

Interactive Effects of Gibberellin Concentration and Guano Fertilizer Dosage on the Growth and Yield of Cauliflower (*Brassica oleracea* var. *botrytis* L.)

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Abstract

Background: Cauliflower (*Brassica oleracea* var. *botrytis* L.) is a high-value horticultural crop whose productivity is influenced by vegetative growth, nutrient availability, and curd development. However, information on the interactive effects of gibberellic acid (GA_3) and organic fertilizer, particularly under different nutrient inputs, remains limited. This study aimed to determine the individual and interactive effects of GA_3 concentration and guano fertilizer dosage on the growth and yield of cauliflower. **Methodology:** The experiment was conducted in Sedati, Ngoro District, Mojokerto Regency, using a factorial Randomized Complete Block Design with two factors, three replications, and 48 experimental units. GA_3 factor was applied at 0, 150, 200, and 250 ppm, while the fertilizer treatments consisted of NPK 16-16-16 as a reference and guano fertilizer at 40, 60, and 80 g plant⁻¹. Plant height, canopy diameter, curd weight, and aboveground biomass were recorded and analyzed using analysis of variance followed by the 5% Honestly Significant Difference test. **Findings:** Significant interactions between GA_3 concentration and guano dosage were observed for plant height at 28, 35, and 42 days after transplanting and for curd weight at harvest. The combination of 200 ppm GA_3 and 60 g plant⁻¹ guano produced the highest plant height, reaching 15.94, 18.72, and 23.22 cm at 28, 35, and 42 days after transplanting, respectively, and the highest curd weight of 524.78 g plant⁻¹. Independently, 200 ppm GA_3 produced the greatest canopy diameter (55.49 cm) and aboveground biomass (663.39 g plant⁻¹) at 42 days after transplanting and harvest, respectively. Guano at 60 g plant⁻¹ produced aboveground biomass (641.11 g plant⁻¹) comparable to NPK (634.19 g plant⁻¹). **Contributions:** These findings demonstrate that GA_3 effectiveness depends on organic nutrient input and highlight 200 ppm GA_3 combined with 60 g plant⁻¹ guano as a promising treatment under the experimental conditions.

Keywords: Cauliflower; Gibberelin; Guano fertilizer; Growth; Yield



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INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the high-value horticultural crops that is widely cultivated and demanded by consumers. The edible portion is the flower head (curd), which is rich in essential nutrients, including vitamin C, vitamin K, vitamin B6, folate, dietary fiber, potassium, magnesium, and antioxidant compounds that contribute to human health (Purnamasari, 2022). Food quality and safety are also important considerations in cauliflower production, particularly because residues from agricultural inputs may affect the quality of horticultural products (Azni et al., 2025). The curd, which is generally white to creamy white in color, is the economically important part of the plant and serves as the primary harvested product (Suhadiyah & Lestari, 2018). However, cauliflower productivity remains relatively low because plant growth and yield are often limited by suboptimal vegetative and generative development, which can reduce production and curd quality (Syofia & Munar, 2014). Therefore, improving vegetative growth and curd development through appropriate plant growth regulation and nutrient management is important for increasing cauliflower productivity.

One approach to improving cauliflower growth and yield is the application of the plant growth regulator gibberellin (GA₃) (Irvan & Adriana, 2017). Gibberellin promotes cell division and elongation, which can enhance vegetative growth and support the development of generative organs (Putri, 2025). Its physiological effects are also associated with processes such as flowering, parthenocarpy, and carbohydrate mobilization during seed germination (Anggraini et al., 2025). Exogenous gibberellin application can further stimulate plant metabolic activity and cell expansion, indicating that its effects are closely related to plant growth processes (Atika et al., 2018). In horticultural crops, appropriate gibberellin concentrations have been reported to improve growth and yield, including in cauliflower (Agustin & Fauzi, 2019). These findings indicate that GA₃ concentration is an important factor in determining plant responses; however, the response to GA₃ may also depend on the availability of nutrients required to support the resulting vegetative growth and yield formation.

In addition to plant growth regulators, nutrient availability is an important factor in determining plant growth and yield. Guano fertilizer is an organic fertilizer containing essential macronutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), which support plant growth and yield formation (Syofiani & Oktabrina, 2017). The relatively high phosphorus content of guano can contribute to root development, flower formation, and yield improvement (Saputri et al., 2025). Beyond supplying nutrients, guano application can improve soil fertility through its effects on soil physical and chemical properties, potentially reducing dependence on inorganic fertilizers (Fathoni et al., 2020). The gradual release of nutrients from guano may also provide a sustained nutrient supply during plant growth while supporting soil productivity. Guano fertilizer may provide a nutrient environment that supports the growth response induced by GA₃, but the extent to which different guano dosages modify the response of cauliflower to GA₃ requires further evaluation (Suryana et al., 2024).

Several studies have demonstrated that the application of gibberellin and guano fertilizer can improve the growth and yield of cauliflower. [Fadholi & Koesriharti \(2022\)](#) reported that gibberellin application significantly affected curd diameter, curd fresh weight, and harvest index. Similarly, [Tarigan et al., \(2024\)](#) reported that guano fertilizer significantly affected flowering time and curd weight. These findings demonstrate that GA₃ and guano fertilizer can influence important components of cauliflower growth and yield. However, previous studies have mainly evaluated the effects of these inputs separately, leaving limited information on their interaction when applied simultaneously to cauliflower.

The research gap addressed in this study is therefore related to the interaction between plant growth regulation and organic nutrient availability. In particular, it remains unclear whether the growth and yield response of cauliflower to GA₃ changes according to the level of organic nutrient input from guano fertilizer. It is also important to determine whether a combination of GA₃ and guano fertilizer can produce growth and yield performance comparable with a conventional NPK fertilization treatment. Evaluating these responses is relevant because the effectiveness of a plant growth regulator cannot be considered independently from the nutrient conditions supporting plant growth.

Therefore, this study was conducted to evaluate the individual and interactive effects of GA₃ concentration and guano fertilizer dosage on the growth and yield of cauliflower (*Brassica oleracea* var. *botrytis* L.). The study specifically evaluated plant height, canopy diameter, curd weight, and aboveground biomass as indicators of vegetative growth and yield performance. The results are expected to clarify how GA₃ responses vary under different guano fertilizer inputs and to provide experimental evidence regarding the performance of guano-based fertilization in comparison with the NPK reference treatment under the tested conditions.

METHOD

Research Methods

The experiment was conducted from December 2025 to March 2026 in Ngoro District, Mojokerto Regency, East Java, Indonesia. The experimental site was located at an altitude of 300 - 700 m above sea level, with temperatures ranging from 21 - 34 °C and annual rainfall of approximately 1,577 mm. Ngoro District has a tropical climate with two seasons, namely the rainy and dry seasons. The soils in Ngoro District are generally classified into alluvial soils in the northern part and regosol soils in the southern part of the district.

The materials used in this study included PM 126 F1 cauliflower seeds obtained from East West Seed, gibberellin (GA₃) as a plant growth regulator, guano fertilizer, NPK 16-16-16 fertilizer as the reference treatment, fungicides, insecticides, and water. The equipment used included hoes, shovels, seedling trays, hand sprayers, watering cans, measuring tapes, digital calipers, digital balances, and other supporting equipment.

The experiment was arranged in a Factorial Randomized Complete Block Design (RCBD) with two factors and three replications, resulting in 48 experimental

units. The first factor was gibberellin (GA_3) concentration consisting of four levels: $Z_0 = 0$ ppm, $Z_1 = 150$ ppm, $Z_2 = 200$ ppm, and $Z_3 = 250$ ppm. The second factor was guano fertilizer dosage consisting of four levels: $P_0 =$ NPK 16-16-16 fertilizer (control), $P_1 = 40$ g plant⁻¹, $P_2 = 60$ g plant⁻¹, and $P_3 = 80$ g plant⁻¹. The combination of these factors produced 16 treatment combinations, each replicated three times.

Research Procedure

Seedling Production and Transplanting

PM 126 F1 cauliflower seeds were obtained from Panah Merah and sown in seedling trays containing a mixture of soil and manure at a 1:1 (v/v) ratio. Healthy and uniform seedlings were selected and transplanted at 21 days after sowing (DAS). Transplanting was carried out in the afternoon to reduce transplanting stress. One seedling was transplanted into each planting hole according to the experimental layout. Immediately after transplanting, the plants were irrigated to maintain soil moisture and facilitate seedling establishment (Manurung et al., 2022).

Guano Fertilizer Application

Guano fertilizer was applied according to the designated treatments: $P_0 =$ NPK 16-16-16 fertilizer (control), $P_1 = 40$ g plant⁻¹, $P_2 = 60$ g plant⁻¹, and $P_3 = 80$ g plant⁻¹. The fertilizer was applied once at transplanting and incorporated into the soil to ensure a uniform distribution of nutrients and their availability during the early stages of plant growth and (Rizki et al., 2022). The fertilizer was placed at a depth of approximately 10–15 cm below the soil surface and incorporated into the soil. This application method was intended to promote root development and improve nutrient availability during the vegetative growth stage (Napitupulu, 2023).

Gibberellin (GA_3) Application

Gibberellin (GA_3) was applied according to the designated treatments: $Z_0 = 0$ ppm, $Z_1 = 150$ ppm, $Z_2 = 200$ ppm, and $Z_3 = 250$ ppm. The gibberellin solution was prepared using a commercial product containing 20% active ingredient. The amounts required to prepare the 150, 200, and 250 ppm solutions were 0.75 g, 1.00 g, and 1.25 g L⁻¹, respectively. Gibberellin was dissolved in water and sprayed onto the foliage using a 1-L hand sprayer until the leaves were thoroughly wetted. The application was conducted three times at 14, 28, and 42 days after transplanting (DAT), with spraying performed uniformly over the plant canopy.

Plant Maintenance

Plant maintenance consisted of irrigation, weeding, fertilization, and pest and disease management. Irrigation was performed according to field conditions to maintain adequate soil moisture. Weeds were removed manually to minimize competition for water and nutrients. Pest and disease control was carried out using appropriate fungicides and insecticides whenever required. All maintenance practices were applied uniformly across all experimental units throughout the growing period until harvest.

Data Collection and Statistical Analysis

The observed parameters included plant height, canopy diameter, curd weight, and aboveground biomass per plant. Plant height and canopy diameter were measured at 14, 21, 28, 35, and 42 days after transplanting (DAT), whereas curd weight and aboveground biomass per plant were recorded at harvest.

Table 1. Measurement Parameters, Methods, and Instruments Used for Data Collection

No.	Parameter	Measurement time	Measurement method	Instrument
1.	Plant height (cm)	14, 21, 28, 35, and 42 DAT	Measured from the base of the plant to the highest growing point	Measuring tape
2.	Canopy diameter (cm)	14, 21, 28, 35, and 42 DAT	Measured in two perpendicular directions and averaged.	Measuring tape
3.	Curd weight (g plant ⁻¹)	At harvest	The harvested curd was weighed to determine fresh weight	Digital analytical scale
4.	Aboveground biomass (g plant ⁻¹)	At harvest	Aboveground plant material was harvested and weighed	Digital analytical scale

The data were subjected to analysis of variance (ANOVA) at the 5% significance level to determine the effects of GA₃ concentration, fertilizer treatment, and their interaction. When treatment effects were significant, mean comparisons were performed using the Honestly Significant Difference (HSD) test at the 5% significance level.

RESULT AND DISCUSSION

Plant Height

The analysis of variance (ANOVA) showed that the interaction between gibberellin (GA₃) concentration and guano fertilizer dosage significantly affected the plant height of cauliflower (*Brassica oleracea* var. *botrytis* L.) at 28, 35, and 42 days after transplanting (DAT). In contrast, at 14 and 21 DAT, plant height was significantly affected only by the individual effects of gibberellin concentration and guano fertilizer dosage. The mean plant height values for the interaction treatments are presented in Table 2, whereas the mean values for the individual effects of gibberellin concentration and guano fertilizer dosage are presented in Table 3.

Table 2. Mean Plant Height of Cauliflower under the Interaction of Gibberellin Concentration and Guano Fertilizer Dosage at 28–42 Days After Transplanting (DAT)

Age	Gibberellin Concentration	Plant Height (cm)			
		Guano Fertilizer Dosage			
		Control (NPK)	40 g plant ⁻¹	60 g plant ⁻¹	80 g plant ⁻¹
28 DAT	0 ppm	12.06 ab	10.44 a	13.16 b	11.39 ab
	150 ppm	14.86 bc	13.61 bc	13.94 bc	13.84 bc
	200 ppm	15.90 c	13.44 bc	15.94 c	14.17 bc
	250 ppm	13.61 bc	13.61 bc	13.94 bc	12.61 ab
	HSD 5%	2.69			
35 DAT	0 ppm	15.50 ab	14.61 a	16.50 b	15.06 ab
	150 ppm	18.05 bc	16.28 ab	18.06 bc	17.39 bc
	200 ppm	18.67 c	16.68 b	18.72 c	17.39 bc
	250 ppm	18.00 bc	17.11 bc	17.85 bc	15.89 ab
	HSD 5%	1.83			
42 DAT	0 ppm	19.94 bc	17.17 a	20.61 bc	18.72 ab
	150 ppm	21.00 bc	19.61 b	21.44 c	20.33 bc
	200 ppm	21.96 cd	20.89 bc	23.22 d	21.28 c
	250 ppm	21.44 c	20.17 bc	21.45 c	19.89 bc
	HSD 5%	1.61			

Note: Values followed by the same letter within the same column and age are not significantly different according to the Honestly Significant Difference (HSD) test at the 5% significance level.

Based on Table 2, the combination of 200 ppm gibberellin and 60 g plant⁻¹ guano fertilizer produced the greatest plant height at 28, 35, and 42 days after transplanting (DAT), reaching 15.94 cm, 18.72 cm, and 23.22 cm, respectively. During the early vegetative stage, the individual application of 200 ppm gibberellin resulted in the greatest plant height, measuring 8.25 cm at 14 DAT and 11.04 cm at 21 DAT. Similarly, the individual application of 60 g plant⁻¹ guano fertilizer produced the greatest plant height, reaching 7.85 cm at 14 DAT and 10.60 cm at 21 DAT.

The greater plant height observed following the application of 200 ppm gibberellin indicates that this concentration effectively optimized plant physiological activity during the vegetative growth stage. Gibberellin promotes cell division and cell elongation, thereby stimulating stem elongation and overall plant growth. Appropriate concentrations of gibberellin enhance hormonal activity, whereas concentrations that are too low or too high may result in suboptimal growth responses. These findings are consistent with those reported by [Utami & Hariyono \(2022\)](#), who found that gibberellin application enhanced the vegetative growth of cauliflower by promoting cell division and elongation.

Table 3. Mean Plant Height of Cauliflower under the Individual Effects of Gibberellin Concentration and Guano Fertilizer Dosage at 14 and 21 Days After Transplanting (DAT).

Treatment	Plant Height (cm)	
	14 DAT	21 DAT
Gibberellin Concentration		
0 ppm	6.45 a	8.95 a
150 ppm	7.53 b	10.14 b
200 ppm	8.25 c	11.04 c
250 ppm	7.71 bc	9.94 b
HSD 5%	0.61	0.83
Guano Fertilizer Dosage		
Control (NPK)	7.66 b	10.18 ab
40 g plant ⁻¹	7.03 a	9.50 a
60 g plant ⁻¹	7.85 b	10.60 b
80 g plant ⁻¹	7.40 ab	9.80 ab
HSD 5%	0.61	0.83

Note: Values followed by the same letter within the same treatment are not significantly different according to the Honestly Significant Difference (HSD) test at the 5% significance level.

The individual application of 60 g plant⁻¹ guano fertilizer also produced superior plant growth compared with the other fertilizer dosages. This response was likely due to the adequate supply of nutrients without causing nutrient imbalance in the soil. Nitrogen contained in guano fertilizer contributes to chlorophyll formation and protein synthesis, thereby enhancing photosynthesis, whereas phosphorus supports root development and energy transfer during plant growth. These findings agree with those of [Samputri et al., \(2023\)](#) who reported that guano fertilizer promotes plant growth by increasing the availability of essential macronutrients during the vegetative stage.

The significant interaction observed at 28–42 DAT indicates that the effectiveness of gibberellin depended on nutrient availability in the growing medium. The combination of 200 ppm gibberellin and 60 g plant⁻¹ guano fertilizer likely created a balanced condition between hormonal stimulation and nutrient availability, resulting in more vigorous vegetative growth. Gibberellin stimulates cell division and elongation, whereas nitrogen, phosphorus, and potassium supplied by guano fertilizer support new tissue formation and plant metabolic processes. Consequently, plants receiving this treatment combination exhibited greater plant height than those under the other treatment combinations ([Dahlia & Setiono, 2020](#)).

The results of the present study are also consistent with those reported by [Tarigan et al., \(2024\)](#) who demonstrated that the combined application of gibberellin and guano fertilizer enhanced the growth of cauliflower. Adequate nutrient availability, together with optimal hormonal activity, promotes vegetative development, resulting in greater plant height than treatments without the combined application of these two factors.

Canopy Diameter

The analysis of variance (ANOVA) showed that the interaction between gibberellin (GA₃) concentration and guano fertilizer dosage did not significantly affect the canopy diameter of cauliflower (*Brassica oleracea* var. *botrytis* L.) throughout the observation period. However, the individual effect of gibberellin concentration significantly affected canopy diameter at 21, 28, 35, and 42 days after transplanting (DAT). Likewise, the individual effect of guano fertilizer dosage significantly affected canopy diameter at 28, 35, and 42 DAT. The mean canopy diameter values for the individual effects of gibberellin concentration and guano fertilizer dosage are presented in Table 4.

Table 4. Mean Canopy Diameter of Cauliflower under the Individual Effects of Gibberellin Concentration and Guano Fertilizer Dosage at 14 – 42 Days After Transplanting (DAT)

Treatment	Canopy Diameter (cm)				
	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT
Gibberellin Concentration					
0 ppm	12.46	19.68 a	29.42 a	38.02 a	47.19 a
150 ppm	12.50	22.62 ab	31.45 ab	40.75 b	50.25 b
200 ppm	12.86	23.31 b	34.66 b	45.47 d	55.49 c
250 ppm	12.69	21.67 ab	32.59 b	42.44 c	51.85 b
HSD 5%	ns	3.47	2.38	1.56	2.06
Guano Fertilizer Dosage					
Control (NPK)	12.74	22.16	33.34 b	43.16 b	52.40 b
40 g plant ⁻¹	12.60	21.54	31.61 ab	40.77 a	50.49 ab
60 g plant ⁻¹	12.72	22.08	32.96 b	42.98 b	52.49 b
80 g plant ⁻¹	12.46	21.49	30.19 a	39.77 a	49.39 a
HSD 5%	ns	ns	2.38	1.56	2.06

Note: Values followed by the same letter within the same treatment are not significantly different according to the Honestly Significant Difference (HSD) test at the 5% significance level. ns = not significant.

Based on Table 4, the application of 200 ppm gibberellin resulted in the greatest canopy diameter at 21, 28, 35, and 42 days after transplanting (DAT), measuring 23.31 cm, 34.66 cm, 45.47 cm, and 55.49 cm, respectively. Under the guano fertilizer treatments, the largest canopy diameter was obtained with the NPK control (P₀), reaching 33.34 cm at 28 DAT, 43.16 cm at 35 DAT, and 52.40 cm at 42 DAT. However, these values were not significantly different from those obtained with 60 g plant⁻¹ guano fertilizer.

The greater canopy diameter observed with the application of 200 ppm gibberellin indicates that this concentration effectively promoted vegetative growth in cauliflower. Gibberellin stimulates cell division and cell elongation, thereby enhancing leaf expansion and canopy development. A wider canopy increases the leaf surface area available for light interception, which improves photosynthetic efficiency and promotes greater assimilate production. Consequently, plants receiving 200 ppm

gibberellin exhibited superior vegetative growth compared with the other treatments. These findings are consistent with those reported by [Triani et al., \(2020\)](#) who found that the application of gibberellin at an optimum concentration enhanced vegetative growth through increased canopy development and leaf expansion.

The individual application of 60 g plant⁻¹ guano fertilizer produced a canopy diameter comparable to that of the NPK control. This result indicates that guano fertilizer supplied sufficient nutrients to support canopy development. Nitrogen promotes chlorophyll formation and vegetative tissue growth, whereas phosphorus and potassium support metabolic processes and improve the efficiency of photosynthate utilization. Adequate nutrient availability therefore promotes optimal leaf development, resulting in increased canopy diameter. These findings suggest that guano fertilizer has the potential to serve as an alternative nutrient source capable of producing plant growth comparable to that achieved with inorganic fertilization ([Tangguda et al., 2022](#)).

The absence of a significant difference between the NPK control (P₀) and the application of 60 g plant⁻¹ guano fertilizer (P₂) indicates that this dosage was sufficient to meet the nutrient requirements of cauliflower during the vegetative stage. This finding suggests that guano fertilizer can partially substitute inorganic fertilizer without reducing vegetative growth. Similar results were reported by [Renatha & Herawati \(2023\)](#), who stated that the application of organic fertilizer enhanced the vegetative growth of cauliflower and produced growth comparable to that obtained with conventional fertilization.

Overall, the results indicate that the application of 200 ppm gibberellin was the most effective treatment for increasing canopy diameter. In addition, the application of 60 g plant⁻¹ guano fertilizer produced canopy development comparable to that of the NPK control, indicating its potential as a sustainable alternative fertilizer for cauliflower cultivation.

Curd Weight

The analysis of variance (ANOVA) showed that the interaction between gibberellin (GA₃) concentration and guano fertilizer dosage significantly affected the curd weight of cauliflower (*Brassica oleracea* var. *botrytis* L.). In addition, the individual effects of gibberellin concentration and guano fertilizer dosage also significantly affected curd weight. The mean curd weight values for the interaction between gibberellin concentration and guano fertilizer dosage are presented in Table 5. Based on Table 5, treatment combination 200 ppm gibberellin and 60 g plant⁻¹ guano fertilizer produced the greatest curd weight (524.78 g), which was significantly higher than most of the other treatment combinations. In contrast, the lowest curd weight (277.11 g) was recorded in the treatment 150 ppm gibberellin and 40 g plant⁻¹ guano fertilizer.

The greater curd weight obtained with treatment indicates that the application of 200 ppm gibberellin combined with 60 g plant⁻¹ guano fertilizer created favorable conditions for cauliflower growth during both the vegetative and generative stages. Gibberellin promotes cell division and cell elongation while facilitating the translocation of photosynthates to sink organs, including the developing curd. At the same time, guano fertilizer supplies essential macronutrients, particularly nitrogen,

phosphorus, and potassium, which support photosynthesis, tissue formation, and reproductive organ development. The combined effects of these treatments enhanced biomass accumulation, resulting in increased curd weight (Kiuk et al., 2024).

Table 5. Mean Curd Weight of Cauliflower under the Interaction of Gibberellin Concentration and Guano Fertilizer Dosage

Treatment	Curd Weight (g)			
Gibberellin Concentration	Guano Fertilizer Dosage			
	Control (NPK)	40 g plant ⁻¹	60 g plant ⁻¹	80 g plant ⁻¹
0 ppm	387.22 ab	313.11 a	328.67 a	307.89 a
150 ppm	388.11 ab	277.11 a	385.00 ab	286.11 a
200 ppm	473.78 b	368.67 ab	524.78 b	351.11 a
250 ppm	376.00 ab	302.11 a	365.33 ab	343.11 a
HSD 5%	113.40			

Note: Values followed by the same letter within the same row and column are not significantly different according to the Honestly Significant Difference (HSD) test at the 5% significance level.

The increase in curd weight was also closely associated with the plant's ability to produce and allocate assimilates to the developing curd. The larger canopy diameter observed under the 200 ppm gibberellin treatment increased light interception, thereby enhancing photosynthetic activity and assimilate production. These assimilates were subsequently translocated and accumulated in the curd, contributing to its greater weight. Similar results were reported by Cahyani (2021), who found that the combined application of gibberellin and guano fertilizer improved the growth and yield of cauliflower through enhanced nutrient availability and increased physiological activity.

Furthermore, the application of 60 g plant⁻¹ guano fertilizer appeared to provide an adequate nutrient supply during curd development. Sufficient and balanced nutrient availability supports curd initiation and enlargement. Phosphorus plays an important role in energy transfer and the development of reproductive organs, whereas potassium enhances the translocation of photosynthates to sink tissues. Consequently, plants receiving this dosage produced heavier curds than those receiving the other fertilizer treatments. These findings are consistent with those of Lisda (2023), who reported that guano fertilizer increased cauliflower yield by improving nutrient availability during the generative stage.

Overall, the results indicate that the combination of 200 ppm gibberellin and 60 g plant⁻¹ guano fertilizer was the most effective treatment for increasing curd weight. This finding suggests a synergistic relationship between the physiological effects of gibberellin and the nutrient supply provided by guano fertilizer, resulting in more effective curd development than the other treatment combinations.

Aboveground Biomass per Plant

The analysis of variance (ANOVA) showed that the interaction between gibberellin (GA₃) concentration and guano fertilizer dosage did not significantly affect

the aboveground biomass per plant of cauliflower (*Brassica oleracea* var. *botrytis* L.). However, the individual effects of gibberellin concentration and guano fertilizer dosage significantly affected aboveground biomass per plant. The mean aboveground biomass per plant values for the individual effects of gibberellin concentration and guano fertilizer dosage are presented in Table 6.

Table 6. Mean Aboveground Biomass per Plant of Cauliflower under the Individual Effects of Gibberellin Concentration and Guano Fertilizer Dosage

Treatment	Aboveground Biomass per Plant (g)
Gibberellin Concentration	
0 ppm	553.64 a
150 ppm	584.47 a
200 ppm	663.39 b
250 ppm	569.56 a
HSD 5%	49.13
Guano Fertilizer Dosage	
Control (NPK)	634.19 b
40 g plant ⁻¹	535.75 a
60 g plant ⁻¹	641.11 b
80 g plant ⁻¹	560.00 a
HSD 5%	49.13

Note: Values followed by the same letter within the same treatment are not significantly different according to the Honestly Significant Difference (HSD) test at the 5% significance level.

Based on Table 6, the application of 200 ppm gibberellin produced the greatest aboveground biomass per plant (663.39 g), which was significantly higher than that of the other gibberellin treatments. Under the guano fertilizer treatments, the application of 60 g plant⁻¹ produced the greatest aboveground biomass per plant (641.11 g), which was comparable to that obtained with the NPK control (634.19 g).

The greater aboveground biomass per plant observed following the application of 200 ppm gibberellin indicates that this concentration effectively promoted both vegetative growth and biomass accumulation in cauliflower. Gibberellin stimulates cell division and cell elongation, thereby enhancing the development of vegetative organs. Improved vegetative growth increases the photosynthetic capacity of the plant, resulting in greater biomass accumulation. Consequently, plants treated with 200 ppm gibberellin produced significantly greater aboveground biomass than those receiving the other gibberellin concentrations. These findings are consistent with those reported by [Widiatmanta & Rohman \(2017\)](#), who demonstrated that gibberellin application increased the total fresh biomass of cauliflower through enhanced physiological activity and vegetative growth.

The application of 60 g plant⁻¹ guano fertilizer produced the greatest aboveground biomass per plant among the fertilizer treatments. This response suggests that the applied dosage supplied sufficient nutrients to support plant growth throughout the growing period. Nitrogen contributes to chlorophyll formation and vegetative tissue development, phosphorus is involved in energy transfer and root

development, whereas potassium enhances the translocation of photosynthates throughout the plant. The balanced availability of these nutrients promotes vigorous vegetative and reproductive growth, leading to greater biomass accumulation (Pirhat, 2025).

Interestingly, the application of 60 g plant⁻¹ guano fertilizer produced aboveground biomass comparable to that of the NPK control. This finding indicates that guano fertilizer has considerable potential as an alternative nutrient source for cauliflower cultivation. The comparable performance of the 60 g plant⁻¹ guano treatment suggests that this dosage can support plant growth while reducing reliance on inorganic fertilizers. Similar findings were reported by Purnama & Rachman (2024), who demonstrated that guano fertilizer improved the growth and yield of cauliflower by increasing the availability of essential macronutrients. Overall, the results indicate that the application of 200 ppm gibberellin and 60 g plant⁻¹ guano fertilizer independently produced the greatest aboveground biomass per plant. Increased aboveground biomass reflects greater biomass accumulation resulting from vigorous vegetative growth and well-developed reproductive organs.

CONCLUSION

The interaction between gibberellin concentration and guano fertilizer dosage significantly affected plant height at 28, 35, and 42 DAT and curd weight at harvest. The combination of 200 ppm gibberellin and 60 g plant⁻¹ guano produced the highest plant height and curd weight, reaching 23.22 cm and 524.78 g, respectively. As main effects, 200 ppm gibberellin significantly increased canopy diameter and aboveground biomass, while 60 g plant⁻¹ guano produced aboveground biomass comparable to the NPK reference treatment. These findings contribute to clarifying that gibberellin responses can vary according to the level of guano fertilizer input and provide information on a guano-based fertilization treatment that performed comparably with NPK for aboveground biomass under the experimental conditions. The study was limited to one location, cultivar, growing season, and treatment range; therefore, further studies under different environmental and cultivation conditions are needed to validate these findings.

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