Research article

Agronomical Performances of Sequential Planting Pak Choi (*Brassica rapa subsp. chinensis* L.) as Responses to Weed-based Liquid Organic Fertilizer

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Abstract

The use of weed-based liquid organic fertilizers (LOFs) in organic Pak Choi production was expected to improve the effectiveness of solid organic fertilizers. Sequential vegetable planting has been practiced to improve the viability of the organic vegetable business. This research aimed to determine the effects of weed-based LOF on the yields of sequentially cropped organically grown Pak Choi. Field experiments were conducted in Rejang Lebong Highland, Indonesia, using complete randomized block design with three replicates, The first planting was in May 2021, and the second planting was in June 2021. Treatments were 0, 25, 50, 75, and 100 ppm of weed-based LOF. The results indicated that in each growing season the use of weed-based LOF had no effect on leaf number, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, and leaf greenness, as well as the N, P, K uptakes of Pak Choi. Nutrient (N, P and K) uptakes of Pak Choi in the second planting were 27.8%, 91.6% and 51.4% lower than those of the first planting, respectively. In addition, shoot fresh weight in the first planting was 56.2% higher than that found in the second planting. Nevertheless, the fresh weight of Pak Choi in both planting seasons was higher than in many studies and that of the Indonesian market standard for Pak Choi.

1. Introduction

The annual per capita consumption of vegetables for Indonesian people steadily increased from 22.91 kg/capita/year (2018), to 23.65 kg/capita/year (2019), 24.19 kg/capita/year (2020) and 25.21

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kg/capita/year in 2021 [1]. This consumption number are considered below than the existing recommendations by World Health Organization, which were ⩾240 g/day or 87.6 kg/capita/year [2]. Efforts to increase per capita consumption require improvement in the supply, accessibility and affordability of vegetables in combination with changes in consumer behavior. Moreover, it was claimed that Indonesian consumers were willing to pay higher prices for organic rather than non-organic vegetables [3]. Increased demand for organic vegetables, including Pak Choi (*Brassica rapa* subsp. *chinensis* L.), encouraged farmers to produce more organic vegetables, and this involved more sequential planting. Increased demand for organic vegetables may also be related to their healthy nutrient contents. According to El-Bassel and El-Gazzar [4], organically grown tomatoes, eggplant, lettuce, squash, carrots, and cabbage contain higher amounts of vitamin C, vitamin E, β-carotene, phosphorous, and calcium, but lower crude protein than those grown using non-organic production systems. In addition, research conducted by Turhan and Özmen [5] indicated that tomatoes fertilized with organic fertilizers produced higher total carotenoids and vitamin C than those fertilized with synthetic fertilizer.

In organic vegetable production systems, the use of solid organic fertilizers is commonly practiced as the major nutrient sources. Solid organic fertilizers do not only increase quantity and quality of cultivated crops by providing nutrients, but they also serve as soil stabilizers through their roles in modifying biological and physical characteristics of growing media. Vermicompost is one of increasing popular solid organic fertilizers used for improving vegetable production around the world. Vermicompost is a natural product generated from a simple biotechnological process of composting by using certain species of earthworms to accelerate the process of organic material decomposition. It also serves as soil ameliorant [6]. Various organic materials have been effectively used to produce vermicompost, and examples include cattle manure, food waste and paper waste [7]. The use of vermicompost has been reported to increase stem diameter, plant height, and yield of tomatoes [8]. In addition, vermicompost applied as fertilizer was reported to increase nutrient uptakes by plants [9]. Vermicompost was used to reduce the use of synthetic urea when attempting to increase the production of mung beans [10]. Regardless its beneficial effects to soil environment, the mineralization process of its nutrients in solid organic fertilizer frequently takes longer than the life cycle of the crops. It was found that most solid organic fertilizer composts applied in the soil got mineralized to less than 10% of initial N content within four to six months [11]. Meanwhile, a leaf-harvested vegetable, such as Pak Choi, can be harvested at four to five weeks after transplanting. Thus, this short growing season vegetable can be replanted in the same piece of land as a succession crop to utilize the residual nutrients from solid organic fertilizer applied in the previous planting. Indeed, the application of LOF has been reported to increase growth of three vegetables, *Ipomoea aquatica*, *Banksia integrifolia* and *Brassica rapa chinensis* [12].

Sequential cropping in organic vegetable production is practiced because farmers need to improve their land use efficiency. This technique involves producing a second crop in the same field in the same growing season immediately following the harvest of the first crop. In this strategy, a second crop is planted right after the first one is harvested, allowing for the collection of two crops from the same field in a single year [13]. Indeed, growing the same crop variety in successive planting is one of the methods used to increase crop harvest. This method has been increasingly practiced as a strategy to better utilize the available area for vegetable production [14], and has been put into practice in the organic vegetable business [15]. Although the sequential growth of Pak Choi is expected to use the nutrients from the previous growing season, growth of this crop should be additionally fertilized with liquid organic fertilizer (LOF) as supplementary source of nutrients.

The effectiveness of vermicompost as nutrient source for vegetable production could be improved with the addition of LOF. The addition was applied via leaves or earth surfaces [16] to elevate crop responses (growth and yield) to the use of solid organic fertilizer. Unlike commercial

LOF, the production of local LOF entails the use of available organic materials in the surrounding vegetable production areas, and includes the use of weeds as major nutrient sources. For example, the production of weed-based LOF was conducted by incubating a mixture of weed leaves of *Tithonia diversifolia, Ageratum conyzoides,* cattle's feces and urine, and EM-4 and water for five weeks [17]. Weed-based LOF for vegetable production to support vermicompost application has been used in sweet corn [18] and potato [19]. However, the use of weed-based LOF as a supplementary source of nutrient in the sequential cropping of organically grown Pak Choi has been less documented. The purpose of this study was to ascertain the effects of weed-based LOF on the growth, yield and nutrient uptakes of Pak Choi produced organically in sequential cropping.

2. Materials and Methods

Two sequential experiments were conducted at 1.054 m above sea level in Rejang Lebong Highland (3°39'35.1" South Latitude, 102°34'23.6" East Longitude), Indonesia. The experimental site had been continuously planted with organic sweet corn and alternately planted with soybeans, carrots, groundnuts, and green onions since 2011. The planting area had been fertilized with vermicompost at the rate of 15 Mg ha^{-1} $year^{-1}$. Vermicompost used in this experiment contained 2.15 g kg^{-1} of total N, 0.24 g kg^{-1} of P, 0.55 g kg^{-1} of K, and 25.6 g kg^{-1} of organic C [17].

The first Pak Choi was planted on 03 May and harvested on 10 June 2021, and the succession crop was planted in the same field on 24 June and reaped on 31 July 2021. Two weeks old Pak Choi seedlings (*cv*. Nauli) were planted in a soil bed (1 m x 5 m), which was 0.75 m apart within the block, and with a space of 1 m between the blocks. Each bed had four rows with a plant spacing of 0.25 x 0.25 m to make of 72 plants in each plot. During the first growing season, each soil bed received 15 Mg ha^{-1} of vermicompost at a week prior to planting. However, there was no application of vermicompost in the second growing season. Three replicates of treatments were used in a completely randomized block design for both consecutive experiments. Treatments included five different concentrations of liquid organic fertilizer (0, 25, 50, 75, and 100 ppm). The production of weed-based LOF was conducted by incubating a blend of 10 kg of cattle feces, 20 L of cattle urine, 5 kg of topsoil, 5 kg of green leaves of *Tithonia diversifolia*, 5 kg of green leaves of *Ageratum conyzoides* L., 20 L of EM-4 solution, and 135 L of water, for five weeks in a blue plastic container.

Laboratory analysis revealed that this liquid organic fertilizer had 7.36 pH, 2.23% N, 0.03% P_2O_5, 0.17% K_2O, 0.035% Ca, 0.025% Mg, 0.905% organic C, 0.505 ppm Cu, and 2.63 ppm Zn. During the course of crop growth, each plant received a total of 800 mL of weed-based LOF, at each treatment concentration, and the applications were conducted at 7, 12, 17 and 22 days after planting with total volumes of 50 mL, 125 mL, 225 mL, and 350 mL $plant^{-1}$. Crops were harvested at 35 days after planting. Weeds were manually removed every other week throughout the growing season. Crops were sprayed with the bio-pesticides Pestona® and Glio® every week to stave off pest infestations.

The average measurements of 10 sample plants per plot were used to determine the crop responses to treatments. The responses were expressed in terms of leaf number, shoot fresh weight (g), root fresh weight (g), shoot dry weight (g), root dry weight (g), and leaf greenness (SPAD values). The number of leaves was calculated at 28 days after planting by counting the number of fully develop leaves. Shoot and root fresh weight were separately determined right after harvesting by weighing the plant parts after cleaning the adhering dirt. Shoot and root dry weight were determined by weighing the dried plant parts after drying at 60-70°C until reaching constant weight. Leaf greenness was calculated by measuring the third fully expanded leaves from the plant apex using SPAD 502 Chlorophyll Meter at 3 weeks after transplanting. Four readings were conducted in each leaf and then averaged.

Nitrogen (N), phosphorus (P) and potassium (K) contents in plant (%) were calculated using wet destructive method [20]. Leaf samples were taken from fully developed leaves, typically at the third leaf from upper most expanded leaves. Nutrient uptakes were calculated as = SNC/100 SDW [21], where SNC is selected nutrient content in plant (g plant^{-1}) and SDW is shoot dry weight (g).

Data homogeneity was evaluated before doing a variance analysis. Analysis of variance aimed to examine the effects of the treatment on observed variables ($P \geqslant 0.05$). To determine the different treatment effects on the first growing season and the second growing season, pooled analysis was conducted using t-Test ($P \geqslant 0.05$). Air temperature, relative humidity, and rainfall data collected during the experiment were gathered from the Meteorology, Climatology, and Geophysical Agency's closest station.

3. Results and Discussion

3.1 Environmental conditions

The monthly precipitation averages and daily air temperature averages around the testing site during the experiment are presented in Table 1.

Table 1. Monthly precipitation averages, daily air temperature averages and relative humidity data for April to July 2021

Months	Monthly Precipitation (mm)	Daily Air Temperature (°C)	Daily Relative Humidity (%)
April	250	24.2	87
May	220	24.7	89
June	138	24.7	89
July	251	23.8	85

Source: Meteorology, Climatology, and Geophysical Agency Bengkulu (ID WMO: 96255)

These growing environments were favorable for Pak Choi [22]. In addition, soil at the experimental site had the following nutrient content: N, P, K and organic C at 0.22%, 0.000524%, 0.01365%, and 2.44%, respectively. At four and eight weeks following the first planting, the soil pH measurements showed that the soil pH was 5.32 and 5.48, respectively, levels which were considered suitable for growing Pak Choi. Soil pH might have been elevated due to the application of both vermicompost and LOF. It was previously reported that the use of vermicompost improved soil pH, aggregates, bulk density, water-holding capacity, organic matter, micronutrients, and biological properties [23].

3.2 Growth and yields Pak Choi

The results indicated that during the first growing season, the use of weed-based LOF had no effects on number of leaves, weight of fresh shoots, weight of fresh roots, weight of dry shoots, weight of dry roots, and leaf greenness of Pak Choi. Similar responses were also noticed during second planting (Table 2). However, there were different responses between the weight of fresh shoots, weight of fresh roots, weight of dry shoots, weight of dry roots, and leaf greenness of Pak Choi grown in the first and those in the second growing season (Table 2). The application of weed-based LOF did not significantly impact the N, P, and K uptakes of Pak Choi in the first and in the second

growing season. Nevertheless, the effect of treatments on growth, yield and nutrient uptakes of Pak Choi during the first growing season was significantly different from those in the second growing season.

The effects of weed-based LOF on leaf number, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, and leaf greenness Pak Choi plant during the first and the second growing season are presented in Table 3. Insignificant treatment effects observed for the number of leaves, weight of fresh shoots, weight of fresh roots, weight of dry shoots, weight of dry roots and leaf greenness of Pak Choi might have been mostly due to the continuous application of vermicompost from 2011 at the experiment site at the rate of 15 Mg ha^{-1} $year^{-1}$. Regular application of vermicompost might have brought about residual effects to the rhizosphere and dwindled the treatment effects. The high nutrient contents of the growing media (especially organic C and N) from the experimental plot leveled the growth and yields of Pak Choi. Research conducted by Ros *et al*. [24] concluded that long-term compost application to the soil (over a period of 12 years) increased organic C and total N levels in soils. Another researcher also confirmed that vermicompost application in the first planting of organic Pak Choi production provided nutrient availability for the second planting of Pak Choi [25].

Table 2. Summary F ($P \geqslant 0.05$) values of weed-based LOF on growth and nutrient uptakes of sequential cropping Pak Choi

Observed Variables	F ($P \geqslant 0.05$)	
	First Planting	Second Planting
Leaf number	0.5300	0.4600
Shoot fresh weight	0.2900	0.2400
Root fresh weight	0.6100	0.3800
Shoot dry weight	0.9100	0.7300
Root dry weight	0.6800	0.5000
Leaf greenness	0.4200	0.2000
Nitrogen uptake	0.3560	0.1580
Phosphor uptake	0.2480	0.7700
Potassium uptake	0.1180	0.1650

Table 3. Effects of concentration of weed-based LOF on Pak Choi during the first growing season ($1^{st.}$ S) and the second growing season ($2^{nd.}$ S)

Liquid Organic Fertilizer (ppm)	Leaf Number		Shoot Fresh Weight (g)		Root Fresh Weight (g)		Shoot Dry Weight (g)		Root Dry Weight (g)		Leaf Greenness (SPAD)	
	$1^{st.}$S	$2^{nd.}$S	$1^{st.}$S	$2^{nd.}$S	$1^{st.}$S	$2^{nd.}$S	$1^{st.}$S	$2^{nd.}$S	$1^{st.}$S	$2^{nd.}$S	$1^{st.}$S	$2^{nd.}$S
0	20.1	21.5	191.2	105.4	12.7	5.1	10.2	6.4	2.3	1.1	57.4	52.0
25	20.4	22.4	192.8	120.9	11.8	6.1	10.1	6.7	2.2	1.3	55.8	50.7
50	20.8	23.2	200.4	116.4	12.5	6.1	10.2	7.5	2.6	1.2	55.8	49.8
75	20.9	25.0	225.8	156.6	14.5	6.8	10.6	8.1	2.7	1.4	55.9	51.1
100	20.1	23.2	194.1	143.6	11.6	6.4	9.6	6.6	2.4	1.5	54.3	49.1
Mean Standard Error	0.20	0.67	5.95	11.31	0.63	1.16	0.28	0.42	0.12	0.07	0.48	0.44
Contrast*	0.0055		⩽0.0001		⩽0.0001		⩽0.0001		⩽0.0001		⩽0.0001	

* Seasonal comparisons between first growing season ($1^{st.}$ S) and the second growing season ($2^{nd.}$S) in the same column in each observed variable according to t-Test ($P \geqslant 0.05$)

Although the effects of weed-based LOF were insignificant in all observed variables in each growing season, the seasonal comparison revealed that Pak Choi's shoot fresh weight per plant during the first growing season was higher than that in the second growing season. This was also true for root fresh weight, shoot dry weight, root dry weight, and leaf greenness (Table 3). Interestingly, the leaf number of Pak Choi plants in the second growing season was higher than that in the first growing season. This implied that in the second growing season Pak Choi plants produced more leaves but smaller in sizes than in the first growing season. This experiment revealed that leaf number in the second planting was 11.2% higher than that in the first planting. Seasonal variation of Pak Choi growth and fresh weight was also reported where those plants grown in late autumn-early winter growing time had higher growth and fresh weight than those in late winter-early spring [26].

With respect to Pak Choi yields, shoot fresh weight is considered to be an important trait for discussion. The results from this experiment indicated that shoot fresh weight plant^{-1} during the first growing season ranged from 190 to 200 g, while the second crops had shoot fresh weights within the range of 105 to 156 g plant^{-1}. A similar trend was reported by Acikgoz [26], who noted that the fresh weight of Pak Choi grown in the first season (late autumn-early winter) (95.27 g plant^{-1}) was higher that of plants grown in the second season (late winter-early spring) (90.36 g plant^{-1}). The fresh weight of Pak Choi in this experiment was comparable to that reported by Rahmawati [27], who stated that organically grown Pak Choi produced shoot fresh weights in the range of 134 to 207 g plant^{-1}. Moreover, shoot fresh weights from this experiment were much higher than those reported by Mohamad *et al*. [28], who concluded that organically grown Pak Choi fertilized with microbial compost and vermicompost produced shoot fresh weights of 45 and 28 g plant^{-1}, respectively. Cantillo and Molon [29] found that organically grown Pak Choi produced average fresh weights of 106 g plant^{-1}, while Mohamad *et al*. [28] reported that organically grown Pak Choi fertilized with microbial compost and vermicompost had fresh weights of 45 and 27 g plant^{-1}. Our experiment revealed that shoot fresh weight in the first planting was 56.2% higher than that in the second planting. In addition, the results from this experiment were generally higher those reported by Hardiansyah *et al*. [30], who found that the use of LOF made from *jiringa* hulls produced the leaf number of 15.9, shoot fresh weight of 68.85 g plant^{-1}, and leaf greenness of 48.48 (SPAD index). The overall number of leaves was also higher than that found in previous report [31] where the highest leaf number was 13.3 after fertilization with 20 Mg ha^{-1} of solid organic fertilizer and 3 supplementations of LOF per week. Indeed, Pak Choi fertilized with vermicompost produced only 7 leaves plant^{-1} [28]. The fresh weights of Pak Choi from this experiment were not only higher than other experiments, but also higher than the Indonesian supermarket standard for Pak Choi, which is 80 g plant^{-1} [32].

3.3 Nutrient uptakes by Pak Choi

The combination and concentration of mineral nutrients in the soil determines how a plant grows and develops [33]. Because of their relative immobility, plants frequently have difficulty getting an adequate supply of essential nutrients to meet the demands of basic cellular functions. The determination of nutrient upatkes by organically grown Pak Choi in sequential planting is very important for proper fertilization management. Although the application of weed-based LOF insignificantly affected nutrient uptakes (N, P, and K), nutrient uptakes by Pak Choi during the first growing season was higher than those uptakes in the second growing season (Table 4).

The insignificant treatment effects on nutrient (N, P, and K) uptakes of Pak Choi in both growing seasons might have been related to the residual effects of continuous application of organic fertilizers, which might have dwindled the effects of LOF treatments. As previously discussed, this experimental site had beenscontinuously fertilized with 15 Mg ha^{-1} year^{-1} vermicompost since 2011.

Long-term compost applications (> 12 years) raised soil levels of organic carbon and total nitrogen and improved the healthiness of the soil [34]. In addition to soil pH, ion interactions in the rhizosphere, influx to the apoplast, and plant nutritional status, and nutrient availability in the soil environment determine ion uptakes of particular nutrients by plant roots [35]. It appeared that the use of weed-based LOF for long term organic Pak Choi production reduced the amount of solid organic fertilizer amendment into the soil. Sufficient nutrient content in the soil, due to previous vermicomposting, might have smoothed the effects of treatments on nutrient uptakes by Pak Choi. Nevertheless, treatment impacts on N, P, and K uptakes by Pak Choi in the second growing season were significantly lower than those in the first growing season (Table 4). Overall, N, P and K uptakes of Pak Choi in the second planting were lower than those in the first planting by magnitudes of 27.8%, 91.6% and 51.4%, respectively. Decreased nutrient uptakes in the second growing season were related to the declining residual effect of nutrient in the soil since the soil was not fertilized with solid organic fertilizer.

Table 4. Effects of concentration of weed-based LOF on N, P, and K uptakes by Pak Choi during the first growing season (1st. S) and the second growing season (2nd. S)

Liquid Organic Fertilizer (ppm)	Nutrient Uptakes (g plant^{-1})					
	Nitrogen		Phosphorus		Potassium	
	1st.S	2nd.S	1st.S	2nd.S	1stS	2nd.S
0	0.105	0.093	0.118	0.040	0.067	0.056
25	0.151	0.103	0.115	0.052	0.134	0.066
50	0.179	0.153	0.138	0.082	0.118	0.083
75	0.205	0.146	0.116	0.071	0.133	0.096
100	0.192	0.156	0.105	0.064	0.134	0.086
Mean Standard Error	0.14	0.13	0.009	0.006	0.11	0.007
Contrast*	0.0070		0.0002		0.0004	

* Seasonal comparisons between first growing season (1st.S) and the second growing season (2nd.S) in the same column in each observed variable according to t-Test (P⩾0.05)

4. Conclusions

Under an organic production system, the use of weed-based LOF did not increase the growth and yield, and the N, P, K uptake of doubled-cropped Pak Choi. Although the treatment effects on Pak Choi growth and yield was insignificant in each growing season, shoot fresh weight in the first planting was 56.2% higher than that found in the second planting. In addition, the N, P and K uptake of Pak Choi in the second planting were lower than in the first planting by 27.8%, 91.6% and 51.4%, respectively. It is worth mentioning that the fresh weight of Pak Choi produced in the first and the second growing seasons was higher than many organically grown Pak Choi reported by other researchers and the Indonesian market standard for this vegetable. Overall, it can be concluded that the use of weed-based LOF in the sequential cropping of organically grown Pak Choi produced economically competitive vegetables.

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References

[1] Center for Agricultural Data and Information System, 2022. *Statistics of Food Consumption.* [online] Available at: https://satudata.pertanian.go.id/assets/docs/publikasi/Buku_Statistik_Konsumsi_2022.pdf. (in Indonesian)

[2] Kalmpourtzidou, A., Eilander, A. and Talsma, E.F., 2020. Global vegetable intake and supply compared to recommendations: a systematic review. *Nutrients*, 12(6), https://doi.org/10.3390/nu12061558.

[3] Slamet, A.S., Nakayasu, A. and Bai, H., 2016. The determinants of organic vegetable purchasing in Jabodetabek Region, Indonesia. *Foods*, 5(4), https://doi.org/10.3390/foods5040085.

[4] El-Bassel, H.A. and El-Gazzar, H.H., 2019. Comparable study between organic and nonorganic vegetables in their contents of some nutritive components. *Journal of Medicine in Scientific Research*, 2(3), 204-208.

[5] Turhan, A. and Özmen, N., 2021. Effects of chemical and organic fertilizer treatments on yield and quality traits of industrial tomato. *Journal of Tekirdag Agricultural Faculty*, 18(2), 213-221, https://doi.org/10.33462/jotaf.741367.

[6] Bellitürk, K., Turan, H.S., Göçmez, S., Solmaz, Y., Üstündag, Ö. and AdIloglu, A., 2020. Effects of vermicompost applications on microelemental contents of olive saplings' production material. *Journal of Tekirdag Agricultural Faculty*, 17(3), 285-291, https://doi.org/10.33462/jotaf.652847.

[7] Arancon, N., Edwards, C.A., Bierman, P., Metzger, J.D. and Lucht, C., 2005. Effects of vermicomposts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. *Pedobiologia,* 49(4), 297-306.

[8] Wang, X-X., Zhao, F., Zhang, G., Zhang, Y. and Yang, L., 2017. Vermicompost improves tomato yield and quality and the biochemical properties of soils with different tomato planting history in a greenhouse study. *Frontier in Plant Science*, 8, https://doi.org/10.3389/fpls.2017.01978.

[9] Barlas, N.T., Cönkeroğlu, B., Unal, G. and Bellitürk, K., 2018. The effect of different vermicompost doses on wheat (*Triticum vulgaris* L.) nutrition. *Journal of Tekirdag Agricultural Faculty,* 15(2), 1-4.

[10] Mulyono, E.T., Pujiwati, H., Fahrurrozi, F., Murcitro, B.G., Supanjani, S., and Hasanudin, H., 2023. Effectiveness of vermicompost in substituting urea for promoting growth and yields of mung bean (*Vigna radiata* L.) in ultisols. *Jurnal Ilmu-Ilmu Pertanian Indonesia*, 25(1), 19-26, https://doi.org/10.31186/jipi.25.1.19-26.

[11] Hartz, T.K., Mitchell, J.P. and Giannini, C., 2000. Nitrogen and carbon mineralization dynamics of manures and composts. *HortScience,* 35(2), 209-212, https://doi.org/10.21273/hortsci.35.2.209.

[12] Nhu, N.T.H., Chuen, N.L. and Riddech, N., 2018. The effects bio-fertilizer and liquid organic fertilizer on the growth of vegetables in the pot experiment. *Chiang Mai Journal of Science,* 45(3), 1257-1273.

[13] Nafziger, E., 2009. *Cropping Systems*. [online] Available at: http://extension.cropsciences.illinois.edu/handbook/pdfs/chapter05.pdf.

[14] Borchers, A., Truex-Powell, E., Wallander, S. and Nickerson, C., 2014. *Multi-Cropping Practices: Recent Trends in Double Cropping United States Department of Agriculture.* [online] Available at: https://www.ers.usda.gov/webdocs/publications/43862/46871_eib125.pdf?v=36.6.

[15] Ugrinović, M., Zečević, B., Girek, Z., Pavlović, S., Krga, I., Damnjanović, J. and Brdan-Jokanovic, M.D., 2020. Beetroot and radish root yield in organic double-cropping production system. *Ratarstvo i Povrtarstvo*, 57(3), 93-98, https://doi.org/10.5937/ratpov57-26906.

[16] Fahrurrozi, F., Muktamar, Z., Setyowati, N., Sudjatmiko, S. and Chozin, M., 2019. Comparative effects of soil and foliar applications of Tithonia-enriched liquid organic fertilizer on yields of sweet corn in closed agriculture production system. *Agrivita,* 41(2), 238-245, https://doi.org/10.17503/agrivita.v41i2.1256.

[17] Muktamar, Z., Sudjatmiko, S., Chozin, M., Setyowati, N. and Fahrurrozi, F., 2017. Sweet corn performance and its major nutrient uptake following application of vermicompost supplemented with liquid organic fertilizer. *International Journal on Advanced Science, Engineering and Information Technology*, 7(2), 602-608, https://doi.org/10.18517/ijaseit.7.2.1112.

[18] Muktamar, Z., Adiprasetyo, T., Yulia, Suprapto, Sari, L., Fahrurrozi, F. and Setyowati, N., 2018. Residual effect of vermicompost on sweet corn growth and selected chemical properties of soils from different organic farming practices. *International Journal of Agricultural Technology*, 14(7), 1471-1482.

[19] Fahrurrozi, F., Sari, D.N., Togatorop, E.R., Salamah, U., Muktamar, Z., Setyowati, N., Chozin, M. and Sudjatmiko, S., 2019. Yield performances of potato (*Solanum tuberosum* L.) as amended with liquid organic fertilizer and vermicompost. *International Journal of Agricultural Technology*, 15(6), 869-878.

[20] Yoshida, S., Forno, D.A. and Cock, J., 1976. *Laboratory Manual for Physiological Studies of Rice*. 3rd ed. Los Baños: The International Rice Research Institute.

[21] Ardakani, M.R., Mazaheri, D., Mafakheri, S. and Moghaddam, A., 2011. Absorption efficiency of N, P, K through triple inoculation of wheat (*Triticum aestivum* L.) by *Azospirillum brasilense*, *Streptomyces* sp., *Glomus intraradices* and manure application. *Physiology and Molecular Biology of Plants*, 17(2), 181-192, https://doi.org/10.1007/s12298-011-0065-7.

[22] Setiawati, W., Murtiningsih, R., Sopha, G.A. and Handayani, D.T., 2007. *Technical Guidances for Production of Vegetable Crops*. Bandung: Balai Penelitian Tanaman Sayuran. (in Indonesian)

[23] Piya, S., Shrestha, I., Gauchan, D.P., and Lamichhane, J., 2018. Vermicomposting in organic agriculture: Influence on the soil nutrients and plant growth. *International Journal of Research*, 5(20), 1055-1063.

[24] Ros, M., Klammer, S., Knapp, B., Archberger, K. and Insam, H., 2006. Long-term effects of compost amendments of soil on functional and structural diversity and microbial activity. *Soil Use and Management*, 22(2), 209-2018, https://doi.org/10.1111/j.1475-2743.2006.00027.x.

[25] Nurhidayati, N., Machfudz, M., and Murwani, I., 2018. Direct and residual effect of various vermicompost on soil nutrient and nutrient uptake dynamics and productivity of four mustard Pak-Coi (*Brassica rapa* L.) sequences in organic farming system. *International Journal of Recycling of Organic Waste in Agriculture*, 7, 173-181, https://doi.org/10.1007/s40093-018-0203-0.

[26] Acikgoz, F.E., 2016. Seasonal variations on quality parameters of Pak Choi (*Brassica rapa* L. *subsp. chinensis* L.). *Advances in Crop Science and Technology*, 4(4), https://doi.org/10.4172/2329-8863.1000233.

[27] Rahmawati, R., 2020. Growth and production of Pakchoy under various type of organic fertilizer. *Agrotech Journal*, 5(1), 41-46, https://doi.org/10.31327/atj.v5i1.1263.

[28] Mohamad, N.S., Abu Kassim, F., Usaizan, N., Hamidon, A. and Safari, Z.S., 2022. Effects of organic fertilizer on growth performance and postharvest quality of Pak Choy (*Brassica rapa* subsp. *chinensis* L.). *AgroTech Food Science, Technology and Environment*, 1(1), 43-50, https://doi.org/10.53797/agrotech.v1i1.6.2022.

[29] Cantillo, M.A.G. and Molon, C.S.R., 2021. Growth and yield response of Pak Choi (*Brassica rapa*) to different foliar fertilizers under protected cultivation. *International Journal of Advanced Research,* 9(9), 430-431, https://doi.org/10.21474/ijar01/13427.

[30] Hardiansyah, P., Nurjanah, U. and Widodo, W., 2019. Growth response and yield of Pakcoy (*Brassica rapa* L.) on various concentrations liquid organic fertilizer of *Jiringa* hulls

[*Phithecellobium jiringa* (Jack) Prain Ex King]. *Akta Agrosia*, 22(2), 43-49, https://doi.org/10.31186/aa.22.2.43-49.

[31] Purbajanti, E.D. and Setyawati, S., 2020. Organic fertilizer improve the growth, physiological characters and yield of Pak Choy. *Agrosains: Jurnal Penelitian Agronomi*, 22(2), https://doi.org/10.20961/agsjpa.v22i2.43112.

[32] Agromediagroup, 2020. Peluang *Usaha Sayuran Hidroponik Masuk Supermarket, Ini Kriterianya dan Buku Panduannya*. [Hydroponic Vegetable Business Opportunities Enter Supermarket]. [online] Available at: https://agromediagroup.com/peluang-usaha-sayuran-hidroponik-masuk-supermarket-ini-kriterianya-dan-buku-panduannya/. (in Indonesian)

[33] Morgan, J.B. and Connolly, E.L. 2013. *Plant-Soil Interactions: Nutrient Uptake*. [online] Available at: https://www.nature.com/scitable/knowledge/library/plant-soil-interactions-nutrient-uptake-105289112/.

[34] Ros, M., Klammer, S., Knapp, B., Archberger, K. and Insam, H. 2006. Long-term effects of compost amendments of soil on functional and structural diversity and microbial activity. *Soil Use and Management,* 22(2), 209-218, https://doi.org/10.1111/j.1475-2743.2006.00027.x.

[35] White, P.J., 2012. Ion uptake mechanisms of individual cells and roots: Short-distance transport. In: P. Marschner, ed., *Marschner's Mineral Nutrition of Higher Plants*. 3rd ed. Cambridge: Academic Press, pp.7-47.