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Yield performances of potato (*Solanum tuberosum* L.) as amended with liquid organic fertilizer and vermicompost

Fahrurrozi, F.[1*], Sari, D. N.[2], Togatorop, E. R.[2], Salamah, U.[1], Muktamar, Z.[1], Setyowati, N.[1], Chozin, M.[1] and Sudjatmiko, S.[1]

[1]Crop Production Department, Faculty of Agriculture, Universitas Bengkulu, Bengkulu 38121, Indonesia; [2]Faculty of Agriculture, Universitas Ratu Samban, Arga Makmur, 38618, Indonesia.

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Abstract Closed Agriculture Production System (CAPS) Research Center, Faculty of Agriculture, Universitas Bengkulu has developed liquid organic fertilizer since 2014 by using locally available natural resources for vegetable production under closed agriculture production system. The effectiveness of liquid organic fertilizer has been evaluated on sweet corn, carrot, caisim, cauliflower, long bean, ground nut and broccoli. This research reported the use of liquid organic fertilizer in combination with vermicompost on yields of organically grown potato. Results indicated that the use of liquid organic fertilizer increased total number of tuber per plant, total weight of tuber per plant, tuber weight per plot, but not tuber diameter and marketable tubers. The use of vermicompost increased tuber diameter, total weight of tuber per plant, tuber weight per plot and number of marketable tubers, but not total weight of tuber per plant. Nevertheless, no interaction effects were recorded to all observed variables. In conclusion, both vermicompost and liquid organic fertilizer could independently increase potato yields. Under closed production system, the used of 10 ton ha^{-1} vermicompost was as effective as of 15, 20 and 25 ton ha^{-1}. Future research should be addressed to determine the concentration of liquid organic fertilizer for potato production.

Keywords: Organic vegetable, potato yield, tuber production

Introduction

Potato is considered as the third most important food crop in the world after rice and wheat that consumed by more than a billion people worldwide (International Potato Center, 2019). This crop is consequently very crucial to maintain global food security to meet continually increased population growth. Increased demands to potato crop are also in line with increased consumer demands to organic products. According to Golijan and Dimitrijevic (2018), organic fruits and vegetables are the largest and the fastest growing segment of

[*] **Corresponding Author**: Fahrurrozi, F. ; **Email**: fahrurrozi@unib.ac.id

the global organic food market which was accounted almost 40 % of total global market of organic products. Increased demand was mainly due increased consumers' awareness to health benefits from organic vegetables. Indeed, increased worldwide demands to organic vegetables have been notably taken place since 1990s (Thompson, 2000). Continuous supply of organic vegetables, including potato, must be ensured to meet increased market demands without forfeiting land and water resources.

The use of solid organic fertilizers has been widely practiced in organic potato production (Lynch *et al*., 2012). Solid organic fertilizer might be animal manure based, green biomass based or any other local organic materials available in the surrounding production sites. Khakbazan *et al.* (2014) also summarized the advantage of organic farming systems, including reduced pest infestations, energy inputs and greenhouse gas emission, leaching of pesticides into water bodies, improved soil health, and increased employment opportunities. However, several disadvantages should be also beard in mind, including financial risks, increased labor needs costs, higher standards of product certification and economic loss during the transitional period.

Vermicompost is one of solid organic fertilizer produced from composting process of organic materials by using various species of earthworms (Ramnarain *et al*., 2019). According to Piya *et al*. (2018), use of vermicompost brought positive impacts on soil quality, plant growth and crop yields as well as increased nutritional value of crops. Such impacts were resulted from improvements of soil physiochemical (aggregation, stability, pH, EC, bulk density, water holding capacity, organic matter, micro and macro-nutrients.), soil biological properties (microbial population and enzymes), increased soil structural stability and reduced soil degradations. The use of vermicompost ranged from small scale gardening to commercial growers in many type of agroecosystems, including in closed production system (Muktamar *et al*., 2017; 2018). The use of vermicompost in potato production was reported to increase potato yield (Ansari, 2008; Widijanto *et al*., 2008). Nevertheless, the use of solid organic fertilizer has limitation in terms of nutrient availability for cultivated crops since mineralization of solid organic fertilizer could take longer time than crop life-cycles (Hartz *et al*, 2000). Such trait endorses the use of liquid organic fertilizer which can be applied through leaves or soil surfaces to optimize the effects of solid organic fertilizer on crop growth and yields.

Under organic production systems, the use of solid organic fertilizer must be properly applied. Continual application of solid organic fertilizer might have created soil environment under sufficient nutrient for cultivated crops. Over fertilizing to the soil might be harmful for crops and also costly for the farmers which eventually reduced land productivity. Once organic ecosystems had been established, the use of solid organic fertilizer must be minimized. Studies on the amount of vermicompost for potato production under organically growing environment have been less reported.

Materials and Methods

A field experiment was conducted at Closed Agriculture Production System (CAPS) Research Station of Faculty of Agriculture University of Bengkulu, located Rejang Lebong, Bengkulu Province, Indonesia, at elevation of approximately 1.050 m above sea level (3°, 27', 30.38" South Latitude and 102°. 36', 51.33'' East Longitude). Experiment was established using split-plot design with three replicates where vermicompost dosages (5, 10, 15, 20 and 25 ton ha^{-1}) as main plot and liquid organic fertilizer (with versus without fertilizer) as sub-plot. Experimental plots, which was organically grown with vegetables for 6 years, were cultivated, harrowed and 15 soilbeds of 5 m x 5 m in each block were constructed two weeks before planting. The experimental plot were separated by 0.75 m within the block and 1 m between the block. A week before planting, each soilbed was accordingly fertilized with 5, 10, 15, 20 and 25 ton ha^{-1} of vermicompost (CAPS vermicompost).

Potato tuber (*cv.* Bliss) was planted at a spacing of 0.25 m x 0.25 m within the sub-plot and separated with 0.75 m between the sub-plots. There were total of 40 potato plants in each plot. Black-silver plastic mulch of 30 milli-micron in thickness were stretched over the soil bed securely thighed into the soil to cover each sub-plot. At seven weeks after planting, crops were sprayed with trichodherma-based fungicide to prevent potential fungi attacks. Each plant was applied with 250 mL liquid organic fertilizer at 2, 3, 4, 5, 6, 7 and 8 weeks after planting, respectively. Application was conducted by spraying the soil surface around the main stem without touching potato plants. Homemade liquid organic fertilizer was locally produced as suggested by Fahrurrozi *et al*. (2016), composting of cattle's faeces, cattle's urine, topsoil, green mass of *Tithonia diversifolia*, solution of effective microorganism with weight ratio of 2:4:1:2:4, respectively. All materials were aerobically incubated in a blue plastic container to reach a volume of 200 L for four weeks.

Potato yield responses to treatments were taken from average of measurement from 5 sample plants in each sub-plot and expressed as tuber diameter, total number of tuber per plant, total weight of tuber per plant, tuber weight per plot and number of marketable tubers (diameter more than 5 cm). Treatment effects were determined by analysis of variances using SAS ($P \geq 0.05$). Means of treatments were compared using Duncan's Multiple Range

Test (P ≥ 0.05). Trends of treatment responses were summarized from Polynomial orthogonal analysis.

Results

There were no significant interaction effects between vermicompost and liquid organic fertilizer on tuber diameter, total number of tuber per plant, total weight of tuber per plant, tuber weight per plot and number of marketable tubers. However, the use vermicompost and liquid organic fertilizer independently significantly affect almost all observed variables.

Effects of vermicompost

The use of vermicompost significantly affected tuber diameter (P≥F=0.0011), tuber weight per plant (P≥F=0.0001), tuber weight per plot (P≥F=0.0002), number of marketable tubers (P≥F= 0.0022), but not total number of tuber per plant (P≥F=0.2118). Potatoes grown with 10, 15, 20 and 25 ton ha^{-1} of vermicompost had significantly higher tuber diameter, total weight of tuber per plant, tuber weight per plot and number of marketable tubers than those of grown with 5 ton ha^{-1} of vermicompost (Table 1).

Table 1. Effects of vermicompost on tuber diameter (TD), tuber number per plant (TNP), total weight of tuber per plant (TWTP), tuber weight per plot (TWP) and number of marketable tubers (NMT)

Vermicompost (ton ha^{-1})	TD (mm)	TNP	TWTP (g)	TWP (g)	NMT
5	39.30[b*]	9.83[a*]	273.13[b*]	3814.7[b*]	4.53[b*]
10	50.18[a]	15.03[a]	896.00[a]	6895.8[a]	10.77[a]
15	50.50[a]	15.96[a]	845.77[a]	7610.7[a]	11.43[a]
20	51.57[a]	13.70[a]	942.90[a]	6826.3[a]	9.87[a]
25	52.68[a]	11.70[a]	832.13[a]	8289.7[a]	8.93[a]

*Means in the same column followed with the same letter are not significantly different according to Duncan's Multiple Range Test at 5%

Relationship between vermicompost dosages and tuber diameter was significantly correlated (R^2=0.716) with quadratic equation of $y = -0.0549x^2 + 2.1945x + 31.126$ (Figure 1). Optimum dosage of vermicompost to increased tuber diameter was 20.30 ton ha^{-1} to produce tuber diameter of 5.341 cm. Results also indicated that relationship between vermicompost dosages and tuber diameter was significantly correlated (R^2=0.658) with quadratic equation of $y = -3.7673x^2 + 136.34x - 251.03$ (Figure 2). Optimum dosage of vermicompost to increase total tuber weight per plant was 19.38 ton ha^{-1} to produce 975.69 gram per plant. Increased diameter of potato tuber was also in accordance with increased total tuber weight per plant (Table 1).

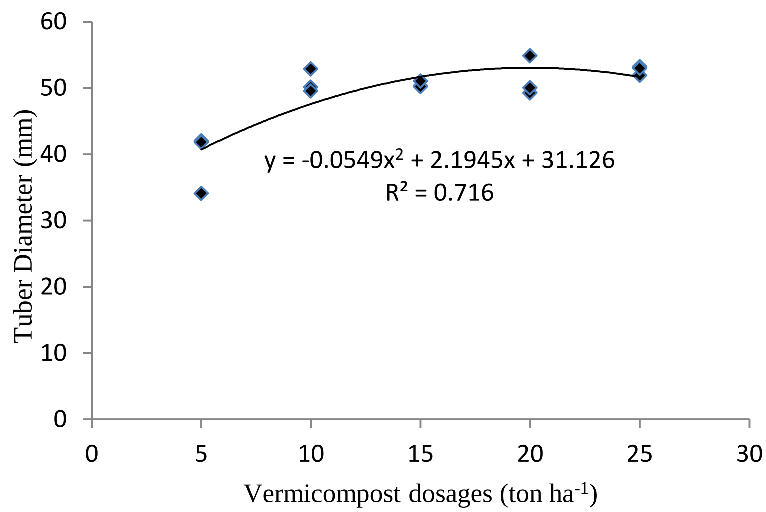

Figure 1. Relationship between vermicompost dosages and tuber diameter

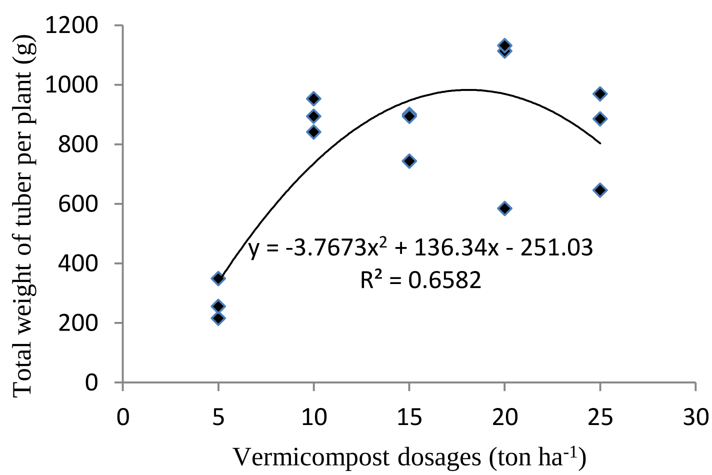

Figure 2. Relationship between vermicompost dosages and total weight of tuber per plant

The relationship between vermicompost dosages and tuber weight per plot was significantly correlated (R^2=0.307) with quadratic equation of $y = -13.528x^2 + 583.45x + 1655.9$ (Figure 3). Optimum dosage of vermicompost to increase tuber weight per plot was 21.56 ton ha^{-1} to produce 7948.55 g tubers per plot.

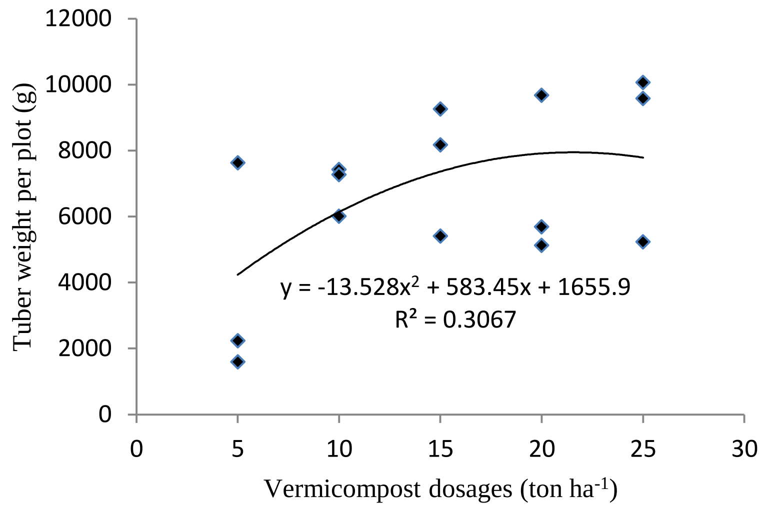

Figure 3. Relationship between vermicompost dosages and tuber weight per plot

Furthermore, relationship between vermicompost dosages and total number of marketable tuber per plant was significantly correlated (R^2=0.571) with quadratic equation of $y = -0.0473x^2 + 1.578x - 1.5467$ (Figure 4). Increased the number of marketable tuber per plant with 10 to 25 ton ha^{-1} vermicompost was significantly higher than those of 5 ton ha^{-1} (Table 1).

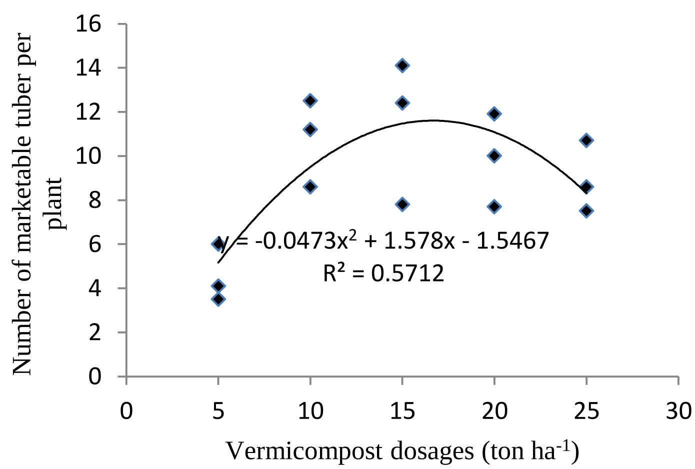

Figure 4. Relationship between vermicompost dosages and number of marketable tuber per plant

Results from this experiment, however, revealed that the application of vermicompost insignificantly effect total tuber number per plant. However, the number of potato tuber vermicomposted with 5 ton ha^{-1} was the lowest among other vermicompost treatments. The number of tubers ranged from 9 to 16 (Table 1).

Effects of liquid organic fertilizer

The use of liquid organic fertilizer significantly influence tuber weight per plant ($P \geq F=0.0466$), number of marketable tubers ($P \geq F= 0.0020$), tuber weight per plot ($P \geq F=0.0209$), but not tuber diameter ($P \geq F=0.6656$) and tuber number per plant ($P \geq F=0.0699$). The use of liquid organic fertilizer increased tuber weight per plant, number of marketable tubers and tuber weight per plot of potato (Table 2).

Table 2. Effects of liquid organic fertilizer on tuber diameter (TD), tuber number per plant (TNP), total weight of tuber per plant (TWTP), tuber weight per plot (TWP) and number of marketable tubers (NMT)

Liquid Organic Fertilizer	TD (mm)	TNP	TWTP (g)	TWP (g)	NMT
With Fertilizer	48.60[a*]	15.15[a*]	831.14[a*]	7302.7[a*]	9.92[a*]
Without Fertilizer	49.26[a]	11.34[b]	685.11[b]	6072.1[b]	8.29[a]

*Means in the same column followed with the same letter are not significantly different according to Duncan's Multiple Range Test at 5%

Higher tuber diameter, total weight of tuber per plant, tuber weight per plot and number of marketable potato tubers grown with 10, 15, 20 and 25 ton ha^{-1} vermicompost than those of grown with 5 ton ha^{-1} vermicompost might have related to nutrient contents in vermicompost which provided sufficient nutrient to support potato yields. Vermicompost used in this experiment contained 7.96 % of C, 3.06 % of N, 2.6 % of P, 1.05 % K, 1.79 % of Ca and 0.59 % of Mg with pH of 5.5 and C/N of 2.6. Similar results were reported by Sikder *et al*. (2017); Hindersah *et al*. (2019) who concluded that potato crops fertilized with vermicompost had significantly higher yields than those of grown without vermicomposting. Increased potato growth and might have also attributed to additional supplied of nutrients from the soil bed which has been continually cultivated through organic production system for six years. Yield increases of potato might also were attributed to increased potassium uptakes by potato tubers. Under organic growing condition, potassium uptakes by potato were higher than those in soil fertilized with inorganic fertilizer (Islam and Nahar, 2012). Tuber diameter is a very important trait in order to meet industrial market requirement. Increased tuber diameter might have also resulted from sufficient nutrient supplied by vermicompost for tuber development as well as vermicompost effect on decreasing of soil compaction. In addition, the use of plastic mulch might have also resulted in less compacted soil under the plastic mulch and better soil aeration (Fahrurrozi, 2018) which eventually allowed potato tuber enlargement. Kang (2004) reported that the use of 8 to 10 ton ha^{-1} vermicompost increased tuber diameter and the highest marketable tuber was attained at 10 ton ha^{-1} of vermicompost application. Experiment conducted by Yourtchi *et al*. (2013) also concluded that vermicomposting increased diameter of potato tubers. Increased tuber diameter might have resulted in increased tuber weight per plant since the bigger tuber diameter might produce the heavier tuber weight and eventually increased marketable tubers.

Results from this experiment, however, revealed that the application of vermicompost insignificantly effect total tuber number per plant. However, the number of potato tuber vermicomposted with 5 ton ha^{-1} was the lowest among other vermicompost treatments. The number of tubers ranged from 9 to 16 (Table 1) and might be considered as reasonable number of potato tubers. For example, the number of tuber for Atlantic variety was only 7-10 tubers per plant (Wilson, 2010). According to Swiader *et al*., 1992), tuber formation takes place on the stolons which arise from the stem tissue and thicken at the nodes of main underground stems. Under relatively similar environmental condition, the number of tuber in potato is determined by potato varieties (Firman, 2008). According to Wurr *et al.* (1997) the number of stolons and the environmental conditions may determine the potential number of tubers in potato crops.

The use of liquid organic fertilizer increased tuber weight per plant, number of marketable tubers and tuber weight per plot of potato (Table 2). The magnitudes of increased were 32.8 %, 21.3 % and 20.3 %, for tuber weight per plant, number of marketable tubers and tuber weight per plot, respectively. Such increased might have attributed to nutrient content in the liquid organic fertilizer used in this experiment (*i.e.* 1.84 % N, 0.43% P, 0.59 K, 2.27 ppm Zn). Similar results were reported by Parman (2007) and Marpaung *et al*. (2014). Under organic production systems, the application of liquid organic fertilizer into the soil was presumably much more effective than that on into soil of non-organic production systems. According to Piya *et al*. (2018), soil quality from improvements under organic production system included increased water holding capacity, increased soil structural stability and reduced soil degradations which, in turn, prevented liquid organic fertilizer from leaching from the percolation and run off. In addition, the ability of plastic mulch used in this experiment to prevent water and nutrient evaporation from the soil bed as well as soil compaction (Fahrurrozi, 2018) might have increased potato growth and yields. Nonetheless, the effect of liquid organic fertilizer on potato yields should be further evaluated since this experiment used 100 % of liquid organic fertilizer. Lower concentration of liquid organic fertilizer must be determined to improve the effectiveness of using liquid organic fertilizer in organic potato production.

In conclusion, this experiment suggested that producing potatoes under organically production systems was enough by using 10 ton ha^{-1} of vermicompost. The use of liquid organic fertilizer increased potato yield more than 20%.

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