The growth and yield of Vietnamese coriander (*Persicaria odorata*) with NPK and goat manure

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Abstract. Vietnamese coriander (*Persicaria odorata*) is a perennial herb from the Polygonaceae family valued as a functional vegetable, for its culinary, and medicinal uses. To maximize its growth and yield, appropriate fertilization is essential. Two separate studies investigated the effects of NPK and goat manure fertilizers on Vietnamese coriander productivity using a Randomized Complete Block Design (RCBD). The study was conducted from February to April 2024 in Bogor, Indonesia (6°35'36"S 106°46'21" E) ± 231 m asl. The first study focused on the effects of different doses of NPK 16:16:16 fertilizer. The experiment involved treatments of 0 (control), 2, 4, and 6 g NPK plant^{-1}, with three replications. Results showed that 6 g plant^{-1} of NPK significantly enhanced leaf area and color. However, different NPK doses had no significant effect on the overall plant weight, although 6 g plant^{-1} yielded the highest results across most variables, except leaf number at 8 weeks after planting (WAP). The second study explored the effect of goat manure doses, treatments included 0, 10, 20, 30, and 40 g plant^{-1}, with three replications. The findings revealed that goat manure significantly improved plant growth and yield, with 40 g plant^{-1} delivering the best results. However, the study noted that the optimum dose was not reached, as the growth response remained linear up to 6 g plant^{-1} of NPK or 40 g goat manure plant^{-1}. Both studies highlight the importance of fertilizer management in optimizing *Persicaria odorata* cultivation, with NPK having higher productivity than goat manure applications.

1 Introduction

Vietnamese coriander (*Persicaria odorata*), is a perennial herb native to Southeast Asia, thriving in tropical and subtropical climates. It typically grows in warm, humid environments, reaching heights of 15-30 cm under stable conditions. The plant thrives in partial shade but can withstand direct sunlight, providing adequate humidity. Widely found in Kalimantan, including Indonesia and Malaysia [1], Vietnamese coriander is commonly used for its leaves, which contain numerous beneficial chemical compounds such as alkaloids, anthraquinones, coumarins, flavonoids, saponins, tannins, and triterpenoids [2, 3].

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The plant is renowned for its unique flavors and has various medicinal and culinary applications, attributed to its rich phytochemical profile. Vietnamese coriander leaves exhibit antioxidant and phenolic properties, helping to prevent diseases caused by free radicals. Additionally, they can be used to treat fever and stomach ailments, as an anti-aphrodisiac, and used to treat snake bites externally [4]. In Southeast Asia, Vietnamese coriander leaves are also widely used in cooking, adding flavor to dishes such as asam pedas, laksa, and botok [1].

Fertilization is important in Vietnamese coriander cultivation. Fertilization provides essential nutrients to optimize growth and yield [5]. On tomatoes, NPK fertilizers are commonly used to supply macronutrients, and determining the correct fertilization dose is necessary for enhancing plant productivity [6]. Each growth stage requires different amounts of nutrients, and field trials are needed to establish the appropriate fertilization for optimal vegetative growth and yield.

In addition to NPK, organic fertilizers such as goat manure improve soil fertility and plant growth. Goat manure is rich in nutrients like nitrogen, which has improved leaf growth in various plants [7]. Studies show that the response to goat manure dosage follows a linear growth curve until it reaches an optimum dose, after which growth levels off or declines [8]. Further research is needed to identify the optimal dosage for Vietnamese coriander to improve its commercial value. The study aims to investigate the effect of NPK (16:16:16) and goat manure fertilizer doses on the vegetative growth and productivity of *Persicaria odorata*.

2 Methods

Two separate studies investigated the effects of NPK and goat manure fertilizers on Vietnamese coriander cultivation. The first study, conducted from January to April 2024 in Bogor, Indonesia (6°35'36"S 106°46'21" E) ± 231 m asl, focused on the effects of different doses of NPK 16:16:16 fertilizer. Using a Randomized Complete Block Design (RCBD), the experiment involved treatments of 0 (control), 2, 4, and 6 g/polybag, with three replications. The second study from February to April 2024 in the same location, explored the effect of goat manure doses on Vietnamese coriander growth. Using a randomized block design, treatments included 0, 10, 20, 30, and 40 g plant^{-1}, with three replications.

Stem cuttings were planted in the nursery, with commercial rooting hormone (Rootone-F) in the NPK experiment, but not in the goat manure experiment. The rooted cuttings were planted in polybags measuring 20 cm x 20 cm with media in the form of topsoil. Each polybag is filled with plants soaked in Rootone-F solution with a solution concentration of 1 g/100 ml. Polybags placed under the shade with 25% paranet. Watering and weed control are carried out every week manually. The variables observed in this study were plant height, increase in plant height, leaf number, leaf area, leaf color using a leaf color chart (BWD) with scoring 1-5, branch number, node number, root length, wet weight, dry weight, water content, and NPK leaf analysis. Leaf nutrient analysis (N, P, K) was conducted at the end of the experiment. N leaf analysis using the Kjeldahl method. P and K were extracted using the wet ash method using HNO_3 and $HClO_4$. P levels were determined using a spectrophotometer, while K was determined using an atomic absorption Spectrophotometer (AAS). The data was analyzed using SAS (Statistical Analysis System) software with F-test analysis. Real differences in the F-test results were further tested using the Duncan Multiple Range Test (DMRT) at the 5% level.

3 Results and discussion

Almost all the variables observed in NPK applications are higher than in goat manure applications. The experiments were executed in the rainy season (Table 1).

Table 1. Weather conditions during the experiments.

Month	Temperature (°C)	Rain intensities (mm day^{-1})	Rain intensities (mm month^{-1})	Rh (%)
February	24.7	21.9	547	91
March	24.8	19.6	528	89
Average	24.7	20.8	537.5	90

3.1 NPK on *Persicaria odorata* growth and yield

Cuttings in the NPK experiment with rooting hormone grow faster with more consistent rooting. Table 2 shows significant NPK applications found on the node number, leaf area, root length, and fresh and dry weight 8 weeks after planting (WAP).

Table 2. The average height is at 4-8 WAP and plant height increases at 4-5 WAP with NPK applications.

NPK g per polybag	4 WAP	4-5 WAP	5 WAP	6 WAP	7 WAP	8 WAP
	.....		cm		.....	
0	12.88	2.82^{d}	16.34	19.17	22.77	25.47
2	12.79	3.63^{bc}	16.42	20.06	22.49	24.76
4	12.09	3.63^{bc}	16.13	19.77	22.73	25.28
6	13.06	4.42^{ab}	16.63	21.06	23.87	26.34

Numbers followed by different letters in the same column are significantly different using DMRT at α 5%.

Giving NPK at 2, 4, and 6 g per polybag significantly increased node numbers higher than the control by 2.55, 4.50, and 10.27%, respectively (Table 3). Each additional dose of NPK fertilizer affects the root length of the plant. Giving NPK at a dose of 2, 4, and 6 g per polybag increased root length compared to the control treatment by 5.76, 10.23, and 18.49% significantly higher than the control, respectively.

Table 3. Average node number, branch, and root length at 8 WAP.

Variables	NPK (g per *polybag*)			
	0	2	4	6
Node number	13.33^{bc}	13.67^{bc}	13.89^{b}	14.77^{a}
Branch number	9.56	9.11	9.78	10.67
Root length (cm)	28.12^{b}	29.74^{b}	31^{ab}	32.50^{a}

Numbers followed by different letters in the same row are significantly different using DMRT at α 5%.

Giving NPK at a dose of 2, 4, and 6 g per polybag significantly increased leaf area higher than control by 10, 18, and 38%, respectively (Table 4). NPK applications 2, 4, and 6 g per polybag increased the scoring number of the leaf color significantly higher than the control by giving 6 g NPK per polybag.

The dose of NPK fertilizer significantly affects the leaf area of 8 WAP. Each additional dose of NPK fertilizer affects the leaf area of the Vietnamese coriander plant. Giving NPK at a dose of 2 g per polybag increased leaf area compared to the control treatment by 10%. Giving a dose of 4 g per polybag increased leaf area compared to the control treatment by 18%. Meanwhile, applying fertilizer at a dose of 6g per polybag gave the highest results in leaf area with a 38% increase in leaf area compared to the control treatment.

Table 4. Average leaf number, leaf area, and leaf color at 8 WAP.

Variables	NPK (g per *polybag*)			
	0	2	4	6
Leaf number	160	183	216	154
Leaf area (mm^2)	216.34^{b}	238.49^{b}	255.19^{b}	300.35^{a}
Leaf color	3.00^{b}	3.33^{ab}	3.33^{ab}	4.00^{a}

Numbers followed by different letters in the same row are significantly different using DMRT at α 5%.

Different NPK fertilizer dosage treatments also significantly increased leaf color with an increase in the 2 and 4 g per polybag treatment of 9.90% compared to the control treatment. Treatment with a 6 g NPK fertilizer per polybag was 25% higher than the control. Giving a dose of 6 g NPK fertilizer per polybag produced the highest value in leaf area and leaf color of 8 WAP Vietnamese coriander plants. This is in line with [9] who stated that the main role of the N element is to accelerate vegetative growth, one of which is leaf formation. The K element functions as an activator of various enzymes in photosynthesis and respiration reactions. The N element is the main component of chlorophyll and a protein closely related to leaf color. There is a linear relationship between the BWD scale and the N concentration in the leaves of rice plants. The higher number on the BWD scale indicates the intensity of the green color of the leaves.

Results of the linear regression equation of the effect of NPK fertilizer dosage on leaf area $y = 13.437x + 212.29$; $R^2 = 0.95$ and leaf color, namely $y = 0.1167x + 3.23$; $R^2 = 0.89$. These results indicate that NPK up to 6 g per polybag on leaf color and leaf area is still linear, so the optimum fertilizer dose has not been found for leaf color and leaf area.

The results of testing leaf NPK concentration (Table 5) show that the total N amount in the plants is sufficient. Timely identification of high nitrogen levels is essential for efficient plant management, enabling prompt interventions to enhance growth conditions and minimize potential harm to the plants [10]. However, increasing the dose of NPK fertilizer did not affect the increase in total N absorption in the leaves of Vietnamese coriander plants. This can happen because the total N-availability in the soil media is sufficient for plants to absorb. It shows that the P nutrient concentration in the leaves of the Vietnamese coriander plant is quite high. The average P concentration in plant dry weight is 0.3-0.5%.

Increasing the dose of NPK fertilizer does not affect the P leaf concentration in Vietnamese coriander plants. The average potassium content in plants is around 2-3% dry weight. The test results showed that the K nutrient content in the leaves of the Vietnamese coriander plant was quite high. However, increasing the dose of NPK fertilizer did not affect the K leaf concentration in Vietnamese coriander plants.

The wet and dry weights were not affected by NPK fertilizer compared to the control. Average wet weight, dry weight, and water content due to NPK fertilizer treatment can be seen in Table 6. Adding a fertilizer dose of up to 6 g per polybag significantly affected Vietnamese coriander's wet and dry weight. However, the 6 g NPK fertilizer dose treatment was not significantly different from the control and 4 g NPK fertilizer dose treatment per polybag. Excess or deficiency of nutrients given to plants resulted in the photosynthesis

process being ineffective and the photosynthate produced being reduced. The imbalance in soil nutrient availability prevents proper plant growth and production [11].

Results showed that 6 g/polybag of NPK significantly enhanced leaf area and color. NPK 6 g/polybag produced significantly the highest leaf area 38.38% than the control. However, different NPK doses had no significant effect on the overall plant weight, although 6 g/polybag yielded the highest results across most variables, except leaf number at 8 WAP.

Table 5. Leaf NPK concentration at 8 WAP with NPK application.

Variables	NPK g per polybag	Concentration (%)
N-Total	0	3.02
	2	2.66
	4	2.78
	6	2.99
P	0	0.53
	2	0.48
	4	0.50
	6	0.53
K	0	2.61
	2	2.66
	4	1.88
	6	2.45

Source: Testing laboratory of the Department of Agronomy and Horticulture, IPB University.

Table 6. Average fresh, dry weight, and water content at 8 WAP.

Variables	NPK g per polybag			
	0	2	4	6
Fresh weight (g)	99.32^{ab}	89.90^{ab}	70.86^{b}	109.83^{a}
Dry weight (g)	20.37^{a}	16.83^{ab}	12.33^{b}	20.82^{a}
Water content (%)	78.03	80.95	82.70	81.11

Numbers followed by different letters in the same row are significantly different using DMRT at α 5%.

3.2 Goat Manure on *Persicaria odorata* growth and yield

Goat manure significantly affected plant height 2-8 WAP, leaf numbers 2, 6, 8 WAP, node numbers 2, 6, 8 WAP, branch number 4, 6, 8 WAP, fresh and weight, water content, root length, leaf area, and leaf color 8 WAP. Table 7 shows the nutrient content in goat manure.

Table 7. Nutrient in goat manure.

Nutrient	Method	Result	Status*
Water content	Gravimetry	17.56	Sufficient
N-Total	Titrimetric	1.3	
P_2O_5 Total	Spectrophotometer	0.8	NPK sufficient
K_2O Total	AAS	1.5	

Source: Testing laboratory of the Department of Agronomy and Horticulture, IPB University.*SNI 7763:2018. KA: 8-25%, $N+P_2O_5+ K_2O \geq 2\%$ [2].

Table 8 shows the effect of fertilizer dosage which is significantly different on plant height at age 8 WAP and the increase in plant height at age 2–8 WAP. A fertilizer dose of 40 g per plant provides high plant yields and the best height increase.

Table 8. Average plant height and height increase at 4-5 WAP with goat manure applications.

Goat manure (g per polybag)	2WAP	4 WAP	6 WAP	8 WAP	2-8 WAP
			.....cm.....		
0	2.12^{b}	4.63^{c}	10.23^{c}	15.56^{c}	13.43^{c}
10	2.43^{ab}	5.54^{bc}	10.97^{bc}	16.69^{bc}	14.26^{bc}
20	2.62^{ab}	6.16^{abc}	12.57^{abc}	17.97^{bc}	15.34^{bc}
30	2.66^{ab}	6.53^{ab}	13.64^{ab}	20.18^{ab}	17.52^{ab}
40	3.04^{a}	7.49^{a}	15.33^{a}	22.12^{a}	19.08^{a}

Numbers followed by different letters in the same column are significantly different using DMRT at α 5%.

Table 9. Average node number, branch, and root length at 8 WAP with goat manure.

Variables	Goat manure (g per *polybag*)				
	0	10	20	30	40
Node number	15^{c}	16^{bc}	16^{bc}	18^{ab}	18^{a}
Branch number	10^{b}	11^{b}	12^{b}	13^{a}	14^{a}
Root length (cm)	20.87^{c}	24.42^{bc}	27.69^{bc}	32.40^{ab}	35.04^{a}

Numbers followed by different letters in the same row are significantly different using DMRT at 5%.

Giving a dose of goat manure of 40 g per plant produced the highest leaf number at each observation. This is because N metabolism is the main factor in vegetative growth, stems, and leaves. The higher the availability of nitrogen elements in the soil, the better the forming process of vegetative organs [9].

Table 10. Average leaf number, leaf area, and color at 8 WAP with goat manure.

Variables	Goat manure (g per *polybag*)				
	0	10	20	30	40
Leaf number	81^{c}	118^{bc}	129^{ab}	165^{a}	160^{ab}
Leaf area (mm^2)	193.17^{b}	232.53^{b}	249.78^{ab}	293.23^{a}	305.65^{a}
Leaf color	6^{b}	6^{ab}	6^{ab}	7^{a}	7^{a}

Numbers followed by different letters in the same row are significantly different using DMRT at 5%.

The results of the NPK analysis of Vietnamese coriander plant leaves (Table 11) show that they contain nitrogen in a fairly high range, indicating that this plant requires sufficient nitrogen intake for its growth. Phosphorus detected in Vietnamese coriander leaves also shows significant amounts crucial for photosynthesis and root formation. Meanwhile, the potassium concentration in Vietnamese coriander leaves is important in osmoregulation and enzyme activation.

Table 11. Leaf NPK at 8 WAP with goat manure application.

Variables	Goat manure g per polybag	Concentration (%)
N-Total	0	2.75
	10	3.09
	20	2.89
	30	2.75
	40	2.32
P	0	0.50
	10	0.49
	20	0.50
	30	0.49
	40	0.48
K	0	1.95
	10	2.16
	20	1.82
	30	1.91
	40	2.38

Source: Testing laboratory of the Department of Agronomy and Horticulture, IPB University.

Table 12 shows that the treatment dose of goat manure is significantly different for the Vietnamese coriander plants' fresh and dry weight. This is because goat manure can provide the highest treatment on several observed variables such as plant height, branch number, node number, leaf number, leaf color, and leaf area which causes the fresh weight and dry weight to increase. Plant volume, size, and weight improve through cell division, expansion, and elongation, which drives the growth of plant organs, such as leaf number, leaf area, and overall plant weight [12]. Leaf number and area significantly influence total plant weight, as photosynthesis in leaves provides the energy for forming plant organs and tissues, including stems and additional leaves, ultimately increasing total plant weight.

Table 12. Average fresh, dry weight, and water content at 8 WAP.

Variables	Goat manure g per polybag				
	0	10	20	30	40
Fresh weight (g)	9.38^{c}	12.59^{bc}	13.18^{bc}	15.61^{ab}	16.03^{a}
Dry weight (g)	1.73^{c}	2.11^{bc}	2.27^{bc}	3.16^{ab}	3.60^{a}
Water content (%)	82.36	80.22	82.08	81.06	81.69

Numbers followed by different letters in the same row are significantly different using DMRT at 5%.

Water content is an important factor influencing quality and commercial selling value [13]. Water content can be measured by the difference between fresh and dry weight relative to fresh weight, indicating the amount of water contained in the plant at harvest. The water content of Vietnamese coriander plants in this study was high. This was caused by high rainfall at the time of the research so the soil water levels increased which caused high plant water levels. High water content can affect Vietnamese coriander leaves texture, taste, and durability [14]. The texture of the leaves will likely feel soft and slightly fluffy. Due to the high water content, the leaves can become smoother and crumble easily when touched. Vietnamese coriander leaves may have a milder and less intense flavor than drier leaves. Plants with high water content have good commercial value because they are fresh and of good quality for vegetables and food flavoring. However, plants with high water content are not good for making medicines because their bioactive content is lower.

The findings revealed that goat manure significantly improved plant growth and yield, with 40 g plant^{-1} delivering the best results. However, the study noted that the optimum dose was not reached, as the growth response remained linear up to 40 g plant^{-1}. Both studies highlight the importance of fertilizer management in optimizing *Persicaria odorata* cultivation, with further research needed to determine the optimum doses of NPK and goat manure for maximum productivity. This plant is a perennial plant that was only harvested once in these experiments. The linear curve with NPK and goat manure application showed the potential for recurrent harvests.

Fig. 1. NPK on plant biomass. Left to right: 0, 2, 4, and 6 g NPK per polybag.

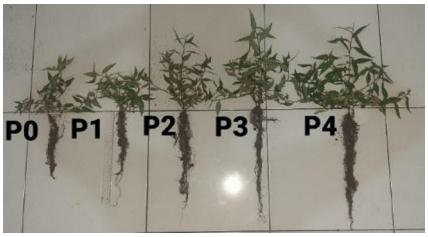

Fig 2. Goat manure on plant biomass. Left to right: 0, 10, 20, 30, and 40 g goat manure per polybag.

NPK fertilizers support greater growth performance in leaf number, plant height, leaf area, node number, and fresh and dry weight than goat manure for *Persicaria odorata*. NPK fertilizers are formulated with precise ratios of nitrogen (N), phosphorus (P), and potassium (K), essential nutrients that promote rapid and sustained plant growth. Nitrogen enhances vegetative growth, phosphorus aids root and flower development, and potassium strengthens plant resilience and overall health [15]. While rich in organic material and beneficial for long-term soil health, goat manure releases nutrients more gradually, as microbial activity is needed to break down organic matter, potentially leading to slower initial plant growth [7].

NPK fertilizers offer rapid nutrient release and higher nitrogen content for vegetative growth, providing *Persicaria odorata* with an immediate supply of essential elements, ideal for fast-growing crops. This contrasts with the slow-release nature of organic amendments like goat manure, which supports soil structure but may not meet the immediate nutrient demands for optimal growth rates in high-yield crops.

4 Conclusion

Results showed that 6 g/polybag of NPK significantly enhanced leaf area and color. However, different NPK doses had no significant effect on the overall plant weight, although 6 g/polybag yielded the highest results across most variables, except leaf number at 8 WAP. The second study from February to April 2024 in the same location, explored the effect of goat manure doses on Vietnamese coriander growth. Using a randomized block design, treatments included 0, 10, 20, 30, and 40 g plant^{-1}, with three replications. The findings revealed that goat manure significantly improved plant growth and yield, with 40 g plant^{-1} delivering the best results. However, the study noted that the optimum dose was not reached, as the growth response remained linear up to 40 g plant^{-1}.

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