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Enhancing Leafy Vegetable Growth and Yield with Goat Urine, *Moringa* Leaf, and Banana Stem-based Liquid Organic Fertiliser

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ABSTRACT

Pak choy and mustard greens are traditionally grown with many inorganic fertilisers, which can reduce soil fertility when applied frequently. The adoption of organic fertilisers offers a sustainable solution to this challenge. This study investigates the impact of liquid organic fertiliser (LOF) derived from goat urine, *Moringa* leaves, and banana stems on the growth and yield of pak choy and mustard greens. The research design employed a randomised complete block design with four treatments and ten replications. These treatments included a control group, 100% nitrogen, phosphorus, potassium (NPK, inorganic fertiliser), 100% LOF, and a 50% NPK + 50% LOF blend. The application of LOF, sourced from goat urine, *Moringa* leaves, and banana stems, demonstrated a significant influence on nearly all plant parameters. Notably, the 100% LOF treatment yielded the highest results for fresh leaf weight (26.46 g), fresh stalk weight (39.64 g), dry leaf weight (4.57 g), stem diameter (48.27 mm), Soil Plant Analysis Development value (SPAD, 40.73 units), plant height (31.59 cm), leaf width (8.45 cm), and leaf length (13.33 cm) for pak choy. Additionally, 100% LOF also produced the highest results for fresh leaf weight (21.34 g), dry root weight (0.31 g), stem diameter (21.53 mm), SPAD value (32.40 units), plant height (31.59 cm), leaf width (10.40 cm), and leaf length (15.65 cm) for mustard greens. This study demonstrates that a blend of goat urine, *Moringa* leaves, and banana stems can be used as a LOF that can replace inorganic NPK fertilisers in growing pak choy and mustard. It not

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only addresses issues with soil fertility but also contributes to environmentally friendly farming practices.

Keywords: Dry weight, fresh weight, mustard greens, NPK, organic fertilisers, pak choy, relative agronomic efficiency

INTRODUCTION

Leafy vegetables are important sources of dietary fibre, critical vitamins, and minerals, all crucial for human nutrition. Leaf vegetables like pak choy and mustard greens are popular choices among consumers. Because it has a great flavour and is simple to prepare, pak choy (*Brassica rapa* L.) is a vegetable plant with significant economic worth. From a climatological, technological, and economic perspective, pak choy plants are excellent candidates for growing in Indonesia. The vegetable plant that produces mustard greens (*B. juncea* L.) may thrive in subtropical and tropical regions. Plants that are part of the Brassicaceae family include mustard greens. Because of the different nutrients in mustard greens and the growing global population, they are needed (Rosalina et al., 2019).

In Indonesia, inorganic fertilisers like NPK continue to be used mostly in growing vegetables, especially pak choy and mustard greens. Such inorganic fertilisers should not be used for an extended period or in excess since this can result in several problems, such as reduced soil nutrient availability, soil water pollution, soil acidification, and a drop in beneficial soil microbes (Abebe et al., 2022). Additionally, the limited availability of subsidised fertilisers and fluctuating market prices have increased fertiliser costs, prompting the investigation of affordable and readily available alternatives for farmers. In this situation, switching to an organic agricultural system appears to be a workable approach. Organic farming is characterised by its commitment to sustainable practices, prioritising natural resource conservation by eschewing agrochemicals (da Costa Stuart et al., 2018). One such strategy is utilising LOF, which demonstrates the implementation of organic agricultural principles and provides a solution to the issue of limited access to subsidised fertilisers.

A practical substitute for conventional fertiliser for agricultural usage is LOF, produced from a mixture of goat urine, *Moringa* leaves, and banana stems. These components have a wide range of nutrients that can be used to enhance plants' nutritional needs. According to Abdullah et al. (2011), goat urine has a high nutrient content, with N at 1.35%, P at 0.13%, and K at 2.10%. *Moringa* leaves make a considerable contribution with 4.02% nitrogen, 1.17% phosphorus, 1.80% potassium, 12.3% calcium, 0.10% magnesium, and 1.16% sodium. These dietary elements are ideal for improving soil fertility and promoting healthy plant growth (Adiaha, 2017). Furthermore, adding additional nutrients required for the best plant growth and productivity is greatly facilitated by P in banana stem extract in concentrations ranging from 0.2 to 0.5% (Saraiva et al., 2012). These resources make excellent candidates for LOF because of their availability, simplicity in cultivation, and affordability, allowing farmers to create organic fertilisers.

Farmers widely use NPK fertiliser because of its reliable composition and simplicity. To maximise plant growth, there is an increasing demand for organic fertilisers with formulations similar to NPK fertilisers. This work investigates goat urine, *Moringa* leaves, and banana stems-based LOF. Several crops, including tomatoes (Culver et al., 2012), corn (Biswas et al., 2016), lettuce, and spinach (Chanthanousone et al., 2022) have shown improved growth and production when *Moringa* leaf extract is applied. Similar to this, using goat urine LOF for a variety of crops, such as vegetables (Syahputra, 2022), maise (Nwite, 2015), and legumes like *Mucuna bracteata* (Sitinjak & Pratomo, 2019), shows significant potential. Additionally, it has been discovered that LOF made from banana stems has a large impact on the growth of tomatoes (Kilo et al., 2023), soybeans (Faozi et al., 2018), and sweet corn (Pangaribuan et al., 2019) among other plants. Notably, little research or information on combining these three organic elements for green vegetables is available. Despite separate studies highlighting the beneficial effects of these materials on various crops, the specific combination of goat urine, *Moringa* leaves, and banana stems into a LOF remains an area under investigation, particularly in terms of its impact on plants such as pak choy and mustard greens. This study addresses this gap by evaluating the impact of this unique blended organic fertiliser, presenting a promising avenue for enhancing plant growth and yield.

MATERIALS AND METHODS

Study Area

This study was conducted from February to March 2023 in the integrated field of the Faculty of Agriculture at the Universitas Lampung, Indonesia. The geographic coordinates are situated between 5° 22’ 11.38” S and 105° 14’ 25.96” E to 5° 21’ 58.35” S and 105° 14’ 43.83” E. The field is 120 meters above sea level, with annual rainfall ranging from 1,164 to 2,737 mm. The soil characteristics in the study area are classified as Ultisols with a pH level of 6.83, organic C (1.59%), nitrogen (0.04%), available P_2O_5 (188.85 ppm), potential P (159.25 mg phosphorus pentoxide [P_2O_5]/100 g), potential K (38.80 mg potassium oxide [K_2O]/ 100 g).

Research Methods

The experimental design employed in this study followed a randomised complete block design (RCBD) comprising four treatments with ten replications each. Mean separation was accomplished by utilising the least significant difference (LSD) test at a significance level of 5%. The research involved the application of four treatments, as follows:

P0: Control
P1: 100% NPK
P2: 100% LOF derived from a blend of goat urine, *Moringa* leaves, and banana stems
P3: 50% NPK + 50% LOF

LOF Production

LOF preparation involves a systematic procedure and specific tools and materials. The essential tools included drums, scales, hoses, and plastic bottles. At the same time, the materials consisted of 20 L of goat urine, 5 kg of *Moringa* leaves, 5 kg of banana stems, 10 L of water, 300 ml of molasses, and 30 ml of Effective Microorganisms 4 (EM-4®, Indonesia). The process commenced with preparing the plant materials, wherein the *Moringa* leaves were meticulously blended, and the banana stems were cut into small pieces. Subsequently, 20 L of goat urine were introduced, adding 5 kg of blended *Moringa* leaves and 5 kg of finely cut banana stems. This mixture incorporated 30 ml of EM-4®, 300 ml of molasses solution, and 10 L of water. Thorough mixing ensued until homogeneity was achieved, after which the container was securely sealed. A hose was connected to the container's outlet, facilitating the connection to a water bottle. The fermentation process was allowed to proceed for 30 days. Prior to application, the fermented extract underwent a filtration process at a ratio of 1 L of organic nutrients to 4 L of water, as illustrated in Figure 1. According to laboratory tests, each LOF's nutrient composition is N at 0.18%, P_2O_5 at 0.06%, and K_2O at 0.77%, with a pH of 5.78.

Research Implementation

Soil aeration on the selected site is the first step in preparing the planting medium. After that, the loosening soil is mixed with 1 kg of dolomite per square metre and let to rest for a week. The soil then goes through a laborious sifting procedure to achieve a fine-grain consistency. Once the soil has the desired texture, it is carefully packed into 40 polybags, each measuring 40 cm × 40 cm, for 40 polybags.

Figure 1. Production workflow for making liquid organic fertiliser

During the seeding phase, pak choy seeds of the Nauli F1 variety and Tosakan mustard greens are sown onto the ready-planting medium using soil. Fourteen (14) days of seeding activities are completed when the sprouting plants have four to five leaves. The pak choy and mustard green seedlings are now moved into the polybag media, with two plants per polybag, and are prepared for transplantation.

Fertiliser NPK 16:16:16 is applied at a rate of 100%, or 3 g per polybag, once when the plants reach one week after planting (WAP), according to a predetermined schedule for fertilisation. Applications of LOF are made nine times, once every three days, by soil drenching with a flush volume of 148.30 ml per polybag for the full dose of LOF. Alternatively, a 50% NPK dose of 1.5 g per polybag and a 50% LOF dose of 73.80 ml are given once during the first week following planting. The outline scheme for making and applying LOF on pak choy and mustard greens can be seen in Figure 2.

Both morning and evening are regularly used for watering. Manual labour is used to carefully remove weeds by hand as part of weed management. Mechanical methods are used to perform pest and disease control procedures, which comprise the direct removal of pests that harm pak choy and mustard greens plants. Plants with disease infestations are quickly segregated from healthy plants to stop the spread of the disease.

Observational Variables

Variables observed in this study were the fresh weight of leaves, fresh weight of stalk,

Figure 2. Application scheme of liquid organic fertiliser

fresh weight of root, dry weight of leaves, dry weight of stalk, dry weight of root, stem diameter, number of leaves, green level of leaves (SPAD readings), plant height, leaf width, leaf length, and stalk length. The agronomic effectiveness of fertiliser is determined by the relative agronomic effectiveness (RAE) with the following formula:

$$\text{RAE} = \frac{\text{Results of the tested LOF} - \text{Control}}{\text{Results of NPK fertiliser} - \text{Control}} \times 100\%$$

If the RAE value ≥ 100%, then the tested fertiliser is effective compared to standard treatment.

RESULTS AND DISCUSSION

The plants under consideration, pak choy and mustard greens showed strong growth and overall great health. Feeding these plants 100% LOF made from goat urine, *Moringa* leaves, and banana stems produced outcomes comparable to those in the 100% NPK and 50% NPK + 50% LOF treatments. Pest incursions were noted during the pak choy plant's growth stages, mostly attributable to green locusts (*Valanga nigricornis*) and caterpillars (*Plutella xylostella*). Despite being below the threshold for intervention, these insect encounters caused damage to the leaves, enabling the implementation of efficient control measures. Both pak choy and mustard greens plants began to experience caterpillar infestations in the latter growth phases, notably around the 4 WAP stage. Most pest control was done manually, carefully removing leaf-eating caterpillars and locusts. Protective paranets were judiciously placed around the production area in addition to manual control efforts to reduce pest pressures and protect the crop.

The statistical analysis revealed that the LOF treatment of goat urine, *Moringa* leaves, and banana stems in both vegetables significantly affected the fresh weight of leaves (Tables 1 and 2), fresh weight of stalks (Tables 1 and 2), fresh weight of roots (Tables 1 and 2), dry weight of leaves (Tables 3 and 4), dry weight of stalks (Tables 3 and 4), dry weight of roots (Tables 3 and 4), stem diameter (Tables 5 and 6), number of leaves (Tables 5 and 6), and level of greenness of leaves (Tables 5 and 6). The analysis also revealed significant effects on plant height (Tables 7 and 8), leaf width (Tables 7 and 8), leaf width (Tables 7 and 8), leaf length (Tables 7 and 8), and stalk length (Tables 7 and 8).

Effect on Growth Parameters

Both the fresh weight of the leaves and roots of pak choy (Table 1) and the fresh weight of the stalks and roots of mustard greens (Table 2) did not differ substantially after treatment with 100% NPK, 100% LOF, or 50% NPK + 50% LOF. For all variables, the treatments of 100% NPK, 100% LOF, and 50% NPK + 50% LOF produced substantially different findings from the controls (Tables 1 and 2). The 100% LOF treatment considerably outperformed both the 50% NPK + 50% LOF and 100% NPK treatments on the fresh weight of pak choy stalks, while the 50% NPK + 50% LOF treatment did not significantly vary from 100% NPK (Table 1). The fresh weight of mustard greens' leaves in the 100% NPK treatment (Table 2) differed noticeably from that of the 100% LOF treatment and the 50% NPK + 50% LOF treatments. However, the 50% NPK + 50% LOF treatment and the 100% LOF treatment did not substantially differ in terms of fresh weight of leaves (Table 2). On the fresh weight of pak choy leaves and stalks (Table 1) and mustard greens leaves (Table 2), the 100% LOF treatment produced the best results. According to the RAE approach, the RAE value of a 100% LOF treatment in pak choy plants is 154.52% (Table 1) and in mustard greens plants is 128.35% (Table 2). It demonstrates that the 100% LOF treatment is superior to the 100% NPK treatment in terms of efficacy.

Fresh biomass yields of leaves, stalks, and roots were comparable to those seen in the 100% NPK treatment after applying 100% LOF (Tables 1 and 2). The similarity in biomass production is probably due to the high K concentration in the 100% LOF treatment. Banana stems, a key ingredient in the production of LOF, are an important source of K minerals. It is important to note

Table 1
The effect of treatments on the parameters of fresh weight of leaves, fresh weight of stalks, and fresh weight of roots of pak choy plants

Treatment	Fresh weight of leaves (g)	RAE (%)	Fresh weight of stalk (g)	Fresh weight of root (g)
Control	14.67 b	-	17.70 c	1.16 b
100% NPK	22.30 a	100.00	31.01 b	1.77 a
100% LOF	26.46 a	154.52	39.64 a	1.96 a
50% NPK + 50% LOF	26.44 a	154.26	37.00 ab	2.12 a
LSD 5%	5.36	-	0.12	0.18

Note. Numbers followed by the same letter in the same column are not significantly different based on the least significant difference (LSD) test at the 5% level; RAE = Relative agronomic effectiveness; NPK = Nitrogen, phosphorus, potassium; LOF = Liquid organic fertiliser

Table 2
The effect of treatments on the parameters of fresh weight of leaves, fresh weight of stalks, and fresh weight of roots of mustard green plants

Treatment	Fresh weight of leaves (g)	RAE (%)	Fresh weight of stalk (g)	Fresh weight of root (g)
Control	14.46 c	-	12.29 b	1.22 b
100% NPK	19.82 b	100.00	18.81 a	1.95 a
100% LOF	21.34 a	128,35	17.96 a	2.05 a
50% NPK + 50% LOF	20.72 a	116,79	18.41 a	2.05 a
LSD 5%	0.74	-	1.04	0.10

Note. Numbers followed by the same letter in the same column are not significantly different based on the least significant difference (LSD) test at the 5% level; RAE = Relative agronomic effectiveness; NPK = Nitrogen, phosphorus, potassium; LOF = Liquid organic fertiliser that banana stems, sometimes regarded as agricultural waste, contain various possible chemicals, including K, P, Fe, and N (Riyandani et al., 2021). A crucial nutrient called potassium has a variety of functions in plant physiology. According to Grzebisz et al. (2013), it is essential for many functions, including photosynthesis, osmotic control, cell proliferation, stomatal organisation, plant water movement, and nitrogen transfer. Additionally, potassium makes it possible for water and nutrients to be transported effectively throughout the plant. According to Prajapati and Modi (2012), a lack of potassium may hinder nitrogen fixation and translocation as well as the absorption of phosphate, calcium, magnesium, and amino acids. Along with potassium, nitrogen is recognised as a crucial factor in higher crop yields. Chlorophyll, proteins, amino acids, different enzymes, nucleic acids, and many other crucial molecules found in plant cells all contain nitrogen as a key component (Reeza & Azman, 2022). Its presence is essential for maximising plant performance and growth.

In the 100% NPK, 100% LOF, and 50% NPK + 50% LOF treatments, the dry weight of pak choy leaves (Table 3) and dry weight of mustard greens roots (Table 4) did not significantly differ, although the three treatments produced various results when compared to the control. The dry weight of the pak choy stalks and roots in the 100% NPK, 100% LOF, and 50% NPK + 50% LOF treatments all revealed results that were not significantly different. On the variable dry weight of the pak choy stalks and roots, the 50% NPK + 50% LOF and 100% NPK treatments significantly outperformed the control (Table 3). The dry weight of leaves mustard green of the 100% LOF treatment was not significantly different from those of the 100% NPK treatment or the 50% NPK + 50% LOF treatment. On the dry weight of mustard green leaves, the treatments of 100% NPK, 100% LOF, and 50% NPK + 50% LOF produced significantly different outcomes from the control (Table 4). The 100% LOF treatment demonstrated significantly different results from the 100% NPK treatment in the mustard greens dry weight of stalk variable. On the mustard greens dry weight of stalk variable, the treatments of 100% NPK, 100% LOF, and 50% NPK + 50% LOF produced significantly different results from the control (Table 4).

Compared to the 100% NPK treatment, the 100% LOF treatment showed a remarkable capacity to match the dry weight of leaves and roots in pak choy and mustard greens plants. An essential measure known as dry weight is crucial in evaluating photosynthetic activities. In fact, according to Anjarwati et al. (2017), measures of the dry weight of plant roots and leaves closely reflect photosynthesis results. According to Sarif et al. (2015), a plant's dry weight is a crucial measure of its capacity to effectively collect nutrients from its growing medium and support strong growth. The ideal photosynthesis that emerges from satisfying a plant's nutritional needs produces increased dry weight values for both the leaves and the roots. Because

Table 3
The effect of treatments on the parameters of dry weight of leaves, dry weight of stalks, and dry weight of roots of pak choy plants

Treatment	Dry weight of leaves (g)	Dry weight of stalks (g)	Dry weight of roots (g)
Control	2.67 b	2.13 b	0.36 b
100% NPK	3.94 a	3.57 a	0.74 a
100% LOF	4.57 a	3.25 ab	0.63 ab
50% NPK + 50% LOF	3.96 a	3.71 a	0.68 a
LSD 5%	1.14	1.18	0.30

Note. Numbers followed by the same letter in the same column are not significantly different based on the least significant difference (LSD) test at the 5% level; NPK = Nitrogen, phosphorus, potassium; LOF = Liquid organic fertiliser

Table 4
The effect of treatments on the parameters of dry weight of leaves, dry weight of stalks, and dry weight of roots of mustard green plants

Treatment	Dry weight of leaves (g)	Dry weight of stalks (g)	Dry weight of roots (g)
Control	1.36 c	0.44 c	0.18 b
100% NPK	1.67 b	1.25 a	0.27 a
100% LOF	1.90 ab	1.08 b	0.31 a
50% NPK + 50% LOF	2.06 a	1.17 ab	0.28 a
LSD 5%	0.32	0.13	0.06

Note. Numbers followed by the same letter in the same column are not significantly different based on the least significant difference (LSD) test at the 5% level; NPK = Nitrogen, phosphorus, potassium; LOF = Liquid organic fertiliser

of the nutrient-rich content of LOF, plants thrive and achieve high dry-weight values in their leaves and roots, which considerably boosts photosynthesis.

The 100% LOF treatment demonstrated significantly different results from the control, 100% NPK, and 50% NPK + 50% LOF treatments in the stem diameter of pak choy (Table 5). However, the results of the 50% NPK + 50% LOF treatment were significantly different from those of the 100% NPK and control treatments. The stem diameter of the pak choy did not significantly differ between the 100% NPK treatment and the control (Table 5). In contrast, the stem diameter of mustard green plants treated with 100% LOF and 50% NPK + 50% LOF did not differ significantly (Table 6). The number of pak choy and mustard green leaves in the 100% NPK, 100% LOF, and 50% NPK + 50% LOF treatments did not differ significantly from one another, but the results from the three treatments were very different from the control. The SPAD values of pak choy leaves under 100% LOF and 50% NPK + 50% LOF treatments (Table 5) did not differ significantly. In contrast, the SPAD value under 100% NPK treatment differed significantly from the control. The SPAD values in the mustard green leaves (Table 6) did not differ significantly from the 100% LOF and 100% NPK treatments. Additionally, there was no noticeable distinction between the 50% NPK + 50% LOF treatment and the 100% NPK treatment's level of green in the leaves. Table 6 shows that the 100% NPK, 100% LOF, and 50% NPK + 50% LOF treatments significantly differed from the control in the SPAD values in the mustard green leaves.

In both pak choy and mustard greens plants, the use of 100% LOF demonstrated a surprising ability to parallel the results seen in the 100% NPK treatment across a spectrum of critical traits, including stem diameter, leaf number, and the SPAD unit. In pak choy and mustard greens, the stem diameter is linked to the number of leaves; a higher number always equates to a bigger stem diameter. It is impossible to understate the importance of nitrogen and phosphorus in *Moringa* leaves and banana stems in encouraging leaf growth. These two vital nutrients are crucial for promoting cell division and acting as the building blocks for synthesising organic compounds in plants, significantly impacting vegetative growth, especially leaf number. As amino acids, proteins, nucleic acids, enzymes, nucleoproteins, and alkaloids are all essential for promoting vegetative growth and enhancing leaf

Table 5
The effect of treatments on the parameters of stem diameter, number of leaves, and Soil Plant Analysis Development (SPAD) of pak choy plants

Treatment	Stem diameter (mm)	Number of leaves (blade)	SPAD (units)
Control	36.37 c	14.70 b	36.19 c
100% NPK	41.03 bc	16.75 a	39.08 b
100% LOF	48.27 a	17.55 a	40.73 a
50% NPK + 50% LOF	42.96 b	17.60 a	40.37 a
LSD 5%	4.71	1.91	0.68

Note. Numbers followed by the same letter in the same column are not significantly different based on the least significant difference (LSD) test at the 5% level; NPK = Nitrogen, phosphorus, potassium; LOF = Liquid organic fertiliser

Table 6
The effect of treatments on the parameters of stem diameter, number of leaves, and Soil Plant Analysis Development (SPAD) of mustard green plants

Treatment	Stem diameter (mm)	Number of leaves (blade)	SPAD (units)
Control	13.98 c	6.15 b	24.92 c
100% NPK	19.88 b	8.45 a	30.97 ab
100% LOF	21.53 a	8.25 a	32.40 a
50% NPK + 50% LOF	21.47 a	8.40 a	30.31 b
LSD 5%	1.14	0.48	1.43

Note. Numbers followed by the same letter in the same column are not significantly different based on the least significant difference (LSD) test at the 5% level; NPK = Nitrogen, phosphorus, potassium; LOF = Liquid organic fertiliser pigmentation, their formation is directly facilitated by adding nitrogen to plants (Mokhele et al., 2012). Notably, the 100% LOF treatment's significantly increased levels of leaf greenness highlight the LOF's significant nitrogen content obtained from goat urine and *Moringa* leaves. Nitrogen not only aids in plant growth but also gives leaves a vivid green tint. The degree of green pigmentation in the leaves of mustard and pak choy is directly connected to the amount of nitrogen taken up by the plants (Nugroho, 2015; Shorna et al., 2020).

The results of the 100% NPK, 100% LOF, and 50% NPK + 50% LOF treatments were not statistically different in the pak choy plant's variable height (Table 7). On factors related to plant height, the 50% NPK + 50% LOF treatment and 100% NPK revealed results that were not significantly different from the control (Table 7). In the 100% NPK, 100% LOF, and 50% NPK + 50% LOF treatments, pak choy leaf width (Table 7) and mustard greens plant height (Table 8) revealed results that were not significantly different. However, the three treatments revealed significantly different results from the control. With 100% LOF and 50% NPK + 50% LOF treatments, the leaf width and length of mustard greens leaves (Table 8) showed findings that were not significantly different, and the two treatments were significantly different with 100% NPK and control. The 100% LOF treatment for pak choy leaf length (Table 7) produced significantly distinct results from those of the other three treatments. The 100% NPK and 50% NPK + 50% LOF treatments did not significantly differ in terms of pak choy leaf length (Table 7). Although there was no statistically significant difference between the 100% LOF and 50% NPK + 50% LOF treatments for pak choy (Table 7), the stalk was much longer than the control. In the 100% LOF and 50% NPK + 50% LOF treatments (Table 8), the length of the mustard greens stalks was not significantly different, but they were significantly longer than the control.

Pak choy and mustard greens' vigorous leaf growth is supported by the 100% LOF, which contains a significant amount of nitrogen. During their vegetative phase, these green vegetables, mostly used for their stems and leaves, have a high demand for nitrogen. Nitrogen, which is frequently regarded as the main force behind plant growth, significantly impacts how plants develop, their general quality, and their ability to produce (Gebeyaw & Belete, 2020). The production of chlorophyll pigment, a vital element in photosynthesis, is another function of nitrogen. It is also crucial to develop proteins, amino acids, plant cells, tissues, and organs, with the vegetative phase of growth being of special significance (Liang et al., 2023; Pernitiani et al., 2018). Plants allocate a significant percentage of their carbohydrates to the growth of their leaves, stems, and roots during the vegetative phase (Rizal, 2017). As a result, nitrogen becomes a key nutrient that has an important effect on plant development, growth, and output (Imran et al., 2021). The adequate nitrogen supply greatly enhances the productive capacity of leafy crops like pak choy and mustard greens.

Table 7
The effect of treatments on the parameters of plant height, leaf width, leaf length, and stalk length of pak choy plants

Treatment	Plant height (cm)	Leaf width (cm)	Leaf length (cm)	Stalk length (cm)
Control	20.34 b	7.01 b	11.62 c	6.36 b
100% NPK	22.16 ab	7.92 a	12.60 b	6.70 b
100% LOF	23.91 a	8.45 a	13.33 a	7.12 a
50% NPK + 50% LOF	22.42 ab	8.13 a	12.62 b	7.14 a
LSD 5%	2.23	0.61	0.64	0.41

Note. Numbers followed by the same letter in the same column are not significantly different based on the least significant difference (LSD) test at the 5% level; NPK = Nitrogen, phosphorus, potassium; LOF = Liquid organic fertiliser

Table 8
The effect of treatments on the parameters of plant height, leaf width, leaf length, and stalk length of mustard greens

Treatment	Plant height (cm)	Leaf width (cm)	Leaf length (cm)	Stalk length (cm)
Control	22.29 b	7.41 c	12.12 c	10.44 c
100% NPK	30.96 a	9.19 b	13.90 b	15.21 a
100% LOF	31.59 a	10.40 a	15.65 a	14.16 b
50% NPK + 50% LOF	31.39 a	10.20 a	15.32 a	14.27 b
LSD 5%	1.39	0.77	0.83	0.80

Note. Numbers followed by the same letter in the same column are not significantly different based on the least significant difference (LSD) test at the 5% level; NPK = Nitrogen, phosphorus, potassium; LOF = Liquid organic fertiliser

Correlation Among Parameters

The results of the correlation study performed on pak choy (Table 9) and mustard greens (Table 10) have shown important insights into the relationships among numerous growth-related variables. Notably, the fresh weight of leaves emerges as a central variable that displays strong correlations with a variety of other growth parameters, including stem diameter, number of leaves, level of leaf greenness, plant height, leaf width, leaf length, and stalk length. However, the fresh weight of leaves did not show a significant correlation with the fresh weight of stalks and roots in the case of pak choy plants (Table 9). On the other hand, mustard greens plants (Table 10) showed a significant association between the fresh weight of leaves and the fresh weight of stalks and roots. This association highlights that the increase in new leaf weight during the vegetative growth's final stages is closely related to the plant's early stages of development. The availability of vital plant nutrients significantly impacts the plant's overall fresh weight, which in turn affects vegetative growth. In contrast, the primary factor affecting dry weight is photosynthesis within the plant (Sarif et al., 2015). These findings are notably consistent with the composition of the LOF, which is derived from goat urine, *Moringa* leaves, and banana stems and has a considerable amount of nitrogen and potassium. Nitrogen stimulates the growth of stems, branches, and leaves, crucial components of overall plant growth. Additionally, according to Adi et al. (2020), green pigmentation plays a substantial part in producing the essential for photosynthesis. In essence, nitrogen plays a significant role in leaf formation. Potassium is one of the three nutrients, along with nitrogen and phosphorus, necessary for plant growth (Muthu et al., 2023). Additionally, potassium controls how photosynthetic products are distributed, causing an increase in leaf width in response to its availability.

In comparison to the 100% NPK treatment, the 100% LOF treatment has demonstrated superior performance. This trend is evident in the average fresh weight of leaves for pak choy (Table 1) and mustard

Table 9
Correlation among growth parameters of pak choy plants

Parameters	2	3	4	5	6	7	8	9	10	11	12	13
1) FWL	X	X	0.62*	0.67*	0.53*	0.85*	0.84*	0.60*	0.59*	0.72*	0.68*	0.34*
2) FWS		0.50*	X	X	X	X	X	X	X	X	X	0.34*
3) FWR			X	X	X	X	X	X	X	X	X	0,37*
4) DWL				0.65*	0.57*	0.58*	0.59*	0.49*	0.48*	0.45*	0.60*	0.44*
5) DWS					0.54*	0.54*	0.58*	0.47*	0.45*	0.47*	0.54*	0.35*
6) DWR						0.43*	0.54*	0.28*	0.32*	0.46*	0.37*	X
7) SD							0.74*	0.66*	0.49*	0.75*	0.74*	0.37*
8) NL								0.64*	0.73*	0.72*	0.72*	0.48*
9) SPAD									0.65*	0.71*	0.76*	0.67*
10) PH										0.64*	0.74*	0.57*
11) LW											0.81*	0.48*
12) LL												0.67*
13) SL												

Note. FWL = Fresh weight of leaves; FWS = Fresh weight of stalk; FWR = Fresh weight of root; DWL = Dry weight of leaves; DWS = Dry weight of stalk; DWR = Dry weight of root; SD = Stem diameter; NL = Number of leaves; SPAD = Soil Plant Analysis Development; PH = Plant height; LW = Leaf width; LL = Leaf length; SL = Stalk length. * = Correlation; x = No correlation

Table 10
Correlation among growth parameters of mustard greens plants

Parameters	2	3	4	5	6	7	8	9	10	11	12	13
1) FWL	0.88*	0.79*	0.59*	0.82*	0.55*	0.88*	0.81*	0.78*	0.87*	0.79*	0.81*	0.81*
2) FWS		0.77*	0.58*	0.84*	0.43*	0.86*	0.82*	0.78*	0.87*	0.67*	0.69*	0.87*
3) FWR			0.57*	0.67*	X	0.78*	0.72*	0.75*	0.76*	0.74*	0.72*	0.68*
4) DWL				0.46*	X	0.64*	0.66*	0.52*	0.60*	0.72*	0.65*	0.48*
5) DWS					0.50*	0.82*	0.83*	0.70*	0.88*	0.71*	0.70*	0.83*
6) DWR						0.55*	0.53*	0.38*	0.55*	0.42*	0.41*	0.55*
7) SD							0.85*	0.75*	0.91*	0.79*	0.80*	0.77*
8) NL								0.72*	0.89*	0.78*	0.68*	0.84*
9) SPAD									0.79*	0.74*	0.76*	0.75*
10) PH										0.80*	0.80*	0.89*
11) LW											0.91*	0.64*
12) LL												0.59*
13) SL												

Note. FWL = Fresh weight of leaves; FWS = Fresh weight of stalk; FWR = Fresh weight of root; DWL = Dry weight of leaves; DWS = Dry weight of stalk; DWR = Dry weight of root; SD = Stem diameter; NL = Number of leaves; SPAD = Soil Plant Analysis Development; PH = Plant height; LW = Leaf width; LL = Leaf length; SL = Stalk length. * = Correlation; x = No correlation

greens (Table 2), which are the primary focus of this investigation. When compared to traditional NPK fertiliser, LOF has a more comprehensive nutritional composition, which can be attributed to its remarkable efficiency. Organic fertilisers are a common practice in organic vegetable production systems to maintain the quality of the land resources (Fahrurrozi et al., 2023). According to Mohamad et al. (2022), adding organic matter to the soil results in a number of positive effects, including improved soil structure stability, increased fertility, a decrease in nutrient leaching, an increase in soil biological activity, improved water retention, and a decrease in greenhouse gas emissions. According to Muarif et al. (2002), organic fertilisers also offer a number of advantages, such as an increase in cation metabolism, improved nutrient availability, and the steady, slow release of a variety of nutrients. The ability of organic fertilisers to enhance soil chemical characteristics through increased cation exchange capacity is one of its unique benefits. Soils with higher cation capacities can give plants more nutrients than soils with lower capacities. Additionally, because they contain microorganisms that increase the already-existing soil microbiota, organic fertilisers help improve soil's biological qualities. According to Situmeang et al. (2017), the addition of LOF that have been microorganism-enhanced has the ability to alter soil structure and make it more porous. Additionally, organic fertilisers are crucial in reducing pollution problems brought on by inorganic fertilisers, helping promote a more environmentally friendly and sustainable agricultural paradigm (Siavoshi et al., 2011).

This study shows that LOF based on goat urine, *Moringa* leaves, and banana stems can provide plants with a complete nutrient supply because these materials contain both macro and micronutrients as well as the growth hormones gibberellins, cytokinins, and ındole-3-acetic acid (IAA) that plants require. In contrast to inorganic fertilisers like NPK, which only contain a few types of nutrients, LOF can make up for the lack of nutrients in inorganic fertilisers.

The significance of organic fertilisers in transforming agricultural practises, particularly in cultivating leafy vegetables such as pak choy and mustard greens, cannot be overstated. It presents a viable alternative to farmers' common practice of using inorganic fertilisers on a wide range of plant commodities or, at the very least, a way to reduce that use. Since inorganic fertilisers only give a single element to address plant nutrient needs and frequently fall short of fully satisfying them, their limitations are readily apparent. Additionally, using inorganic fertilisers can negatively affect the environment and the crops, contrary to their intended use. The adoption of LOF made from plant-based materials offers an alternative and environmentally friendly method of fertilisation that is conducive to the development of organic farming. However, several interrelated factors, including the source of organic waste, the length of fermentation, and the storage conditions of these extracts, affect the nutritional profile of plant-derived extracts (Pangaribuan et al., 2019). In organic farming, notably in the development of leafy vegetables and a variety of other plant commodities, applying LOF is an efficient and very cost-effective technology. In this line, LOF made from goat urine, *Moringa* leaves, and banana stems emerges as a promising substitute that adheres to organic farming's core values. These studies will surely help to improve organic agricultural techniques and increase their long-term viability.

CONCLUSION

In terms of fresh weight of leaves, fresh weight of stalks, dry weight of leaves, stem diameter, greenness level of leaves, plant height, leaf width, and leaf length of pak choy plants, treatment with 100% LOF blend of goat urine, *Moringa* leaves, and banana stems produced the highest results. On mustard greens plants, the

100% LOF treatment with a mixture of goat urine, *Moringa* leaves, and banana stems had the highest results in terms of fresh leaf weight, dry root weight, stem diameter, greenness level of leaves, plant height, leaf width, leaf length. It is known that 100% of LOF treatment is >100% due to the RAE calculation. These findings highlight the potential of LOF made from goat urine, *Moringa* leaves, and banana stems as an alternative to standard inorganic NPK fertilisers when growing leafy vegetable greens. This research contributes significantly to the knowledge of sustainable farming practises by demonstrating superior results in critical growth parameters for both pak choy and mustard greens, offering a promising avenue for increasing crop yield and quality while reducing reliance on synthetic fertilisers.

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