by a single plant. This affects the absorption and distribution of nutrients in the plant, leading to a decrease in the quality and yield of long bean crops. The important role of potassium and nitrogen found in KNO_3 fertilizer can increase the metabolic processes in long bean plants, thus speeding up the growth process from vegetative to generative, supporting faster flower and fruit formation. The application of paclobutrazol is very significant in accelerating flowering, as proven by the fact that higher concentrations accelerate the flowering age of long bean plants. According to Safitri (2023), the application of growth regulators to influence flowering generally applies three principles: the plant genotype determines the flowering pattern, the plant must reach the mature stage to respond to flowering treatments, and several growth regulators control flowering.

Table 3. Average flowering age of long beans due to combination treatment of paclobutrazol concentration and N fertilizer type

Paclobutrazol Concentration (ppm)	Flowering age (DAP)			
	NPK (Control)	Urea	ZA	$KN0_3$
0	32.67 ef	33.00 f	32.67 ef	29.67 ab
150	31.67 cdef	29.33 ab	30.00 abc	29.00 a
200	33.00 f	32.00 def	31.00 bcde	30.33 abcd
250	32.00 def	31.67 def	30.67 abcd	30.33 abcd
HSD 5%		1.39		

Note: same lowercases after average numbers imply that they are not statistically different at $\alpha = 5\%$.

Table 4. Average number of pods due to paclobutrazol concentration and type of N fertilizer treatments for 5 week harvesting

Treatment	Number of pods per plant				
	Week 1	Week 2	Week 3	Week 4	Week 5
Paclobutrazol Concentration (ppm)					
0	8.33 a	17.08 b	12.35	8.75	6.58
150	12.17 b	21.25 b	14.18	10.67	8.50
200	8.17 a	13.00 a	11.32	9.85	7.68
250	6.50 a	12.58 a	11.23	8.23	6.07
HSD 5%	2.56	4.26	ns	ns	ns
Types of N Fertilizer					
NPK (Control)	7.83	16.08	11.07	8.13	5.97
Urea	9.17	16.17	13.13	8.87	6.70
ZA	8.67	14.08	11.68	10.05	7.88
KN03	9.50	17.58	13.20	10.45	8.28
HSD 5%	ns	ns	ns	ns	ns

Note: Average numbers followed by the same letter in the same row and column are not significantly different according to the HSD 5% test.

3.4. Number of Pods

The variance analysis results show that the combination of paclobutrazol concentration with the type of N fertilizer did not significantly interact with the number of pods per plant of long beans. The single factor of paclobutrazol concentration significantly affected the number of pods per plant in the first to second weeks, while the single factor of N fertilizer type did not significantly affect the number of pods per plant. Table 4 shows that the highest average number of pods per long bean plant was obtained in the first week with P1 (150 ppm paclobutrazol) treatment, which was 12.17 pods, and in the second week, which was 21.25 pods. The single factor of N fertilizer type did not significantly affect the number of pods per long bean plant. The high yield of long bean plants due to the 150 ppm concentration is attributed to the calculation method used, which is the yield potential supported by the environment and the application of a wider planting distance. This planting distance ensures optimal sunlight absorption and other supports, leading to optimal final production even without paclobutrazol (Fitriyah, 2023). The field used in the research also affected the harvest results. Soil porosity greatly affects soil fertility, but nowadays, factors that can change this condition include the application of fertilizers that can increase the nutrients and soil content needed by

plants. Nitrogen contains essential nutrients that serve as building blocks for amino acids, proteins, and chlorophyll, which are crucial in the photosynthesis process and stimulate vegetative growth, such as shoot formation, stem development, and leaf growth. Nitrogen helps plants develop more chlorophyll. Nitrogen has various benefits for plants, including enhancing overall growth, promoting healthy and greener leaves, and increasing protein content within the plant (Oriska, 2012). According to Rahmawan *et al*. (2019), nitrogen in the soil can be lost due to leaching caused by soil erosion or rainwater, resulting in more nitrogen being lost or carried away by the soil through water leaching or erosion.

3.5. Pod Weight

The variance analysis results show that the combination treatment of paclobutrazol concentration with the type of N fertilizer significantly affected the weight per pod of long bean. Table 5 shows that the combination treatment of 0 ppm paclobutrazol concentration with KNO_3 fertilizer resulted in the highest average weight per pod of long bean plants, which was 43 grams. With the availability of nitrogen for the plants, the raw materials for protein formation are available in sufficient quantities, improving seed filling and pod formation, thus increasing the weight per pod of long bean plants. According to Aknantasari (2022) KNO_3 fertilizer, in addition to containing the K^+ element, also contains the NO_3^- element, which can replace the K element that is bound by the soil. As a result, the K in the soil becomes available and can be directly absorbed by the plants. Nitrogen (N) in KNO3, which is already in the nitrate form, can accelerate the absorption of nitrogen by plants. Therefore, KNO_3 fertilizer can be applied to speed up plant growth (Soepardi, 2009).

Table 5. Average weight per pod of long bean due to the combination of paclobutrazol concentration and type of N fertilizer

Paclobutrazol Concentration (ppm)	Weight per pod (gram)			
	NPK (Control)	Urea	ZA	$KN0_3$
0	28.67 abc	31.00 abc	30.67 abc	43.00 d
150	23.00 a	33.00 bc	33.00 bc	34.00 cd
200	31.00 abc	25.00 abc	27.00 abc	34.00 cd
250	33.67 c	24.00 ab	27.00 abc	23.67 a
HSD 5%		9.16		

Note: Numbers followed by the same letter in the same row and column are not significantly different according to the HSD 5% test.

3.6. Number of Seeds

The variance analysis results show that the combination of paclobutrazol concentration with the type of N fertilizer significantly affected the number of seeds per pod of long bean plants. Table 6 shows that the combination treatment of 0 ppm paclobutrazol concentration with ZA fertilizer resulted in the highest number of seeds per pod. It is suspected that the formation of amino acids, proteins, and fats necessary for the plant's pod formation will lead to perfect seed filling, thus increasing the number of seeds per pod. Research by Saptorini *et al*. (2019) found the treatment of paclobutrazol at 0 ppm affects the number of seeds per pod, while the presence of ZA (ammonium sulfate) can support the growth process of long bean plants. The long bean plants can grow more normally, with flower and pod development remaining undisturbed, leading to the production of more seeds per pod.

Table 6. Average number of seeds per pod of long bean plants due to the combination treatment of paclobutrazol concentration and type of N fertilizer

Paclobutrazol Concentration (ppm)	Number of Seeds per Pod			
	NPK (Control)	Urea	ZA	$KN0_3$
0	14.00 de	14.00 de	17.00 f	11.00 abc
150	10.67 ab	14.67 ef	14.00 de	12.00 abcde
200	10.00 a	11.67 abcd	10.67 ab	13.67 cde
250	13.0 bcde	10.00 a	12.67 abcde	12.67 abcde
HSD 5%		2.76		

Note: Average numbers followed by the same letter in the same row and column are not significantly different according to the HSD 5% test.

Table 7. Average fruit set of long bean plants due to paclobutrazol concentration and type of N fertilizer

Treatment	Fruit set (%)
Paclobutrazol Concentration (ppm)	
0	66.64 a
150	78.32 b
200	58.96 a
250	53.17 a
HSD 5%	10.06
Types of N Fertilizer	
NPK (Control)	64.94
Urea	61.13
ZA	63.34
KN03	67.88
HSD 5%	ns

Note: Average numbers followed by the same letter in the same row and column are not significantly different according to the HSD 5% test.

3.7. Fruit Set

The variance analysis results show that the single factor of paclobutrazol concentration significantly affected the fruit set, while the single factor of N fertilizer type did not significantly affect the fruit set of long bean plants. Table 7 shows that the 150 ppm paclobutrazol treatment was the best concentration for increasing the number of flowers and improving the fruit set. This treatment resulted in a fruit set percentage of 78.32%. The low fruit set value is due to not all blooming flowers successfully becoming fruit, caused by high rainfall and wind leading to flower drop in long bean plants. According to Jaya *et al*. (2020), high rainfall can cause failure during the flowering and fruiting stages due to inadequate pollination, thus affecting the harvest results. The potassium content in KNO_3 can enhance the metabolic process in long bean plants, thereby accelerating the growth process and facilitating a quicker transition from the vegetative to the generative phase, which supports faster flower and fruit formation. The application of paclobutrazol is highly significant in accelerating flowering, as evidenced by the fact that higher concentrations result in an earlier flowering age in long bean plan (Kurnianingsih *et al*. 2015).

4. CONCLUSION

The research results show that the combination treatment of 150 ppm paclobutrazol concentration and KNO_3 fertilizer provides the best results for the earliest flowering age at 29 DAP and the highest weight per pod at 43 grams/plant. The 150 ppm paclobutrazol concentration treatment gave the best results for the parameters of the number of leaves (age 49 - 77 DAP), flowering age (age 29 DAP), the number of pods per plant (weeks 1 and 2), weight per pod, and fruit set.

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