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Research Article

Growth and yield of basil (*Ocimum sanctum* L.) supplemented with liquid organic fertilizer from moringa leaves and chicken eggshells

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ABSTRACT

This study examined the effects of liquid organic fertilizer (LOF) derived from Moringa leaves and chicken eggshell fertilizer on basil (Ocimum sanctum L.) growth and yield. The experiment was conducted at Muhammadiyah University of Sidoarjo and arranged in a randomized block design with three replicates. The research incorporated two factors namely moringa leaf LOF at concentrations of 25, 50, and 75 mL L^{-1} and chicken eggshell powder at levels of 3, 6, and 9 g. The observation included plant height, leaf number, branches, root length, and fresh and dry weights. Data were analyzed using ANOVA, followed by Tukey's Honestly Significant Difference (HSD) test at a 5% significance level. Results revealed a significant interaction between LOF and eggshell treatments. The 25 mL L^{-1} LOF plus 3 g of eggshell fertilizer produced the best results in all growth parameters. This suggests that these organic fertilizers can effectively enhance basil growth. The findings emphasize the potential of combining organic fertilizers at certain levels to optimize basil growth and yield.

Keywords: biostimulant; cultivation; sustainable agriculture

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INTRODUCTION

One of the vegetables known by the people of Indonesia is basil (*Ocimum sanctum* L.). Almost every province in Indonesia has basil (Kalsum & Kesmayanti, 2021). The basil is a perennial plant in tropical climates but annuals in temperate climates (Mubaroq et al., 2022). The plant has a powerful and distinctive aroma and has many benefits. Basil leaves can be used as cooking ingredients, herbal medicines, cosmetic raw materials, perfumes, and ornamental plants. Basil leaves can be consumed raw as fresh vegetables or mixed in dishes to add flavor (Aranta et al., 2019). As a herbal medicine, basil leaves can be used for anti-worm medicine, rheumatism, mouth ulcers, and as basil tea to treat flatulence (Mahmud et al., 2023). In addition, basil can also overcome lousy breath, body odor, sluggish body, or fever and heartiness (Robbihi, 2020). Basil leaves contain tannin, flavonoids, steroids or triterpenoids, and essential oils (Lukman et al., 2020). Essential oils help relieve flu, muscle cramps, inflammation of the inner lining of the nose, insect stings, and snake bites.

The potential of basil as a main crop in Indonesia is significant, yet its productivity still needs improvement. Only a few farmers cultivate basil as a main crop, most growing it as a side crop or hedge plant. Efforts to increase the productivity and quality of basil plants can be made with reasonable care or maintenance, namely the provision of fertilizer (Nurfitriyah et al., 2022). Since the excessive use of chemical

fertilizers has side effects such as causing soil pollution, promoting organic fertilizer is important.

Organic fertilizer is the weathering of the decay of organic materials derived from plants, animal waste, and human waste processed by biotechnology. Organic fertilizers can be solid or liquid, depending on the manufacturing process (Warintan et al., 2021). The benefits of organic fertilizer include improving soil structure, increasing fertility, and nutrient availability for plants.

Sources of organic fertilizer are very diverse, such as moringa leaves. Moringa leaves are widely available in Indonesia (Hutauruk & Idris, 2023). Moringa plants have complete macronutrients and amino acids, as well as flavonoids, isothiocyanates, phenolic acids saponins, tannins and vitamins, and other compounds that can be used as an insects-repellant (Vergara-Jimenez et al., 2017). Some hormones are found in moringa leaves, such as cytokinins, which can induce cell division and growth and delay cell aging, and zeatin, an anti-oxidant and an anti-aging agent (Yuniati et al., 2020; Junaidi, 2021). To accelerate plant growth, moringa leaf fertilizer can be used by spraying on the leaves (Suhastyo & Raditya, 2019). A study shows that applying moringa leaf organic fertilizer significantly affects plant height and leaf numbers. This is because the nitrogen content is relatively high in moringa leaves, so it can increase the availability of nutrients in the soil and help the photosynthesis process (Tomia & Pelia 2021).

One type of waste that is rarely utilized by the community is eggshells, and these wastes continue to increase (Sajar, 2023). The eggshells can increase the calcium level in the soil because they contain 95.1% minerals and 3.3% protein. The eggshell has 98.34% calcium carbonate, 0.84% magnesium carbonate, 3% phosphorus, and 0.71% calcium phosphate (Lestari & Saputra, 2023). Calcium is a stimulant for forming root hairs, plant stems, and seed formation of various plants, including crops and horticultural plants (Jariyah & Putri, 2022). Research conducted by Rahmawati et al. (2022) showed that eggshell fertilizer significantly and positively affected plant height, leaf number, and stem diameter of mustard greens (*Brassica juncea*). This is because calcium, magnesium, and phosphorus content in eggshells can encourage root growth and improve soil structure, providing a promising solution for farmers. This study explored the potential of liquid organic fertilizer from moringa leaf and chicken eggshells in enhancing the growth and yield of basil (*Ocimum sanctum* L.).

MATERIALS AND METHODS

This research was carried out at Muhammadiyah Sidoarjo University in Graha Pesona Modong Housing, Tulangan, Sidoarjo, from October to November 2023. Researchers used liquid organic fertilizer of moringa (LOF), eggshell flour, and basil seeds.

The study employed a randomized block design with two factors and three replicates. The first factor was the concentrations of liquid organic fertilizer (LOF) consisting of 25, 50, and 75 mL L^{-1} water, while the second factor was the level of chicken eggshells consisting of three levels: 3, 6, and 9 g per plant. The experimental unit was a plot sized 50 cm x 50 cm. The media was supplemented with a mixture of goat manure and rice husk (1:1; v/v ratio) that was prepared 2-3 days before application. The basil seeds were sowed in four holes per plot and covered with soil. Basil seeds sprouted within 7-14 days.

The LOF was prepared by combining 5 kg of fresh moringa leaves, 10 L of rice washing water, 250 mL solution of bacterial consortium as decomposer (EM4), and ¼ kg of brown sugar. The moringa leaves were cut into small pieces, pounded, and mixed with brown sugar, EM4, and rice washing water in a bucket. The mixture was stirred every two days. It was allowed to ferment for 15 days until producing a fragrant smell. After filtering, the LOF was stored in bottles as main stock.

LOF was applied when the plants reached a specific growth stage. Each plant received 300 mL of LOF. Eggshell fertilizer was broadcasted according to the

treatment dosage. Fertilization was carried out every three days, either in the morning or evening, and the basil plants were harvested at the appropriate age.

To make an eggshell fertilizer, the eggshells were washed and dried under the sunshine for 2-3 hours. After drying, it was ground into fine powder. The eggshell powder was applied around the plants.

The plants were watered twice a day, in the morning and evening. Weed was removed every week using manual uprooting. In cases of pest attacks, organic pesticides were employed for pest control.

To evaluate the effects of the treatments, plant height, leaf number, number of branches, root length, wet weight, and dry weight were measured. Analysis of variance (ANOVA) was performed to understand treatment effects, and Tukey's Honestly Significant Difference (HSD) test was applied for further examination of mean comparison at a 5% significance level.

RESULTS AND DISCUSSION

Plant height of basil plants

The variance analysis showed a significant interaction between the treatment of LOF and eggshell on the plant height (Table 1). Table 1 shows that at 14 and 21 days after planting (DAP), there was no significant difference in plant height among all treatments. However, starting from 28 DAP, differences between treatments began to appear. At 28 DAP, the 50 mL L^{-1} moringa LOF plus 3 g eggshell treatment showed the lowest plant height (5.8 cm), while 25 mL L^{-1} LOF plus 3 g eggshell had the highest value (14.8 cm), although the value was significantly different from the other treatments.

Table 1. Average plant height of basil from the treatment of moringa leaf liquid organic fertilizer (LOF) and chicken eggshell fertilizer.

Treatments		Plant height (cm)				
LOF (mL L^{-1})	Eggshell (g)	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP
25	3	2.5	4.1	14.8e	28.2d	32.7b
25	6	3.7	4.2	14.7e	24.5cd	26.3ab
25	9	2.2	3.4	7.4ab	13.3a	24.5a
50	3	2.1	3.1	5.8a	19.4b	23.4a
50	6	2.3	3.0	7.6ab	14.4a	23.9a
50	9	2.4	3.2	11.6d	24.4c	21.7a
75	3	2.1	2.9	9.1bc	20.7bc	21.6a
75	6	2.3	3.4	10.2cd	18.9b	26.6ab
75	9	2.1	3.1	8.3bc	12.1a	25.0a
Tukey HSD 5%		ns	ns	2.21	4.31	7.15

Note: Values in the same column followed by the same letter are not significantly different based on Tukey's HSD test at α = 5%. ns = not significant. DAP-days after planting.

At 35 DAP, treatment 25 mL L^{-1} moringa LOF with 3 g eggshell showed the highest growth (28.2 cm), followed by 25 mL L^{-1} moringa LOF plus 9 g eggshell (13.3 cm), which had the lowest growth. Meanwhile, at 42 DAP, 25 mL L^{-1} moringa LOF with 3 g eggshell remained superior with a height of 32.7 cm, while treatments such as 75 mL L^{-1} moringa LOF with 3 g eggshell fertilizer, 50 mL L^{-1} LOF with 3 g eggshell fertilizer, and 50 mL L^{-1} LOF with 6 g eggshell fertilizer showed lower values but did not differ significantly.

Leaf number of basil plants

ANOVA analysis showed a significant interaction between the treatment of LOF and eggshell on the parameter of the leaf number (Table 2). Table 2 shows that at 14 and 21 DAP, there were no significant differences between treatments, with plant

height ranging from 4.0 to 6.7 cm. However, at 28 DAP, significant differences began to appear, with treatments 25 mL L^{-1} moringa LOF with 3 g eggshell fertilizer and 25 mL L^{-1} moringa LOF with 6 g eggshell fertilizer producing the highest growth (40.0 cm and 36.0 cm, respectively). On the other side, 50 mL L^{-1} moringa LOF with 6 g eggshell fertilizer had the lowest value (9.0 cm).

Although plant height varied at 35 and 42 DAP (Table 1). The variation in the leaf number between treatments was more pronounced (Table 2). The 25 mL L^{-1} moringa LOF with 3 g eggshell fertilizer treatment remained superior with 203.0 cm at 35 DAP and 490.3 cm at 42 DAP. Overall, 25 mL L^{-1} moringa LOF with 3 g eggshell fertilizer and 25 mL L^{-1} moringa LOF with 6 g eggshell fertilizer gave the highest results in increasing the growth of basil plants, especially after 28 DAP.

Table 2. Average leaf number of basil from treatment of moringa leaf liquid organic fertilizer (LOF) and chicken eggshell fertilizer.

Treatment		Leaf number				
LOF (mL L^{-1})	Eggshell (g)	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP
25	3	5.0	6.7	40.0c	203.0d	490.3c
25	6	4.3	6.3	36.0c	126.0c	442.0c
25	9	4.0	5.3	21.0ab	54.3a	161.0a
50	3	4.0	5.3	16.3ab	61.0ab	247.0ab
50	6	4.0	5.3	9.0a	71.0ab	210.0a
50	9	4.0	5.3	27.3bc	108.0bc	327.0b
75	3	4.3	5.7	15.3ab	61.3ab	170.0a
75	6	4.0	5.7	16.0ab	58.3a	172.0a
75	9	4.0	4.3	11.7a	53.0a	196.0a
Tukey HSD 5%		ns	ns	14.32	47.65	115.8

Note: Values in the same column followed by the same letter are not significantly different based on Tukey's HSD test at α = 5%. ns = not significant.

Number of branches of basil plants

ANOVA analysis showed that the treatment of moringa leaf LOF had a significant effect on the number of branches. Table 3 shows that the branch number at 42 DAP was not significantly different among treatments. A similar branch number indicates that the canopy structure of basil was almost similar among treatments at 42 DAP, although plant height was slightly different among treatments (Table 1).

Table 3. Average branch number of basil from treatment of moringa leaf liquid organic fertilizer (LOF).

Treatment LOF (mL L^{-1})	Branch number at 42 DAP
25	31.8a
50	30.0a
75	29.3a
Tukey HSD 5%	6.8

Note: Values in the same column followed by the same letter are not significantly different based on Tukey's HSD test at α = 5%.

Root length of basil plants

Table 4 shows that the root length of 3, 6, and 9 g eggshell application resulted in non-significant differences, i.e., 66.6 cm, 57.6 cm, and 62.5 cm, respectively. In *Brassica rapa*, Aryandhita and Kastono (2021) noted that application of Ca does not affect root weight. Hapsari et al. (2018) pointed out that Ca in plants is mostly in the form of Ca-pectate, Ca-phosphate, and dissolved Ca, in which the level was affected by soil moisture content.

Table 4. Average root length of basil from treatment of chicken eggshell fertilizer.

Eggshell (g)	Root length (cm)
3	66.6a
6	57.6a
9	62.5a
Tukey HSD 5%	12.5

Note: Values in the same column followed by the same letter are not significantly different based on Tukey's HSD test at α = 5%.

Fresh and dry weight of basil plants

The ANOVA revealed a significant interaction between moringa leaf LOF and eggshell fertilizer on fresh and dry plants (Table 5). Treatments 25 mL L^{-1} moringa LOF with 3 g eggshell fertilizer (42.9 g), and 75 mL L^{-1} moringa LOF with 3 g eggshell fertilizer (39.6 g) showed the highest plant fresh weight, followed by 25 mL L^{-1} moringa LOF with 6 g eggshell fertilizer (36.7 g), all of which had very high values compared to other treatments. Meanwhile, treatment 75 mL L^{-1} moringa LOF with 9 g eggshell fertilizer (7.2 g) produced the lowest fresh weight, followed by 75 mL L^{-1} moringa LOF with 6 g eggshell fertilizer (11.8 g), and 50 mL L^{-1} moringa LOF with 6 g eggshell fertilizer (13.9 g).

Table 5. Average fresh and dry weight of basil from treatment of moringa leaf liquid organic fertilizer (LOF) and chicken eggshell fertilizer.

Treatment		Weight of basil plant (g)	
LOF (mL L^{-1})	Eggshell (g)	Fresh	Dry
25	3	42.9e	7.5f
25	6	36.7e	5.6e
25	9	19.0bcd	2.4ab
50	3	26.6d	3.5c
50	6	13.9abc	1.8a
50	9	22.2cd	3.2c
75	3	39.6e	4.8d
75	6	11.8ab	1.8a
75	9	7.2a	2.2ab
Tukey HSD 5%		8.49	8.49

Note: Values in the same column followed by the same letter are not significantly different based on Tukey's HSD test at α = 5%.

Based on these results, treatments with higher values (such as 25 mL L^{-1} moringa LOF with 3 g eggshell, and 75 mL L^{-1} moringa LOF with 3 g eggshell) significantly differed from those with lower values (such as 75 mL L^{-1} moringa LOF with 9 g eggshell). In contrast, some other treatments such as 25 mL L^{-1} moringa LOF with 6 g eggshell, and 50 mL L^{-1} moringa LOF with 3 g eggshell) did not show significant differences.

Table 5 shows that the combination of the lowest moringa leaf LOF (25 mL L^{-1}) and the lowest eggshell (3 g) resulted in the highest dry weight (7.5 g), suggesting that this treatment provided an optimal balance of nutrients for basil growth. A slight reduction in dry weight was observed in 25 mL L^{-1} moringa LOF with 6 g eggshell (5.6 g), indicating that increasing the eggshell dosage did not enhance biomass accumulation.

In contrast, 50 mL L^{-1} moringa LOF with 6 g eggshell, and 75 mL L^{-1} moringa LOF with 6 g eggshell (1.8 g each) recorded the lowest dry weights. Its implies that higher moringa LOF (50 and 75 mL L^{-1}) combined with a moderate eggshell dose (6 g) might have led to unfavorable conditions, possibly due to nutrient imbalance or reduced nutrient uptake efficiency. Thus, moringa LOF and eggshell contributed to plant biomass, however, the effectiveness depends on the dosage applied.

Treatment of LOF of moringa leaves and eggshells had a significant effect on plant height, leaf number, fresh weight, and dry weight of Basil plants. Moringa leaf LOF treatment also significantly affected the number of branches, while eggshells substantially affected root length. Further analysis showed that the treatment of 25 mL L^{-1} LOF combined with 3 g eggshell produced the highest value in each parameter observed.

This can be explained by the high calcium content in eggshells (Lestari & Saputra, 2023), which is essential for cell elongation and division, supporting the structural integrity of plant cell walls. Moringa leaves contain nitrogen and hormones such as auxin, cytokinin, and gibberellin (Yuniati et al., 2020). It is probable that nitrogen and cytokinin in moringa leaf LOF play a crucial role in stimulating cell division and promoting shoot and stem growth, leading to overall plant development.

Furthermore, calcium is not only a direct nutrient source but also influences soil properties. It has the ability to increase soil pH, reducing acidity and thereby enhancing the availability of essential nutrients such as phosphorus, potassium, and magnesium. This improved nutrient availability can further support plant growth and biomass accumulation.

The plant growth process involving cell division and enlargement can be explained in the context of plant physiology, where the availability of appropriate nutrients strongly influences both processes. Research by Rombe & Pakasi (2020) shows calcium functions as a secondary signal in plant growth mechanisms, affecting cell wall formation. Moreover, Ananta et al. (2023) stated that applying moringa leaf-based LOF on mustard green increases biomass and leaf number. Here, moringa leaves are a potential source of nutrients and growth hormones.

Furthermore, the treatments did not significantly affect root length, which could be caused by internal plant factors that are more dominant in root development. Root growth is strongly influenced by the plant's genetic factors, which regulate the root growth rate through hormonal mechanisms (Sha et al., 2024). Hormones such as auxin are essential in regulating root growth, especially in lateral root formation and primary root elongation (Rivas et al., 2022). Suppose the plant has a solid genetic capacity to produce roots efficiently. In that case, external factors (such as fertilizers or other treatments) may not significantly influence root length. It is suspected that the basil plants may have adapted to the given conditions or treatments, thus not responding to significant changes in root length. In research by Vergara-Jimenez et al. (2017), the structure and growth of roots are largely influenced by genetic factors. Plants with genetically efficient root systems tend to be more stable in absorbing nutrients and water, so the influence of external treatments may be minimal.

The apparent differences in plant weight between treatments can be explained through several factors that affect plant growth and development. Plant weight reflects the total amount of water and solutes present in plant tissues, which is strongly influenced by physiological processes such as photosynthesis, water transport, and nutrient accumulation. In treating 25 mL L^{-1} moringa leaf LOF combined with 3 g eggshell, which produced the highest weight (42.9 g), the plants likely experienced an optimal increase in photosynthesis (Yuniati et al., 2020). Moringa leaf LOF containing elements of nitrogen and cytokinin plays a role in stimulating photosynthetic activity and cell division, producing more organic matter stored in biomass. Chicken eggshells, rich in calcium, can also increase plant resistance to stress and support more efficient absorption of water and nutrients, increasing fresh weight accumulation (Hamzah et al., 2023). In contrast, in treating 75 mL L^{-1} moringa LOF combined with 9 g eggshell, which produced the lowest fresh weight (7.2 g) plants may not optimize these physiological processes. Unbalanced nutrient concentrations or a lack of one of the essential nutrients may inhibit the processes of photosynthesis, cell division, and transpiration, leading to lower plant fresh weight.

Plant dry weight reflects the biomass produced after the water content is removed. In treating 25 mL L^{-1} moringa LOF combined with 3 g of eggshell, the highest

result (7.5 g) showed that the plants obtained an optimal supply of nutrients, supporting the photosynthesis process to the maximum. Moringa leaf LOF, rich in nutrients, promotes increased carbohydrate production through photosynthesis and biomass accumulation. In addition, the nitrogen content in moringa LOF is an essential element in photosynthesis apparatus.

Calcium from chicken eggshells has the vital function of forming bonds between pectin in the middle lamellas to strengthen the cell wall, reinforcing the cellular structure and supporting overall tissue growth. It increases the plant's capacity to withstand environmental stress and supports optimal metabolism. Another study by Rahmayanti (2020) showed that calcium also plays a role in cellular signaling mechanisms that regulate various physiological functions, including nutrient uptake and response to environmental stress. By strengthening cell walls and improving membrane function, calcium helps plants absorb and distribute nutrients more efficiently, supporting higher biomass accumulation. With the optimal combination of nitrogen and cytokinin from Moringa leaf LOF and calcium from eggshell, plants can increase their metabolic activity, photosynthesis, and overall nutrient efficiency (Hasibuan et al., 2021). This contributed to the increase in biomass reflected in the dry weight of the basil plants.

In contrast, in the treatments of 50 mL L^{-1} moringa LOF combined with 6 g eggshell, and 75 mL L^{-1} moringa LOF combined with 6 g eggshell that produced the lowest dry weight (1.8 g), the plants may not have received the amount or balance of nutrients needed for optimal growth. Lack of certain nutrients, such as nitrogen, phosphorus, or potassium, can limit photosynthesis and biomass formation. In addition, imbalances in micro- and macroelements can also inhibit the development of plant tissue (Dami et al., 2019) leading to low dry weight accumulation. This significant difference in dry weight yield, reflected in the Tukey HSD value of 0.75 g, indicates that treatments with better and more intense nutrient content have a significant positive effect on the ability of plants to produce greater biomass.

CONCLUSIONS

Moringa LOF and eggshell powder are effective in improving basil growth. Treatment of 25 mL L^{-1} moringa LOF plus 3 g chicken eggshell showed the highest effect on growth parameters including plant height, leaf number, wet weight, and dry weight. The positive effect of the treatment is likely due to the calcium content in eggshells, and the nitrogen and cytokinin content in moringa leaf LOF. Thus, the treatment 25 mL L^{-1} moringa leaf LOF plus 3 g chicken eggshell fertilizer treatment is the most effective treatment in increasing the development of basil plants in the present study.

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