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The effect of fish waste and duck manure on the growth and yield of pak choi

Muhammad Idris[1)], Imam H. Bangun[2)], Nurma Ani[3)], Dermawan Hutagaol[3)], Fajar Siddik[3)]

[1)] North Sumatera State Islamic University, Faculty of Science and Technology, Department of Biology, Jl. Lap. Golf, 20353, Pancur Batu, Deli Serdang Regency, Indonesia
[2)] Universitas Muhammadiyah Sumatera Utara, Faculty of Agriculture, Department of Agrotechnology, Medan, Indonesia
[3)] Al Azhar University Medan, Faculty of Agriculture, Department of Agriculture, Medan, Indonesia

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Abstract: In 2021, pak choi production in Indonesia was 727.47 Mg, marking an increase of 8.2% compared to the 2020 production, which was 667.47 Mg. Therefore, there is a clear need for cultivation improvement, particularly through the implementation of organic fertilisers. This study aimed to investigate the impact of liquid organic fertiliser (LOF) derived from fish waste and duck manure on the growth and yield of the pak choi plant (*Brassica rapa*. L. var. Nauli F1). A randomised block design factorial was used with two factors and three replications. The first factor considered was LOF from fish waste, comprising three levels (LOF_0 = control, LOF_1 = 25 $cm^3 \cdot dm^{-3}$ of water, and LOF_2 = 50 $cm^3 \cdot dm^{-3}$ of water). The second factor focused on duck manure fertiliser (DMF) and involved four levels (DMF_0 = control, DMF_1 = 3.7 $kg \cdot plot^{-1}$, DMF_2 = 5.55 $kg \cdot plot^{-1}$, and DMF_3 = 7.4 $kg \cdot plot^{-1}$). The results showed that the application of LOF from fish waste positively influenced the growth and yield of pak choi, with the most effective treatment observed in LOF_1 (25 $cm^3 \cdot dm^{-3}$ of water). However, the application of DMF did not yield a significant difference in its effect on the growth and yield of the pak choi plant. The control treatment (DMF_0) reported comparable results and the combination of LOF from fish waste and DMF did not show a significant effect, with the most favourable findings observed in the LOF_2DMF_0 treatment (50 $cm^3 \cdot dm^{-3}$ and control).

Keywords: *Brassica rapa* L., plant parameters, liquid organic fertiliser, manure, nutrient

INTRODUCTION

Pak choi (*Brassica rapa* L.) is a vegetable plant that belongs to the Brassicaceae family. The popularity of the plant is primarily attributed to the broader stems and leaves compared to conventional green mustard. Consequently, this particular mustard variant is extensively cultivated and has a fairly bright business prospect for pak choi farmers (Anjani, Santoso and Sumarjan, 2022). The plant can be grown in the lowlands and highlands provided enough sunlight is obtained, and good soil aeration with a soil pH of 6.5 – 7 (Sarido and Junia, 2017).

In Indonesia, the production of mustard, including pak choi, amounted to 727.47 Mg in 2021, marking an 8.2% rise from the 2020 figure of 667.47 Mg (BPS, 2021b). This increment may not be sufficient to cater to the demands of the growing population, which experienced a growth rate of 0.9% in 2021 and 1.12% in 2022 (BPS, no date). Therefore, there is a pressing need to augment pak choi production to ensure an ample vegetable supply for the people of Indonesia. The application of inorganic fertilisers appears to be the quickest remedy but also poses significant challenges such as environmental pollution, ecological harm, and higher production costs (Purba *et al.*, 2020; Keshavarz Mirzamohammadi *et al.*, 2021). Global climate change has negatively impacted soil organic matter quality. In line with the circular economy, agro-industrial, livestock, and agricultural waste with suitable physicochemical composition can be used for fertiliser production (Ma, Shen, and Liu, 2020). Organic fertilisation technology can also improve farmers' livelihoods and promote environmental health. Furthermore, organic amendments provide several benefits, including reducing dependency on fertilisers, so farmers can contribute to environmental sustainability using organic waste (Pellejero *et al.*, 2022).

Organic fertilisers can add nutrients to the soil, such as N, P, and K, as well as increase the ability to absorb nutrients and improve their chemical properties (Chen, 2006). They can replace 25 to 50, or 75%, of chemical fertilisers used for vegetables, resulting in higher yields and meeting the nutritional needs of the vegetables tested (Thanh *et al.*, 2023). The application of compost from onion residues mixed with cow dung had a positive impact on plant growth and yield of tomatoes (Pellejero *et al.*, 2021). Several examples of organic fertilisers include liquid organic fertiliser (LOF) from fish waste and duck manure fertiliser (DMF). According to Mulyani *et al.* (2019), in Jatinangor, Sumedang Regency, West Java, Indonesia, there are potential sources of organic raw materials from animal waste, such as duck waste (182.25 $kg \cdot d^{-1}$). The fish waste data is based on data on marine fish production, which is quite large, namely 6.22 mln Mg in 2015 (FAO, 2018) and 6.71 mln Mg in 2018 (FAO, 2020). The condition shows that the amount of fish waste produced in Indonesia is quite large and can be used as liquid fertiliser. A previous study by Ahuja *et al.* (2021) showed that organic fertilisers derived from fish waste contained essential nutrients such as N, P, K, calcium, magnesium, and sulphur in significant amounts.

The study by Fahlivi (2018) resulted in using LOF derived from fish waste, which had a high level of macronutrients, namely 2.11% of N, 0.22% of P, and 0.25% of K. Meanwhile, DMF could be an effective alternative to increase the productivity of sugarcane (Ratanarak and Prachuabmoh, 1991). These results indicated that using organic fertilisers, such as duck manure, could be a viable option to maintain and improve soil health and microbial diversity, contributing to more sustainable agricultural practices as an alternative to synthetic fertilisers (Wang *et al.*, 2014). This study aims to use LOF from fish waste and DMF materials, which are readily available and underutilised by the community. Therefore, the effect of LOF from fish waste and DMF, as well as their interaction on the growth and yield of the pak choi plant should be determined (*Brassica rapa* L. var. Nauli F1).

MATERIALS AND METHODS

STUDY SITE

The experiment was performed at a farmer's land, Jl. Perjuangan, Babalan District, Langkat Regency, North Sumatra Province, Indonesia (4.010702, 98.297616; 4 m a.s.l.) during the growth season (October–December) 2020, with rainfall and rainy day range of 1953 mm and 110 days, respectively (BPS, 2021a).

MATERIALS

The materials used were fish waste (±10 kg), dried duck waste (±150 kg), Decis 25 emulsifiable concentrate (EC) (*deltamethrin* – $C_{22}H_{19}Br_2NO_3$), analytical scale (Henherr BL-H2), molasses, brown sugar, effective microorganisms (EM 4), pak choi seeds (var. Nauli F1) and water.

METHODS

This study was conducted using randomised block design (RBD) factorial, and the experiment consisted of two factors and three replications. The first factor was LOF from fish waste with three levels (LOF_0 = control, LOF_1 = 25 $cm^3 \cdot dm^{-3}$ of water, LOF_2 = 50 $cm^3 \cdot dm^{-3}$ of water). The second factor was duck manure fertiliser (DMF) with four levels (DMF_0 = control, DMF_1 = 3.7 $kg \cdot plot^{-1}$, DMF_2 = 5.55 $kg \cdot plot^{-1}$, DMF_3 = 7.4 $kg \cdot plot^{-1}$) to obtain a total of 12 treatments, with three replications and 36 trial units.

The production process of LOF involved mixing 30 dm^3 of water with 10 kg of finely ground fish waste, 1 dm^3 of molasses, 250 g of brown sugar, and 1 dm^3 of EM 4. This mixture was thoroughly combined, and the incubation process took place for 30 days. Additionally, the study area covered 100 m^2 and consisted of 36 plots. Each plot measured 150 × 150 cm and was spaced at 30 × 30 cm intervals, accommodating 12 plants in each plot. Before planting, an equal amount of compost fertiliser served as the base for each plot. The treatment dosage of DMF was applied one week before planting and was thoroughly mixed with the soil to ensure complete homogeneity. LOF was applied to the soil gradually during the early planting stage, two weeks, and four weeks after planting. The seven-day-old seedlings of pak choi were transplanted into the study plots and watered. Daily watering using a hand sprayer (2 dm^3 of water per plot) was conducted in the morning and afternoon. At the same time, weed, pest, and disease control measures were taken to protect the pak choi plant from *Crocidolomia binotalis* and *Plutella maculipennis*. The pests were managed by applying Decis 25 EC with 0.4 $cm^3 \cdot dm^{-3}$ of water every two days. Pak choi was harvested 45 days after transplanting (DAT) and cleaned for production component observation. The growth parameters consisted of a) plant height (measured from the growing media surface to the highest leaf at 14, 28, and 45 DAT), and b) number of leaves (counted only for fully opened leaves at 14, 28, and 45 DAT). The yield parameters were: a) wet weight (of the cleaned pak choi, measured using an analytical scale (at harvest), b) root length (measured on cleaned roots at harvest, from the base of the stem to the tip of the root).

DATA ANALYSIS

Data were statistically analysed using ANOVA (analysis of variance). The significant variables were tested using DMRT (Duncan multiple range test) at a significance level of 5% (Weber and Skillings, 2018) using Microsoft Excel 2016 and R-Studio (Version 3.2.1) applications. Linear and quadratic regression analyses were used to investigate the relationship between the dosage of LOF from fish waste and duck manure. The regression analysis used modelling to predict the growth and yield based on the given fertiliser dosage. Meanwhile, the quadratic regression analysis was used to examine whether the relationship between the fertiliser dosage and the growth/yield was non-linear, indicating the existence of an optimal fertiliser dosage.

Linear models follow the formula prescribed by Agresti (2015):

$$Y_{ijk} = \mu + LOF_i + DMF_j + B_k + E_{ijk} \quad (1)$$

where: Y_{ijk} = response value of the variable for unit j in block i and k, μ = overall average of the dependent variable, LOF_i = treatment effect of the LOF factor at the level i (i = 1, 2, ..., t), DMF_j = treatment effect of the DMF factor at level j (j = 1, 2, ..., t), B_k = block effect of the unobserved factor in block k (k = 1, 2, ..., b), E_{ijk} = measurement error or noise that the factors in the model cannot explain, t, b = last variable in the sequence.

Quadratic models follow the formula prescribed by Agresti (2015):

$$Y = a + bX + cX^2 + \varepsilon \tag{2}$$

where: Y = dependent variable, X = independent variable, a, b, c = regression coefficients to be estimated, ε = random error.

RESULTS AND DISCUSSION

RESULTS

Effect of liquid organic fertiliser from fish waste and duck manure fertiliser on pak choi plant growth

The statistical analysis showed that applying liquid organic fertiliser (LOF) positively impacted plant growth. However, LOF did not have a significant impact on observing plant height. The observation of the number of leaves showed a significant impact ($p \leq 0.05$) 45 DAT (Fig. 1). LOF and duck manure fertiliser (DMF; $p \leq 0.05$) affected the number of leaves in pak choi 45 days after transplanting but it differed from the plant height at the same observation.

The utilisation of DMF affected the growth of pak choi leading to a decline in height at 45 DAT, as depicted in Figure 1. The highest plant height was achieved by the DMF_0 control treatment (17.08 cm), followed by DMF_2 (14.77 cm), DMF_3 (14.62 cm), and DMF_1 (14.56 cm) at 45 DAT. LOF treatment also exhibited the maximum number of leaves, as evident from Figure 1, followed by the control LOF_0 (20.74 leaves), and treatments LOF_1 (20.42 leaves) and LOF_2 (20.31 leaves). As shown in Table 1, DMF significantly ($p \leq 0.01$) influenced the number of leaves at 45 DAT, with the control DMF_0 application (21.59 leaves) resulting in the maximum number of leaves, followed by DMF_1 (20.17 leaves), DMF_2 (20.19 leaves), and DMF_3 (20.02 leaves).

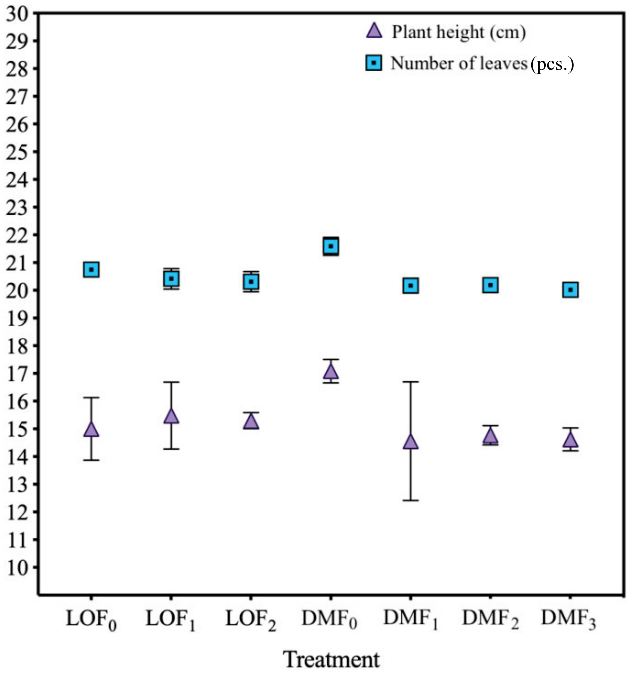

Fig. 1. The effect of the application of liquid organic fertiliser (LOF) and duck manure fertiliser (DMF) on the growth of pak choi at 45 days after transplanting; separate symbols (at mean and standard deviation); source: own study

Effect of liquid organic fertiliser from fish waste and duck manure fertiliser on pak choi yield

The wet weight and root length observations indicated that liquid organic fertiliser (LOF) and duck manure fertiliser (DMF) had an impact ($p \leq 0.01$) on the yield components of pak choi, as shown in Figure 2. Furthermore, incorporating LOF_1 (25 $mm^3 \cdot dm^{-3}$ of water) could be viewed as a potential way to enhance the plant's yield components, as presented in Table 1.

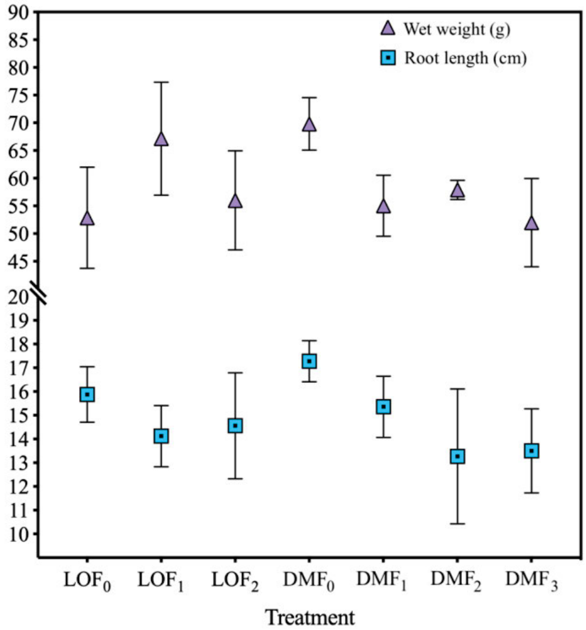

Fig. 2. The effect of the application of liquid organic fertiliser (LOF) and duck manure fertiliser (DMF) on the yield of pak choi at 45 days after transplanting; separate symbols (at mean and standard deviation); source: own study

The results in Figure 2 indicate that when applied 25 $cm^3 \cdot dm^{-3}$ of water, LOF from fish waste (LOF_1) led to the highest wet weight in pak choi. The LOF_1 treatment resulted in a wet weight of 67.16 g, while the control (DMF_0) produced 69.81 g. Furthermore, the LOF_2 and LOF_0 treatments yielded 56.01 and 52.87 g, respectively. The application of DMF at doses of 3.7 and 5.55 kg also showed promising results, producing wet weights of 55.02 and 57.02 g, respectively. Using LOF from fish waste resulted in the longest root length in almost all treatments, with the LOF_0 control producing the longest root length of 15.88 cm and the LOF_1 and LOF_2 producing shorter root lengths of 14.12 and 14.56 cm, respectively. Applying the DMF_0 control resulted in the longest root length of 17.28 cm ($p \leq 0.01$), followed by the DMF_1, DMF_2, and DMF_3 at 15.36, 13.27, and 13.50 cm.

Table 1. Summary of the liquid organic fertiliser (LOF) and duck manure fertiliser (DMF) application in observing the plant height and the number of leaves (14, 28, 45 days after transplanting (DAT)), wet weight, and root length (45 DAT).

Treatment	Plant height (cm)			Number of leaves (pcs.)			Wet weight (g)	Root length (cm)
	14 DAT	28 DAT	45 DAT	14 DAT	28 DAT	45 DAT	45 DAT	45 DAT
LOF_0	11.57^{a}	15.00^{a}	16.86^{a}	8.17^{a}	16.86^{a}	20.74^{a}	52.87^{b}	15.88^{a}
LOF_1	12.19^{a}	15.48^{a}	17.59^{a}	8.08^{a}	17.59^{a}	20.42^{ab}	67.16^{a}	14.12^{a}
LOF_2	11.89^{a}	15.30^{a}	16.91^{a}	8.39^{a}	16.91^{a}	20.31^{b}	56.01^{b}	14.56^{a}
DMF_0	13.89^{aA}	17.08^{a}	19.53^{a}	9.26^{a}	19.53^{a}	21.59^{a}	69.81^{a}	17.28^{a}
DMF_1	11.12^{b}	14.56^{b}	16.04^{b}	7.92^{b}	16.04^{b}	20.17^{b}	55.02^{bc}	15.36^{b}
DMF_2	11.21^{b}	14.77^{b}	16.56^{b}	7.74^{b}	16.56^{b}	20.19^{b}	57.89^{b}	13.27^{c}
DMF_3	11.30^{b}	14.62^{b}	16.35^{b}	7.92^{ba}	16.35^{b}	20.02^{b}	51.99^{c}	13.50^{c}
LOF_0 DMF_0	13.13^{a}	18.35^{a}	16.05^{a}	9.00^{a}	18.35^{a}	22.22^{a}	59.40^{a}	17.87^{a}
LOF_0 DMF_1	11.02^{a}	15.96^{a}	13.99^{a}	8.11^{a}	15.96^{a}	20.22^{a}	46.54^{a}	17.11^{a}
LOF_0 DMF_2	11.44^{a}	16.9^{a}	15.22^{a}	6.89^{a}	16.9^{a}	20.44^{a}	60.09^{a}	14.96^{a}
LOF_0 DMF_3	10.70^{a}	16.23^{a}	14.75^{a}	8.67^{a}	16.23^{a}	20.10^{a}	45.45^{a}	13.57^{a}
LOF_1 DMF_0	14.14^{a}	19.9^{a}	16.79^{a}	9.11^{a}	19.9^{a}	21.55^{a}	78.87^{a}	16.63^{a}
LOF_1 DMF_1	11.93^{a}	16.78^{a}	15.94^{a}	8.44^{a}	16.78^{a}	20.19^{a}	72.65^{a}	15.03^{a}
LOF_1 DMF_2	11.82^{a}	17.25^{a}	15.13^{a}	8.00^{a}	17.25^{a}	20.15^{a}	57.44^{a}	11.84^{a}
LOF_1 DMF_3	10.85^{a}	16.44^{a}	14.05^{a}	6.77^{a}	16.44^{a}	19.78^{a}	59.66^{a}	12.99^{a}
LOF_2 DMF_0	14.41^{a}	20.33^{a}	18.42^{a}	9.66^{a}	20.33^{a}	21.00^{a}	71.16^{a}	17.34^{a}
LOF_2 DMF_1	10.42^{a}	15.39^{a}	13.74^{a}	7.22^{a}	15.39^{a}	20.11^{a}	45.85^{a}	13.94^{a}
LOF_2 DMF_2	10.38^{a}	15.53^{a}	13.97^{a}	8.33^{a}	15.53^{a}	19.96^{a}	56.14^{a}	13.01^{a}
LOF_2 DMF_3	12.36^{a}	16.39^{a}	15.05^{a}	8.33^{a}	16.39^{a}	20.19^{a}	50.86^{a}	13.95^{a}
CV (%)	6.78	9.70	11.20	12.00	9.70	1.81	22.53	12.49

Explanations: Duncan's test indicates that numbers followed by different letters in the same column are statistically significant at the 0.05 level (indicated by lowercase letters) and highly significant at the 0.01 level (indicated by capital letters), *CV* = coefficient of variance.
Source: own study.

Effect of combination of liquid organic fertiliser from fish waste and duck manure fertiliser on growth and yield of pak choi

The statistical evaluation indicated that using liquid organic fertiliser (LOF) and duck manure fertiliser (DMF) in combination positively affected plant growth. However, the effect was nonsignificant during the 45 DAT, as shown in Figure 3. The recorded data regarding plant growth, comprising plant height and the number of leaves, can be examined in Table 1.

In this study, it was found that the combination of LOF and DMF positively affected plant growth, with an increase in height observed over 45 DAT. The LOF_1DMF_0 (Photo 1a) and LOF_2DMF_1 treatments had the highest and lowest plant heights at 18.42 and 13.74 cm, respectively. However, the combination did not significantly affect the number of leaves on the plant. The absence of LOF and DMF (LOF_0 and DMF_0) resulted in the highest number of leaves at 22.22. The measurement of pak choi plant yield, including wet weight and root length, after applying a combination of LOF and DMF can be seen in Figure 4.

Using a combination of LOF and DMF resulted in a positive result in pak choi yield. This study showed that

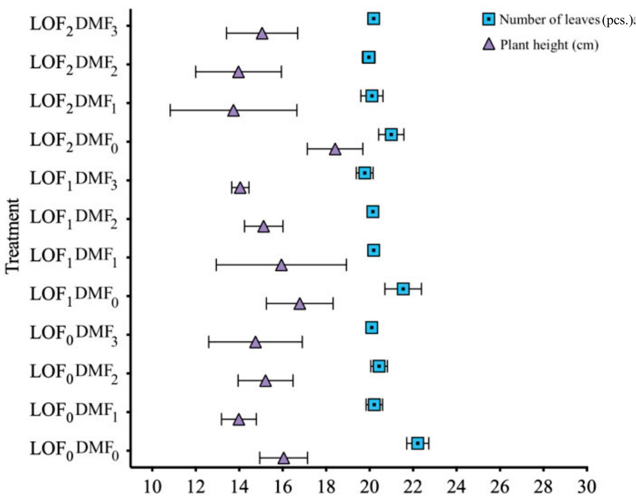

Fig. 3. The effect of the application of liquid organic fertiliser (LOF) and duck manure fertiliser (DMF) combinations on the growth of pak choi; separate symbols (at mean and standard deviation); source: own study

Photo 1. Experimental design details of the application of liquid organic fertiliser (LOF) and duck manure fertiliser (DMF): a) study plot (LOF_1DMF_0), b) all study plots, c) study plot (LOF_1DMF_2) (phot.: *F. Siddik*)

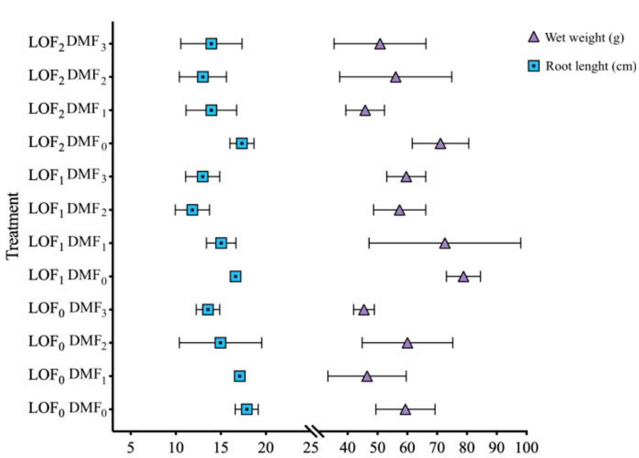

Fig. 4. The effect of the application of liquid organic fertiliser (LOF) and duck manure fertiliser (DMF) combinations on the yield of pak choi; separate symbols (at mean and standard deviation); source: own study

organic fertilisers increased the wet weight of the plant. The combination of LOF from fish waste of 25 $cm^3 \cdot dm^{-3}$ of water and no DMF (LOF_1DMF_0) (Photo 1a) yielded the highest wet weight of 78.87 g, which was 41.8% higher than the lowest observed in LOF_2DMF_1. However, the use of both fertilisers did not have a significant effect on root length in all combinations. The combination without fertiliser showed the longest root length of 17.87 cm, followed by LOF_2DMF_0 and LOF_0DMF_1 at 17.34 and 17.11 cm respectively. The shortest root length was observed in the LOF_1DMF_2 (Photo 1c) treatment with a length of 11.84 cm.

Figure 5 shows the results of the LOF regression analysis conducted on variables such as plant height at 45 DAT, number of leaves at 45 DAT, wet weight, and root length. The regression analysis indicated that the most effective amount of LOF for improving the growth and productivity of pak choi was 25 $cm^3 \cdot dm^{-3}$ of water. This dosage led to noticeable improvements in variables, such as plant height at 45 DAT, number of leaves at 45 DAT, wet weight, and root length compared to other dosages. The connection between LOF and plant height can be represented by a quadratic regression equation:

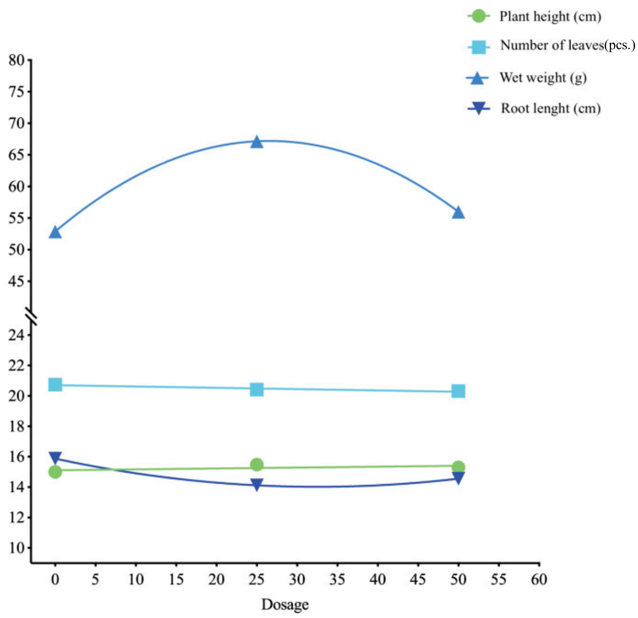

Fig. 5. Regression analysis between liquid organic fertiliser (LOF) and plant height at 45 DAT (cm), number of leaves at 45 DAT, wet weight (g), and root length (cm) of pak choi; source: own study

$$\hat{Y} = 14.72 + 2.845x - 0.705x^2; R^2 = 1 \quad (3)$$

where: $\hat{Y}$ = plant height, x = LOF, R^2 = determination coefficient.

The correlation between the number of leaves and LOF can be expressed as $\hat{Y} = 20.92 - 0.0215x$ in a linear regression equation, with an R^2 value of 0.9264. Meanwhile, the correlation between LOF and the wet weight was best described by a quadratic regression equation $\hat{Y} = 13.14 + 52.45x - 12.72x^2$ with an R^2 value of 1. The correlation between LOF and root length was reported by the quadratic regression equation $\hat{Y} = 19.84 - 5.06x + 1.1x^2$ with an R^2 value of 1. Therefore, it was recommended to use LOF at a concentration of 25 $cm^3 \cdot dm^{-3}$ of water to promote growth and productivity in pak choi since this is the optimal dosage according to the LOF regression analysis. Observation data in this research can be seen in Photo 1.

DISCUSSION

Effect of each treatment on pak choi plant growth

According to this study, the growth of pak choi can be improved by using liquid organic fertiliser (LOF) in a dosage of 25 $cm^3 \cdot dm^{-3}$ of water. Even though the observed plant height did not show a significant difference at all observation ages, using LOF had a better positive impact. The number of leaves was significantly affected by the application of LOF with the best results achieved at a dosage of 25 $cm^3 \cdot dm^{-3}$ of water. This differed from a previous study by Munar, Bangun and Lubis (2018), where using LOF made from kepok banana peels with a dosage of 75 $cm^3 \cdot polybag^{-1}$ increased the plant growth. Meanwhile, LOF treatment with high N content showed an increased number of leaves and resulted in better performance. Fishbone waste also increased N and K uptake during a 2-year study by Reppun *et al.* (2021). Other factors that affected the results were water availability, soil nutrition (Savvides, Fanourakis and Ieperen van, 2012), and environmental factors such as temperature (Kalisz *et al.*, 2012).

The application of duck manure fertiliser (DMF) significantly differed in terms of the plant height ($p \leq 0.05$), and the number of leaves ($p \leq 0.01$). Therefore, DMF did not respond to the growth of pak choi from observed parameters, and plant growth depended on the existing soil nutrients. Another possible consideration was that the high rainfall intensity caused nutrient leaching carried by surface erosion (Hagedorn *et al.*, 1997). Rainfall indirectly influenced mineralisation by affecting soil moisture levels. High rainfall led to the leaching of nutrients, reducing nutrient availability for mineralisation (Brady and Weil, 2008). The mineralisation of the organic N fraction of farm manures, both in the year of application and subsequent seasons, significantly contributed to the availability of N for plants. Temperature after the application was also essential, and superficial relationships were derived for each group of manures for the amount of N mineralised and thermal time (Bhogal *et al.*, 2016).

Another study showed that using inorganic fertiliser (NPK) at a dose of 450 $kg \cdot ha^{-1}$ could make pak choi grow to a height of 28.06 cm with 16.00 leaves at 49 DAT (Silitonga *et al.*, 2018). According to Tripathi *et al.* (2015), using inorganic fertiliser with 100 kg of N_2, 60 kg of P_2O_5, and 60 kg of K_2O per ha resulted in the best growth treatment with a height of 22.69 cm and 16.09 leaves at 45 DAT. However, using LOF and DMF fertilisers resulted in more leaves than inorganic fertilisers.

Effect of each treatment on pak choi yield

The application of organic farming using liquid organic fertiliser (LOF) from fish waste increased the yield of pak choi. This trend corresponded with the increased plant height and number of leaves during the experiment. From the observation of wet weight, the use of LOF positively increased yield compared to without LOF. Furthermore, the observation of root length also showed that applying LOF affected the root length of the plant. Using LOF at all doses resulted in shorter root lengths than without LOF due to nutrient stress. The optimal treatment for increasing the yield of LOF was 25 $cm^3 \cdot dm^{-3}$ of water, considering the efficiency factor of the regression value in Figure 5. The increase was likely due to the N content in LOF, which supplied nutrients to the plant. Additionally, nutrient N was confirmed to affect leaf differentiation speed and growth (Poinkar *et al.*, 2006), and LOF assisted in absorbing P in plant roots as a biostimulant. Applying high-level fish bone waste also resulted in an 88% increase in total P uptake and a 33% increase in average P concentration (Reppun *et al.*, 2021). Another study brought in similar results since using LOF significantly improved the growth and yield of pak choi, as evidenced by the increased root length and dry weight of roots and shoots after each harvest (Riddech, Phuong and Van, 2019). Furthermore, it was found that the use of high doses of LOF from fish waste significantly improved the growth and yield of pumpkins (Lubis *et al.*, 2021).

The application of duck manure fertiliser (DMF) significantly differed in terms of wet weight and root length at 45 DAT showing $p \leq 0.05$ and $p \leq 0.01$, but the higher results was found in the control without DMF. Traditional organic waste processing had several problems, such as long processing duration, nutrient loss during long composting, frequent need for aeration, and heterogeneous final products (Nair, Sekiozoic and Anda, 2006). The solution to optimising the composting process while reducing greenhouse gas emissions combined compost and vermicompost to process poultry manure. However, this process caused greenhouse gas and ammonia emissions, including nitrous oxide (N_2O), carbon dioxide (CO_2), and methane (CH_4), which led to stratospheric ozone depletion and global warming (Crutzen, 2016). A study conducted by Wang *et al.* (2014) aimed to reduce failures in compost production and greenhouse gas emissions by using earthworms and various organic materials in the composting process of duck manure. The results showed that earthworms positively reduced the total combined N_2O-CH_4 emissions equivalent to CO_2 and had a marginal effect on CO_2 emissions during the pre-composting and combined composting of duck manure. Therefore, pre-composting and combined composting with the addition of weed straw and zeolite were recommended as a method for disposing of duck manure, reducing NH_3 and greenhouse gas emissions, and providing nutrient-rich products as fertilisers.

Several studies on inorganic fertiliser compared its effectiveness with LOF and DMF. Using 100 kg of N_2, 60 kg of P_2O_5, and 60 kg of K_2O per ha of inorganic fertiliser resulted in a root length of 11.63 cm in pak choi (Tripathi *et al.*, 2015). Another study by Din, Cheng and Sarmidi (2017) found that combining inorganic fertiliser (NPK 15:15:15) with aerated compost extract at a dose of 150 $mg \cdot kg^{-1}$ improved the yield, producing a wet weight of 59.89 g as the best treatment. However, both studies showed that LOF at 25 $cm^3 \cdot dm^{-3}$ of water increased pak choi production more than inorganic fertiliser. This result was important since practical guidance was provided for applying LOF in enhancing the growth and yield of pak choi. Obtaining the optimal dosage was a strength of this study, which added to the knowledge base of sustainable and effective agricultural practices.

Effect of treatment combination on growth and yield of pak choi

In this study, it was found that the combination of liquid organic fertiliser (LOF) from fish waste and duck manure fertiliser (DMF) did not significantly impact the observed parameters. The need for proper interaction between the nutrients from LOF and DMF could be attributed to various factors. The two treatments did not complement each other to enhance plant growth and yield, leading to the absence of any interaction. Additionally, the response to the treatments during the exponential phase could have limited the optimal development of the plant (Ridwan, 2019). The non-significant effect on the interaction of the two treatments was caused by environmental factors controlled for good plant growth and production. According to Safrida, Ariska and Yusrizal (2019), for the plant to exhibit optimal vegetative growth, there needs to be compatibility between their genetic traits, nutritional requirements, growing media, and environmental conditions. This perspective was supported by Driesen *et al.* (2020), where plant growth was not determined by internal factors but was also influenced by various external factors, including water availability in plant tissues, air temperature, and sunlight intensity in the plant surroundings. Furthermore, applied treatments significantly impacted plant growth and productivity when these external factors were adequate.

The importance of identifying factors that contributed to plant growth and productivity was highlighted in the previous study by Lakitan (2010). The absence of support between the two treatments significantly impacted the plant's ability to absorb essential nutrients, leading to decreased growth and productivity. Therefore, understanding the roles and functions of each treatment was essential to ensure that they complemented each other and promoted plant growth optimally. Plant growth was a complex process involving multiple factors influencing the plant's response to treatments. It was essential to consider all external factors, such as environmental conditions, soil type, and nutrient availability, to ensure external factors did not limit the plant growth and productivity. By creating a favourable environment to promote plant growth and productivity, higher yields and better-quality produce were attained. Moreover, the absence of positive interaction between the two treatments was attributed to similar functions and roles. The interaction resulted in a substantial increase in growth and yield when both treatments had a comparable impact on plant growth. The identification of treatments with distinct functions, capable of complementing each other, became crucial for synergising plant growth and productivity.

CONCLUSIONS

1. The application of liquid organic fertiliser (LOF) from fish waste enhanced the growth and yield of pak choi. LOF at a dosage of 25 $cm^3 \cdot dm^{-3}$ of water also improved growth by increasing plant height (4.3%) and yield through an increase in wet weight (27%) compared to that without LOF.
2. The application of duck manure fertiliser (DMF) showed no significance on the growth and yield observations of the plant. However, a higher impact was observed by the control treatment (without DMF) with better results than the application of DMF at all doses.
3. A combination of LOF and DMF did not significantly affect the observed growth and yield of the plant compared to only LOF or DMF applications. However, LOF application at 25 $cm^3 \cdot dm^{-3}$ of water with or without DMF improved plant height and leaf number by 4.6% and 8.4% at 45 DAT and 28 DAT, respectively. The LOF + DMF application also increased the yield by 32% compared to without any fertiliser addition.

REFERENCES

Agresti, A. (2015) *Foundations of linear and generalized linear models*. Hoboken: John Wiley & Sons.

Ahuja, I. *et al.* (2021) "Fish waste as fertiliser: Effect of drying methods on fish waste and supplementing fish waste with other residual raw materials to form an organic fertiliser," *NORSØK Rapport*, 6(7), pp. 1–50.

Anjani, B.P.T., Santoso, B.B. and Sumarjan (2022) "Pertumbuhan Dan Hasil Sawi Pakcoy (Brassica rapa L.) Sistem Tanam Wadah Pada Berbagai Dosis Pupuk Kascing [Growth and yield of mustard pak choi (*Brassica rapa* L.) with container planting system at various doses of vermicompost]," *Jurnal Ilmiah Mahasiswa Agrokomplek*, 1 (1), pp. 1–9. Available at: https://doi.org/10.29303/jima.v1i1.1091.

Bhogal, A. *et al.* (2016) "Mineralization of organic nitrogen from farm manure applications," *Soil Use and Management*, 32, pp. 32–43. Available at: https://doi.org/10.1111/sum.12263.

BPS (2021a) *Kabupaten Langkat Dalam Angka 2021 [Langkat Regency in Figures 2021]*. Stabat: Badan Pusat Statistik Kabupaten Langkat. Available at: https://langkatkab.bps.go.id/publication/2021/02/26/2271d90a1a1612724ee8e506/kabupaten-langkat-dalam-angka-2021.html (Accessed: March 10, 2023).

BPS (2021b) *Statistik Hortikultura 2021 [Horticulture Statistics 2021]*. Stabat: Badan Pusat Statistik Kabupaten Langkat. Available at: https://www.bps.go.id/publication/2022/06/08/44e935e8c141bcb37569aed3/statistik-hortikultura-2021.html (Accessed: April 23, 2023).

BPS (2023) *Jumlah Penduduk Pertengahan Tahun Menurut Provinsi [Mid-Year Population by Province]*. Available at: https://www.bps.go.id/indicator/12/1975/1/jumlah-penduduk-pertengahan-tahun.html. (Accessed: March 26, 2023).

Brady, N.C. and Weil, R.R. (2008) *The nature and properties of soils*. 14th edn. Upper Saddle River: Pearson Prentice Hall.

Chen, J.H. (2006) "The combined use of chemical and organic fertilizers and/or biofertilizer for crop growth and soil fertility," in *International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertilizer Use*, pp. 1–11. Bangkok, Thailand, 16–20 Oct 2006. Land Development Department.

Crutzen, P.J. (2016) "The influence of nitrogen oxides on atmospheric ozone content," in P. Crutzen and H. Brauch (eds.) *A pioneer on atmospheric chemistry and climate change in the Anthropocene. Springer briefs on pioneers in science and practice*. Cham: Springer, pp. 108–116. Available at: https://doi.org/10.1007/978-3-319-27460-7_3.

Din, A.R.J.M., Cheng, K.K. and Sarmidi, M.R. (2017) "Assessment of compost extract on yield and phytochemical contents of pak choi (*Brassica rapa* cv. *chinensis*) grown under different fertilizer strategies," *Communications in Soil Science and Plant Analysis*, 48 (3), pp. 274–284. Available at: https://doi.org/10.1080/00103624.2016.1269793.

Driesen, E. *et al.* (2020) "Influence of environmental factors light, CO2, temperature, and relative humidity on stomatal opening and development: A review," *Agronomy*, 10(12), 1975. Available at: https://doi.org/10.3390/agronomy10121975.

Fahlivi, M.R. (2018) *Physicochemical characteristics of liquid fertilizer from fish viscera*. Final project. United Nations University Fisheries Training Programme. Available at: https://www.grocentre.is/static/gro/publication/347/document/rizal15prf.pdf (Accessed: May 18, 2022).

FAO (2018) *The state of world fisheries and aquaculture 2018 – Meeting the sustainable development goals*. Rome: Food and Agriculture Organization of the United Nations.

FAO (2020) *The state of world fisheries and aquaculture 2020 – Sustainability in action* [eBook]. Rome: Food and Agriculture Organization of the United Nations. Available at: https://doi.org/10.4060/ca9229en.

Hagedorn, F. *et al.* (1997) "Effect of rainfall pattern on nitrogen mineralization and leaching in a green manure experiment in South Rwanda," *Plant and Soil*, 195, pp. 365–375. Available at: https://doi.org/10.1023/a:1004266205502.

Kalisz, A. *et al.* (2012) "Yield and nutritional quality of several non-heading Chinese cabbage (*Brassica rapa* var. *chinensis*) cultivars with different growing period and its modelling," *Korean Journal of Horticultural Science & Technology*, 30(6), pp. 650–656. Available at: https://doi.org/10.7235/hort.2012.12108.

Keshavarz Mirzamohammadi, H. *et al.* (2021) "Irrigation and fertilizer treatments affecting rosmarinic acid accumulation, total phenolic content, antioxidant potential and correlation between them in peppermint (*Mentha piperita* L.)," *Irrigation Science*, 39(5), pp. 671–683. Available at: https://doi.org/10.1007/s00271-021-00729-z.

Lakitan, B. (2010) *Dasar-dasar fisiologi tumbuhan [Basics of plant physiology]*. 12. Jakarta: RajaGrafindo Persada.

Lubis, E. *et al.* (2021) "Use of liquid organic fertilizer fish waste and chicken manure fertilizer on the production of pumpkin (*Cucurbita moschata*)," *International Journal of Science, Technology & Management*, 2(5), pp. 1775–1779. Available at: https://doi.org/10.46729/ijstm.v2i5.348.

Ma, Y., Shen, Y. and Liu, Y. (2020) "Food waste to biofertilizer: A potential game changer of global circular agricultural economy," *Journal of Agricultural and Food Chemistry*, 68(18), pp. 5021–5023. Available at: https://doi.org/10.1021/acs.jafc.0c02210.

Mulyani, O. *et al.* (2019) "Potential of local organic matters in Jatinangor West Java Indonesia as raw materials for organic fertilizer," *IOP Conference Series Earth and Environmental Science*, 393, 012048. Available at: https://doi.org/10.1088/1755-1315/393/1/012048.

Munar, A., Bangun, I.H. and Lubis, E. (2018) "Pertumbuhan Sawi Pakchoi (*Brassica rapa* L.) Pada Pemberian Pupuk Bokashi Kulit Buah Kakao Dan Poc Kulit Pisang Kepok [Growth of mustard greens (*Brassica rapa* L.) on the application of bokashi fertilizer cocoa fruit skins and kepok banana peel POC]," *AGRIUM: Jurnal Ilmu Pertanian*, 21(3), pp. 243–253. Available at: https://doi.org/10.30596/agrium.v21i3.2449.

Nair, J., Sekiozoic, V. and Anda, M. (2006) "Effect of pre-composting on vermicomposting of kitchen waste," *Bioresource Technology*, 97(16), pp. 2091–2095. Available at: https://doi.org/10.1016/j.biortech.2005.09.020.

Pellejero, G. *et al.* (2021) "Effect of the application of compost as an organic fertilizer on a tomato crop (*Solanum lycopersicum* L.) produced in the field in the Lower Valley of the Río Negro (Argentina)," *International Journal of Recycling of Organic Waste in Agriculture*, 10(2), pp. 145–155. Available at: https://doi.org/10.30486/ijrowa.2021.1909797.1135.

Pellejero, G. *et al.* (2022) "Agronomic application effects of organic wastes on a squash crop production," *International Journal of Recycling of Organic Waste in Agriculture*, 11(1), pp. 143–151. Available at: https://doi.org/10.30486/IJROWA.2021.1941922.1353.

Poinkar, M. *et al.* (2006) "Effect of organic manure and biofertilizers on growth and yield of turmeric (*Curcuma longa* L.)," *Journal of Soils and Crops*, 16(2), pp. 417–420.

Purba, K.F. *et al.* (2020) "Technical efficiency and factors affecting rice production in tidal lowlands of South Sumatra province Indonesia," *Potravinarstvo*, 14, pp. 101–111. Available at: https://doi.org/10.5219/1287.

Ratanarak, U. and Prachuabmoh, P. (1991) "Effect of chemical fertilizer and duck manure on yield and quality of sugarcane in Eastern region [Thailand]," in *Proceedings of the 29th Kasetsart University Annual Conference*, pp. 103–108. Bangkok, Thailand, 4–7 Feb 1991. Kasetsart University.

Reppun, F. *et al.* (2021) "Effects of fresh and anaerobically digested algae (*G. salicornia*) as soil amendments on yield and nutrient concentrations of Pak choi," *Agroecology and Sustainable Food Systems*, 45(9), pp. 1270–1299. Available at: https://doi.org/10.1080/21683565.2021.1917470.

Riddech, N., Phuong L.N.X. and Van, T.T.A. (2019) "Effect of effective microorganisms (EM) with liquid organic fertilizer on the growth of pak choi (*Brassica rapa* var. *chinensis*) seedlings," *Chiang Mai Journal of Science*, 46(2), pp. 247–260.

Ridwan, M. (2019) "Produktivitas tumpangsari beberapa varietas caisim dan takaran pupuk kandang ayam dalam pola tumpang-sari tanaman caisim dan bawang daun [Productivity of intercropping of several caisim varieties and dosage of chicken manure in the intercropping pattern of caisim and onion plants]," *Jurnal Sains Agro*, 4(1).

Safrida, S., Ariska, N. and Yusrizal, Y. (2019) "Respon beberapa varietas padi lokal (*Oryza sativa* L.) Terhadap amelioran abu janjang sawit pada lahan gambut [Responses of several local rice varieties (*Oryza sativa* L.) to ameliorants of palm oil ash in peatlands]," *Jurnal Agrotek Lestari*, 5(1), pp. 28–38. Available at: https://doi.org/10.35308/jal.v5i1.1964.

Sarido, L. and Junia (2017) "Uji pertumbuhan dan hasil tanaman pakcoy (*Brassica rapa* L.) Dengan pemberian pupuk organik cair pada system hidroponik [Test the growth and yield of pak choi plants (*Brassica rapa* L.) by administering liquid organic fertiliser in a hydroponic system]," *Agrifor: Jurnal Ilmu Pertanian Dan Kehutanan*, 16(1), pp. 65–74. Available at: https://doi.org/10.31293/af.v16i1.2591.

Savvides, A., Fanourakis, D. and Ieperen van, W. (2012) "Co-ordination of hydraulic and stomatal conductances across light qualities in cucumber leaves," *Journal of Experimental Botany*, 63 (3), pp. 1135–1143. Available at: https://doi.org/10.1093/jxb/err348.

Silitonga, M. *et al.* (2018) "The effect of biochar dose and NPK fertilizer on the production and growth of pak choi plant," *IOP Conference Series: Earth and Environmental Science*, 205, 012028. Available at: https://doi.org/10.1088/1755-1315/205/1/012028.

Thanh, D.T. *et al.* (2023) "Effects of organic fertilizers produced from fish pond sediment on growth performances and yield of Malabar and Amaranthus vegetables," *Frontiers in Sustainable Food Systems*, 7, 1045592. Available at: https://doi.org/10.3389/fsufs.2023.1045592.

Tripathi, K.M. *et al.* (2015) "Evaluation of vermicompost and chemical fertilizers on performance of Pak choi (*Brassica rapa* cv. Hong Tae) and soil biological process," *Journal of the Institute of Agriculture and Animal Science*, pp. 243–250. Available at: https://doi.org/10.3126/jiaas.v33i0.20711.

Wang, J. *et al.* (2014) "Emissions of ammonia and greenhouse gases during combined pre-composting and vermicomposting of duck manure," *Waste Management*, 34(8), pp. 1546–1552. Available at: https://doi.org/10.1016/j.wasman.2014.04.010.

Weber, D.C. and Skillings, J.H. (2018) *A first course in the design of experiments: A linear models approach* [eBook]. Boca Raton: Routledge.