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Optimizing the Application of Complete Microfertilizer in Fertigation for Cayenne Pepper (*Capsicum frutescens* L.)

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Abstract

Cayenne pepper (*Capsicum frutescens*) is one of the important horticultural commodities in Indonesia. According to Central Statistics Agency data, annual consumption has been rising amid fluctuating production, including a 37.68-thousand-ton decline in 2023 compared with 2022. Cayenne pepper requires a specific nutrient profile to achieve optimal yields. Micronutrients, including boron, copper, iron, manganese, molybdenum, and zinc, are vital for photosynthesis, flower development, and nutrient uptake; deficiencies impair growth, fruit quality, and disease resistance, underscoring the need for balanced fertilization. Micronutrient deficiencies can reduce plant growth, fruit quality, and disease susceptibility. Research on micronutrient provision in cayenne pepper plants remains limited. This research aims to determine the most effective method of nutrient application for cayenne pepper plants. The design used was a single-factor randomized group design. The results of the study demonstrate that micronutrient applications can increase the height and diameter of cayenne pepper stems, with foliar spray applications yielding the best response in terms of vegetative parameters. However, micro-nutrient application has not significantly affected the yield and yield components of cayenne pepper.

Keywords: Ferads application, fertigation, micronutrient, precision fertilization

Introduction

Cayenne pepper (*Capsicum frutescens* L.) is a valuable horticultural crop in Indonesia, offering health benefits like antioxidants, phenols, capsaicinoids, vitamin C, and anthocyanins (Loizzo et al., 2015; Padmanabhan et al., 2016). BPS data show rising consumption in 2023, up 41.2 thousand tons from 2022, yet production fell by 37.68 thousand tons (Statistics Indonesia, 2024). Proper fertilization addresses soil nutrient gaps, as cayenne requires balanced macro- and micronutrients; deficiencies in elements like boron, copper, iron, manganese, and zinc reduce growth, yield, and health, limiting dry matter akin to phosphorus or calcium shortages (Bosland & Votava, 2012; Magalhães et al., 2022; Martens & Westermann, 1991).

Micronutrient applications via soil, foliar, or fertigation boost yields, as seen in chilies, tomatoes, and peanuts (Baloch et al., 2008; Muthukrishnan, 1993; Navrot & Levin, 1976; Patil et al., 2008; Singh et al., 2000).

Fertigation with drip irrigation enhances efficiency, reduces water use, and increases yields by 61% over traditional methods by delivering soluble nutrients directly to the roots (Dixon & Liu, 2022; Jat et al., 2011; Naswir et al., 2009). Fertilizers applied as foliar sprays improve growth, nutrient uptake, fruit yield, and quality (e.g., vitamin C, carotenoids) in peppers (Wolska et al., 2018; Muzadi, 2020).

Recent studies on micronutrients in chili are scarce, hindering the development of optimal

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recommendations. This research evaluates the most effective micro-fertilizer method for cayenne pepper under polyethylene mulch fertigation.

Materials and Methods

The research took place from April to October 2024 at the Cikarawang Experimental Farm, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University. The planting material used in this research is the cayenne pepper cultivar 'Asmoro'. Other materials used include cattle manure, urea, SP-36, and KCl as basic fertilizers for cayenne pepper plants, and Meroke® Fitoflex compound micro-fertilizer.

The design used was a randomized complete block design with application method as a single factor: control, foliar spray, drip irrigation, and soil drench. The fertilizer concentrations are in Table 1, as described by Umami et al. (2022). Air temperature and humidity were measured using an Elitech GSP-6 data logger. Rainfall data were obtained from the Bogor Climatology Station.

Each treatment was repeated 5 times, yielding 20 experimental units. Each experimental unit contained 24 plants, yielding a total population of 480. Micro fertilizers were applied at 2-15 weeks after planting (WAP), with a 2-week interval. N, P, and K fertilization using urea, SP-36, and KCl fertilizers, each with a concentration based on FERADS recommendations (Susila, 2023), through soil analysis results. FERADS is a decision support system (DSS) computer program that determines fertilization recommendations for vegetable crops based on soil analysis. The results of FERADS-based fertilization recommendations can be applied to vegetable crops via drip irrigation or manual application. During the research, temperature, humidity, and light intensity measurements were taken using an automatic data logger. Observations were made on several characters during the study, including vegetative and generative characters, as well as yield and yield components. Data was analyzed using analysis of variance (ANOVA) to determine whether there was an effect of the treatment tested. Results showing a significant effect will be further analyzed using the duncan multiple range Test (DMRT) at the 5% level to examine the differences between treatments. Data processing was performed using SAS 9.1, Microsoft Excel, and STAR data processing software.

Results and Discussion

General Environment

Before planting, soil analysis was conducted to assess soil chemical properties and nutrient levels, and the FERADS program was used to obtain fertilization recommendations for cayenne pepper. The soil analysis showed the following results (Table 2) soil C-organic content of 1.67%, pH 6.36, total N 0.22%, available P 23.04 ppm (medium), available K 373.00 ppm (very high). Based on these results, the fertilization recommendations for chilli on 150 m^2 of land were 0.49 t/ha Urea, 0.31 t/ha SP36,

Table 1

*Micro-fertilizer * Application Methods and Fertilizer Concentrations*

Application methods	Fertilizer concentrations (mg/L)
Control (without application)	0
Foliar spray	125
Drip irrigation	125
Soil drench	125

Notes. *Meroke Fitoflex®

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6.5 t/ha dolomite, and 28.65 t/ha organic matter (Susila, 2023).

Temperatures, relative humidity, and light intensity during the study are presented in Table 3. In general, the average daily temperature at the research site was 27.8° C. The average air humidity during the study was 80%, and the average light intensity was 58,773 lux.

Effect of Micro-fertilizer Application Methods on Cayenne Pepper Vegetative Growth

The analysis of variance results indicated that methods of applying micro fertilizers significantly affected plant height at 4, 8, and 10 weeks after planting (Table 4). Plant height at 10 weeks ranged from 103.16 to 113.36 cm, with the foliar spray application resulting in the tallest plants (Figure 1). According to Malik et al. (2020), leaf application of micronutrients significantly enhances growth parameters, including plant height, branch number, and yield attributes, such as fruit number and weight. The direct application of nutrients to plant leaves enables rapid absorption into plant tissues and organs (Anees et al., 2011).

The full-concentration micro-fertilizer treatment does not significantly affect stem diameter and shows only a noticeable effect at the 4-week mark after planting (Table 4). The average stem diameter of plants at 10 weeks after planting ranged from 10.88 to 11.88 mm (Figure 2). Providing balanced, sufficient nutrients will optimize plant growth.

Effect of Micro-fertilizer Application Methods on Cayenne Pepper Generative Growth

Micronutrient fertilizers do not affect the age at which 50% of cayenne pepper plants reach anthesis. On average, plants attain 50% anthesis 41–43.4 days after planting (Table 5). Optimal environmental conditions—such as temperature, soil quality, salinity, water

Table 2

Cikarawang Soil Chemical Properties

Parameter	Values	Unit	Methods
pH	6.36		pH meter
Organic C content	1.67	%	Spectrophotometer
Cation exchange capacity	18.11	cmol/kg	Titrimetric
Total-N	0.22	%	Kjeldahl
Available P	23.00	ppm	Spectrophotometer
Available K	373.00	ppm	AAS
Total-Fe	55484.00	ppm	AAS
Total-Mn	2322.00	ppm	AAS
Total-Cu	53.10	ppm	AAS
Total-Zn	175.40	ppm	AAS
Total-B	12.83	ppm	Spectrophotometer

Table 3

Daily Average Temperature, Humidity, and Light Intensity in June-November 2024

Parameter	Values
Temperature	27.80 °C
Humidity	80.00 %
Light intensity	58,773.33 lux

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Table 4

Effect of Micro-fertilizer Application Methods on Cayenne Pepper Plant Height and Stem Diameter

Application methods	Plant height (cm) (WAP)				Stem diameter (cm) (WAP)			
	4	6	8	10	4	6	8	10
Control	42.76 b	75.36	90.48 b	103.16 c	5.28 b	7.96	9.10	10.88
Foliar spray	43.96 ab	78.00	95.60 a	113.36 a	5.65 a	8.22	9.54	11.49
Drip irrigation	40.58 c	75.08	90.24 b	104.00 bc	5.22 b	7.94	9.21	11.34
Soil drench	44.72 a	79.20	94.08 ab	107.04 b	5.63 a	8.36	9.51	11.88
	0.0008	0.0906	0.0340	0.0005	0.0351	0.3058	0.1620	0.2530
Significance	**	ns	*	**	*	ns	ns	ns
CV (%)	2.79	3.55	3.21	2.28	4.64	4.92	3.68	4.21
Normality	0.77	0.25	0.13	0.66	0.37	0.91	0.84	0.13
Homogeneity	0.97	0.94	0.93	0.79	0.66	0.58	0.52	0.93

Notes. Values followed by different letters in the same column are significantly different according to DMRT (α = 0.05). WAP = week after planting.

Figure 1

Cayenne Pepper Height at 10 Weeks After Planting Across Various Methods of Micro-fertilizer Application

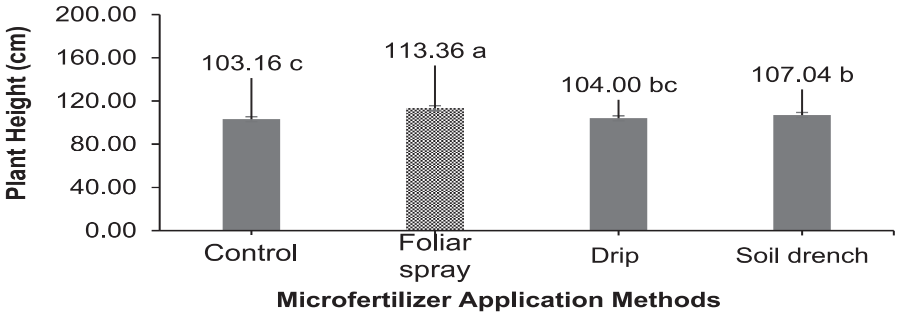
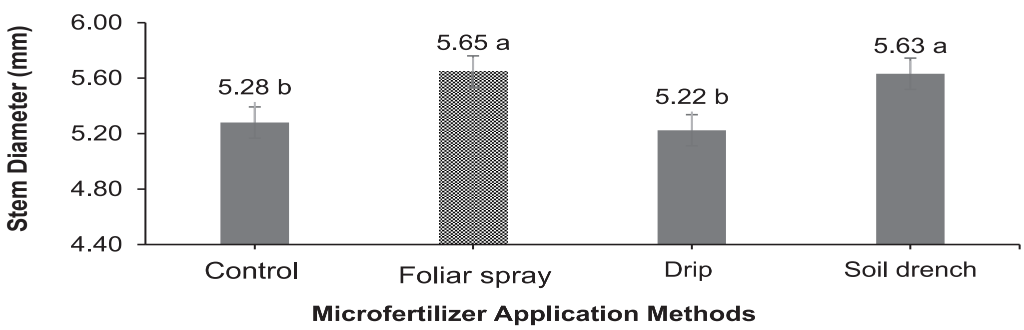


Figure 2

Cayenne Pepper Stem Diameter at 4 WAP Across Various Methods of Micro Fertilizer Application



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availability, and light—promote timely flowering, whereas extremes in temperature, salinity, or water stress delay it; studies by Lee et al. (2023) and Riboni et al. (2014) confirm that stress can either hasten or postpone flowering.

Micro-fertilizer application methods did not significantly affect the number of flowers or fallen flowers on cayenne pepper plants 5 weeks after planting (Figure 3). This could be because cayenne pepper plants have a small number of flowers at this stage, making any differences less noticeable.

The number of chilli flowers is affected by various factors such as temperature and nutrient availability. Research by Rosmaina et al. (2022) suggests that high temperatures can significantly reduce chilli flower production. Temperatures above 32.86 °C can decrease

Table 5

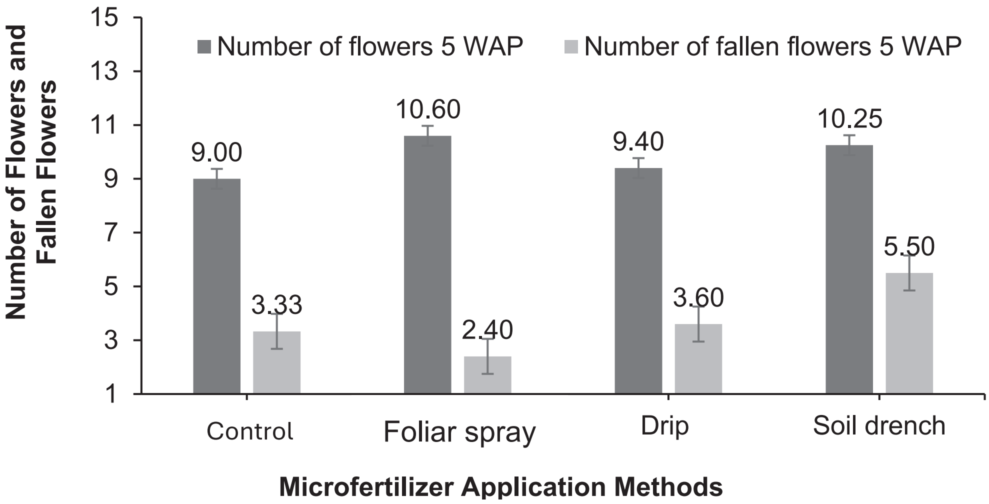
Effect of Micro-fertilizer Application Methods on Days to 50% Anthesis, Flower Number, and Number of Fallen Flowers

Treatments	Days to 50% anthesis	Flower number per plant at 5 WAP	Number of flowers falls per plant at 5 WAP
Application methods			
Control	41.00	9.00	3.33
Foliar spray	43.40	10.60	2.40
Drip irrigation	41.80	9.40	3.60
Soil drench	41.75	10.25	5.50
P-value	0.1765	0.8750	0.2120
Significance	ns	ns	ns
CV (%)	3.97	36.29	57.15
Normality	0.30	0.395	0.556
Homogeneity	0.67	0.785	0.286

Notes. Values followed by different letters in the same column are significantly different according to DMRT (α = 0.05). WAP = week after planting.

Figure 3

Number of Flowers and Number of Fallen Flowers of Cayenne Pepper across Various Methods of Micro-fertilizer Application



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chilli production by 50%, and temperatures of 39 °C can reduce output by 87.52%. Akram (2017) highlighted the importance of sufficient nutrients, especially phosphorus (P) and potassium (K), for the growth and flowering of chilli plants. An optimal application of 100 kg/ha P and 120 kg/ha K results in the highest number of flowers per plant.

Effect of Micro-fertilizer Application Methods on Cayenne Pepper Yield and Yield Components

Analysis of variance showed no significant effects of micro-fertilizer methods on fruit length (average 6.21 cm, max 6.28 cm), weight (2.63–2.77 g), number per plant (peaking at 343 fruits per plant via foliar spray at harvest 4), marketable/unmarketable weights, or productivity (14.18–15.14 t/ha average. The productivity in this study exceeds the national 7.8 t/ha (Statistics Indonesia, 2024).

Genetic traits (Sayekti et al., 2021), cultivation, including pruning, NPK frequency <21 days; (Tjokrosumarto, 2017; Anatalia et al., 2021), macronutrients (N, P, K for growth per flowering; Kumar et al., 2021; Malik et al., 2020), and environment primarily drive these traits, as micronutrients (Zn, Fe, B) support metabolism/enzymes without directly boosting fruit production (Ahmed et al., 2024; Baloch et al., 2008; Ramgiry et al., 2019; Singh, 2023). Application of nutrients through fertigation allow the delivery of soluble nutrients directly to the root zone, enhancing nutrient uptake efficiency, minimizing losses through volatilization, runoff, and leaching, and supporting steady growth, higher chili yields, a higher proportion of grade A fruit, and 25%–40% fertilizer savings (Eleni, 2023; Tinaprilla et al., 2024). Foliar spraying enables rapid leaf uptake despite cuticle barriers influenced by thickness and composition (Fernandez & Brown, 2013), whereas soil drenching dissolves nutrients into soil moisture for microbe-enhanced root uptake (Podar & Maathuis, 2022).

Micro-fertilizer application methods did not significantly affect individual fruit weight (Table 7). In general, the weight of cayenne pepper fruits ranged from 2.63 to 2.77 g, with the drip application method yielding the highest value (Figure 5). Chilli fruit weight is influenced by several factors, especially those related to farming methods, environmental conditions, and plant genetics. Plant management methods such as leaf pruning can significantly affect the production characteristics of chilli, including fruit

Table 6

Effect of Micro-fertilizer Application Methods on Cayenne Pepper Fruit Length

Treatments	Fruit length (cm)									
	Harvest									
	1	2	3	4	5	6	7	8	9	10
Application methods										
Control	6.60	6.70	6.18	6.28	6.13	6.16	6.22	6.14 a	6.19	6.15
Foliar spray	6.43	6.36	6.26	6.32	6.21	5.94	6.04	5.99 a	6.31	6.27
Drip irrigation	6.38	6.43	6.20	6.36	6.40	6.18	6.34	6.27 a	6.26	6.22
Soil drench	6.44	6.26	6.21	6.18	6.23	6.10	6.15	5.25 b	6.28	6.24
P-value	0.50	0.06	0.94	0.64	0.32	0.69	0.60	0.00	0.87	0.87
Significance	ns	ns	ns	ns	ns	ns	ns	**	ns	ns
CV (%)	3.46	3.63	3.45	3.65	3.58	5.61	5.53	5.79	3.7	3.72
Normality	0.31	0.28	0.91	0.15	0.98	0.46	0.46	0.46	0.24	0.24
Homogeneity	0.91	0.98	0.80	0.30	0.54	0.94	0.94	0.94	0.13	0.13

Note. Values with different letters in the same column are significantly different according to DMRT (α = 0.05).

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weight. Proper pruning can increase the number of fruits per plant and enhance the total fruit weight (Tjokrosumarto, 2017).

Statistically, micro-fertilizer application methods did not significantly affect the number of fruits per plant; it increased until the sixth harvest (16 WAP). The average number of fruits per plant was highest in the fourth harvest, with an average of 343 fruits, and the foliar spray application method gave the highest number of chili fruits per plant compared to other treatments, while the lowest number of fruits per plant was in the first harvest, with an average of 53 fruits. Micronutrients do not significantly affect the number of chilli fruits, which might be related to the fact that micronutrients such as zinc, iron, and boron primarily support metabolic processes rather than directly affecting fruit production. They are essential for enzyme function and nutrient absorption but have no direct impact on the reproductive process that determines fruit number and quantity (Baloch et al., 2008; Ramgiry et al., 2019).

Fruit production is more closely related to macronutrients (nitrogen, phosphorus, potassium) than to micronutrients (Kumar et

Figure 4

Cayenne Pepper Fruit Length Across Various Methods of Micro-fertilizer Application

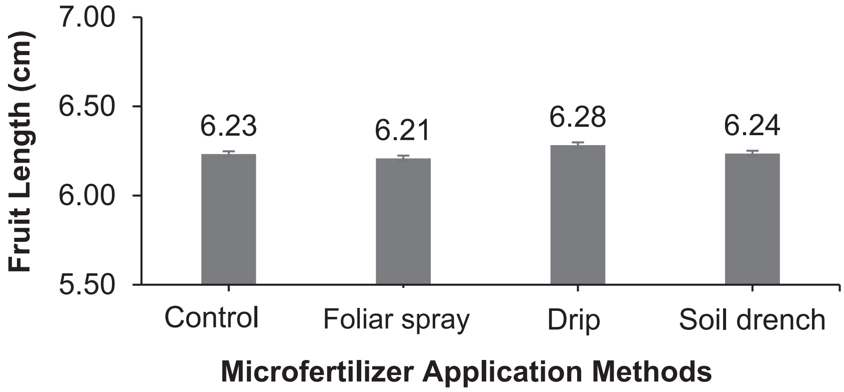

Table 7

Effect of Micro-fertilizer Application Method on Individual Cayenne Pepper Fruit Weight

Treatments	Weight per fruit (g)									
	Harvest									
	1	2	3	4	5	6	7	8	9	10
Application methods										
Control	3.12	3.02	2.83	2.97	2.63	2.45	2.51	2.48	2.48	2.18
Foliar spray	3.11	2.94	2.84	2.85	2.85	2.36	2.46	2.40	2.95	2.65
Drip irrigation	2.99	3.02	2.77	2.94	2.71	2.67	2.83	2.80	2.75	2.45
Soil drench	3.19	2.92	2.84	2.89	2.75	2.54	2.59	2.52	2.80	2.50
P-value	0.72	0.92	0.96	0.92	0.68	0.48	0.30	0.26	0.13	0.13
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	8.67	9.63	8.33	9.88	10.71	12.57	12.12	12.35	10.53	11.82
Normality	0.64	0.18	0.40	0.70	0.37	0.89	0.89	0.89	0.18	0.18
Homogeneity	0.56	0.86	0.84	0.80	0.95	0.57	0.57	0.57	0.55	0.55

Note. Values with different letters in the same column are significantly different according to DMRT (α = 0.05).

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al., 2021). Macronutrients are essential for vegetative growth and flowering, which are important stages in fruit development. Without adequate levels of macronutrients, plants may not be able to produce large quantities of fruit regardless of the availability of micronutrients (Malik et al., 2020; Sugiyanta, 2018).

ANOVA results indicate no significant effect of micro-fertilizer application methods on marketable (Table 9) or non-marketable fruit weight (Table 10). Marketable fruit weight rose from the first to the fourth harvest, then declined from the fifth onward.

Micronutrients like zinc, iron, and boron support metabolism and enzyme functions essential for plant health, yet they exert minimal direct influence on chilli fruit quality traits such as taste, size, or color compared to macronutrients (e.g., nitrogen, phosphorus, potassium) (Singh, 2023). These macronutrients drive flowering and fruit development, directly enhancing quality. Foliar fertilization boosts leaf activity and water uptake, indirectly aiding root growth, and provides faster nutrient absorption than soil

Figure 5

Weight per fruit of cayenne pepper at 5 WAP across various methods of micro-fertilizer application.

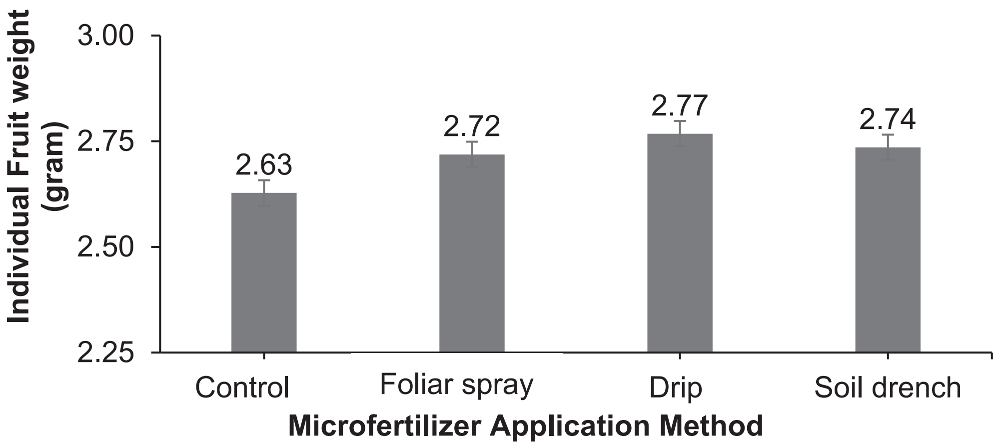

Table 8

Effect of Micro-fertilizer Application Methods on the Number of Cayenne Fruits per Plant

Application methods	Number of fruits per plant									
	Harvest									
	1	2	3	4	5	6	7	8	9	10
Control	68.00	173.00	219.00	368.00	228.00	322.00	153.00	159.00	161.00	157.00
Foliar spray	47.00	173.00	285.00	370.00	234.00	337.00	147.00	151.00	146.00	162.00
Drip irrigation	36.00	134.00	248.00	322.00	239.00	387.00	174.00	179.00	178.00	175.00
Soil drench	61.00	172.00	230.00	312.00	246.00	293.00	117.00	123.00	178.00	174.00
P-value	0.48	0.40	0.27	0.57	0.98	0.41	0.20	0.21	0.81	0.97
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	64.40	26.18	21.69	23.45	31.65	25.65	26.28	25.38	36.57	41.57
Normality	0.91	0.13	0.55	0.51	0.26	0.62	0.81	0.81	0.62	0.13
Homogeneity	0.44	0.77	0.87	0.64	0.42	0.87	0.79	0.79	0.54	0.56

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Table 9

Effect of Micro-fertilizer Application Methods on the Weight of Marketable Fruits of Cayenne Pepper

Application methods	Marketable fruit weight per plant (g)									
	Harvest									
	1	2	3	4	5	6	7	8	9	10
Control	223.95	681.17	1075.26	1665.42	851.91	1062.12	425.40	449.40	334.80	324.80
Foliar spray	146.92	652.51	1048.79	1584.72	861.52	1089.62	499.80	503.80	446.87	438.87
Drip irrigation	124.52	506.23	1037.71	1628.27	914.79	1215.60	594.00	599.00	477.98	469.98
Soil drench	176.53	724.49	1000.57	1614.54	1066.57	909.59	389.80	395.80	497.13	489.13
P-value	0.55	0.55	0.99	1.00	0.85	0.83	0.55	0.54	0.75	0.75
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	66.39	38.60	31.33	30.89	46.73	48.45	49.24	45.54	57.87	60.01
Normality	0.29	0.13	0.57	0.38	0.48	0.76	0.99	1.00	0.00	0.01
Homogeneity	0.37	0.39	0.04	0.15	0.80	0.69	0.62	0.73	0.99	1.00

Note. Values followed by different letters in the same column are significantly different according to DMRT (α = 0.05).

Table 10

Effect of Micro-fertilizer Application Methods on the Weight of Unmarketable Fruits of Cayenne Pepper

Application methods	Weight of unmarketable fruits per plant (g)									
	Harvest									
	1	2	3	4	5	6	7	8	9	10
Control	0.21	3.59	7.17	279.66	20.21	22.18	1.60	9.00	34.07	30.47
Foliar spray	0.52	2.41	1.44	60.28	45.52	43.03	7.00	14.20	32.91	28.95
Drip irrigation	0.63	4.77	3.93	164.42	18.74	55.93	5.80	13.00	37.51	33.51
Soil drench	0.95	2.09	8.98	47.64	35.96	23.44	1.40	8.20	28.05	24.45
P-value	0.85	0.81	0.67	0.16	0.71	0.30	0.15	0.17	0.91	0.92
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	231.02	148.39	192.02	121.53	130.10	85.66	110.47	42.32	64.05	72.01
Normality	0.30	0.23	0.02	0.35	0.04	0.31	0.75	0.60	0.01	0.01
Homogeneity	0.57	0.19	0.05	0.82	0.45	0.34	0.20	0.47	0.98	0.98

Note. Values followed by different letters in the same column are significantly different according to DMRT (α = 0.05).

methods, helping correct deficiencies swiftly (Ferrari et al., 2021).

Micro-fertilizer applications did not significantly affect the weight of unmarketable fruits (Table 10). Environmental stressors, including weed competition, inadequate light, high humidity, and disease pressure, are major contributors to unmarketable cayenne pepper fruits. Proper weed control, optimal light exposure, and disease management are crucial for reducing unmarketable fruit and enhancing yield quality in cayenne pepper cultivation (Febrianto et al., 2024; Setiawati et al., 2016). The presence of unmarketable chilli fruit is partly due to the high incidence of pests and diseases affecting cayenne pepper plants simultaneously, especially during the rainy season. Pest and disease attacks significantly affect chilli fruit

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production, reducing yield and quality. Fungal diseases such as anthracnose are common in chilli cultivation and can cause severe yield losses. Anthracnose affects fruit quality by causing fruit rot and decay, resulting in losses of 10%-80% during the rainy season (Setiawati et al., 2021).

Micro-fertilizer application methods did not significantly affect cayenne pepper productivity (Table 11, Figure 6). Yields ranged from 14.18 t/ha (control) to 15.14 t/ha (drip irrigation), with an overall average of 14.60 t/ha across 10 harvests (Figure 6)—far exceeding the national average of 7.8 t/ha in 2023 (Statistics Indonesia, 2024). However, iron and zinc support key physiological processes like chlorophyll synthesis and plant vigor; their influence on chilli fruit yield remains limited compared to macronutrients (Ahmed et al., 2024; Malik et al., 2020). These elements enhance growth parameters but rarely consistently boost fruit number or total production. Improved vegetative growth often fails to translate into higher yields due to sink limitations and altered carbon allocation. Even with elevated photosynthetic rates, plants may struggle to channel excess carbohydrates to reproductive sinks such as fruits, leading to carbon accumulation and feedback downregulation of photosynthesis (Kirschbaum, 2011; Long et al., 2006).

Table 11

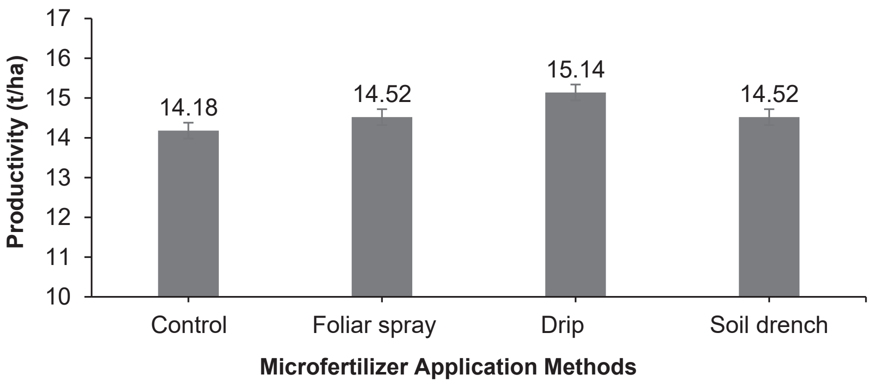
Effect of Micro-fertilizer Application Methods on Cayenne Pepper Productivity

Application methods	Productivity at each harvest (t/ha)									
	1	2	3	4	5	6	7	8	9	10
Control	0.45	1.36	2.15	3.33	1.70	2.13	0.85	0.90	0.67	0.65
Foliar spray	0.29	1.30	2.10	3.17	1.72	2.18	1.00	1.01	0.90	0.88
Drip irrigation	0.25	1.01	2.07	3.26	1.83	2.43	1.19	1.20	0.96	0.94
Soil drench	0.35	1.45	2.00	3.23	2.13	1.82	0.78	0.79	0.99	0.98
P-value	0.54	0.55	0.99	1.00	0.85	0.83	0.55	0.54	0.75	0.76
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	66.68	38.67	31.39	30.87	46.80	48.47	49.09	45.71	57.89	59.88
Normality	0.31	0.13	0.57	0.38	0.48	0.76	0.99	1.00	0.00	0.01
Homogeneity	0.37	0.39	0.04	0.15	0.80	0.69	0.63	0.73	0.99	1.00

Notes. Values followed by different letters in the same column are significantly different according to DMRT (α = 0.05).

Figure 6

Productivity of Cayenne Pepper from the 1st Harvest to the 10th Harvest at Various Micro-fertilizer Application Methods



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Conclusions

The application of micronutrients significantly increased the height and stem diameter of cayenne peppers. Micro-fertilizers applied via foliar spray provide the best response in vegetative parameters of cayenne pepper plants. The application of micronutrient methods as foliar, drip, or soil drench in this study did not increase the yield and yield components of cayenne pepper. Further research should evaluate the concentration and application frequency of micro-fertilizers to determine the most effective concentration for crops, and combine micro-fertilizers with macro-fertilizers (N, P, K) to assess the synergistic potential between the two nutrient types in enhancing plant growth and yield. It is suggested that research be conducted over a more extended period to examine the possibility of cumulative effects of micro-fertilizer application on crop yield.

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