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Yield responses and nutrient uptakes of groundnut (*Arachis hypogaea* L.) as affected by liquid organic fertilizer and vermicompost

Fahrurrozi, F.[1*], Muktamar, Z.[2], Sudjatmiko, S.[1], Setyowati, N.[1], Sari, D. N.[3] and Togatorop, E. R.[3]

[1]Crop Production Department, Faculty of Agriculture, Universitas Bengkulu, Bengkulu 38121, Indonesia; [2]Soil Science Department, Faculty of Agriculture, Universitas Bengkulu, Bengkulu 38121, Indonesia; [3]Faculty of Agriculture, Universitas Ratu Samban, Arga Makmur, 38618, Indonesia.

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Abstract Results indicated that the application of 15 Mg ha-1 vermicompost was considered as the best dosage for increasing pod weight, grain weight of groundnuts as well as N, P, and K uptakes. Moreover, the use of liquid organic fertilizer did not increased growth and yields of organically grown groundnuts. The use of liquid organic fertilizer did not improve the effectiveness the use of vermicompost in promoting growth and yields of organically grown groundnuts.

Keywords: Crop rotation, Groundnut, Organic fertilizer, Organic vegetable production, Nutrient uptakes

Introduction

Crop rotation in organic vegetable production systems is crucially important to maintain the sustainability of land resources and crop productivity. Crop rotation is the process of switching the cultivated crops that are grown on a specific plot of land from one growing season to the following season. Reza (2016) enumerated the benefits of crop rotation, including enhanced soil fertility and structure, control of disease, pest, and weed, increased soil organic matter, preventing of soil erosion, enhanced biodiversity, increased crop yield, and decreased commercial risk. The arrangement of crop rotation in organic vegetable production involved the use of a legume crop, since it is able to work in harmony with rhizobium at the roots of plants, which can fix atmospheric nitrogen. Foyer *et al*. (2016) determined that such fixation is accomplished by

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

converting atmospheric nitrogen) into organic nitrogen or ammonium for plant metabolisms. In organic production of non-legume crops, plants must be rotated with a legume crop, such as groundnut (*Arachis hypogaea* L.), to avoid diminishing crop productivity due to degradation of soil fertility and attacks of crop pests.

Planting groundnut as rotated crops in cropping systems have been practiced in sweet corn production, e.g., by planting groundnut after five cycles sweet corn or two cycles of sweet corn followed by groundnut (Jordan *et al*., 2009). Although this crop served as a rotated crop, which was expected to restore soil fertility after continuous planting and to cease pest attacks, yield of groundnut must be able to provide economic benefits to the growers. The uses of liquid organic fertilizer as well as soil organic fertilizer to grow groundnut as rotated crops are expected to improve agronomic performances of rotated groundnut. Vermicomposting has been reported to increase yield of groundnut (Sridevi *et al*., 2016; Chavan *et al*., 2019). Vermicomposting has been shown to improve soil quality, plant growth, crop yields, and crop nutritional value through the improvement of soil physiochemical and biological properties (Piya *et al*., 2018). Dosage of vermicompost is one of the determinant factors to improve yield of many organically grown vegetables. However, in organic vegetable production, the effectiveness of vermicompost fertilizing must be companioned with the use of liquid organic fertilizer in order to improve crop yields, e.g., in sweet corn (Muktamar *et al*., 2017) and potato (Fahrurrozi *et al*., 2019). This combination is expected to increase yield of groundnuts as a rotated crop in organic vegetable production.

Applications of solid and liquid organic fertilizers in organic groundnut production might alter nutrient availability for this crop in the rooting zones which later determine nutrients uptakes by this crop and growth and yields of groundnut. The use of vermicompost in combination with inorganic fertilizer increased N, P, and K uptakes by groundnut (Sharma *et al*., 2020). Recently, Dadhich *et al.* (2021) found that the combined application of NPK, vermicompost, and foliar spray of $ZnSO_4$ was superior to those of without foliar application of $ZnSO_4$ in increasing growth, yield, quality and economic return of groundnut. The experiment aimed to determine the effect of liquid organic fertilizer on nutrient uptakes and yields of groundnut grown in different dosages of vermicompost.

Materials and methods

A field experiment was conducted at organic soil in highland Rejang Lebong, Bengkulu, Indonesia (3°, 27’, 30.38” South Latitude and 102°. 36’, 51.33'' East Longitude), at the altitude of approximately 1.054 m above sea level from April to July 2019. This location, an Inceptisols, was organically cultivated for sweet corn production since 2011.

The experiment was used a Split Plot Design with three replicates. Vermicompost with dosages of 5, 10, 15, 20, and 25 Mg ha-1 served as main plot, whereas and the sub-plot was the liquid organic fertilizer applications; (1) not fertilized and (2) fertilized with 100% liquid organic fertilizer.

The experimental land was harrowed and 15 plots of 5 m x 5 m in each block were constructed two weeks before planting. Each plot as separated by 0.75 m within the block and 1 m between the blocks. The application of vermicompost as treatments was executed at a week before planting. Nutrient content of vermicompost used in this experiment was 3.06 % N, 2.6 % P, 1.05 % K, 1.79 % Ca, 0.59 % Mg and 7.96 % C, with pH of 5.5 (Muktamar *et al*., 2017).

Groundnut (*cv*. Tuban) was planted at a spacing of 0.30 m x 0.30 m within the sub-plot and separated with 0.75 m between the sub-plots. There were total of 90 groundnuts in a sub-plot (6 rows of 15 plants). The production of liquid organic fertilizer used in this experiment followed method proposed by Muktamar *et al.* (2017). Nutrient content of this liquid organic fertilizer was 2.23 % N, 0.03 % P_2O_5, 0.17 % K_2O, 0.035 % Ca, 0.025 % Mg, 0.505 ppm Cu, 2.63 ppm Zn and 7.36 of pH. The applications of liquid organic fertilizer (100 % in concentration) were conducted at 2, 3, 4, 5, 6, 7, 8, 9, and 10 weeks after planting, respectively, with a total volume of 1400 mL, by uniformly spraying the plants.

Groundnuts were mechanically weeded every other week and the soil around the main stems was raised up to prevent uprooting. After 3 weeks of planting, crops were also weekly sprayed with bio-pesticide Pestona® (contains active ingredients of azadirachtin, ricin, polyphenols, alkaloids, sitral, eugenol, annonain) and bio-fungicide Glio® (contains active ingredient of *Gliocladium* sp dan *Trichoderma* sp) to avoid crops from pest and pathogen attacks. Groundnut responses to treatments were evaluated from average measurement of 10 sample plants in each sub-plot. Responses of groundnut to treatments were evaluated in terms root to shoot ratio (dry weight basis), number of pods per plant, pod weight (g $plant^{-1}$), seed weight (g $plant^{-1}$), N uptakes (mg $plant^{-1}$), P uptakes (mg $plant^{-1}$), and K uptakes (mg $plant^{-1}$). Plants were harvested at 101 days after planting. In addition, N, P, K uptakes were determined taking the leaf samples from upper most fully developed leaves at 11 weeks after planting, cleaned and dried in oven at 60-70^oC until the weight is constant. Nutrient contents analysis was determined using methods of Yoshida *et al.* (1976). Nutrient uptakes (mg $plant^{-1}$) were calculated as proposed by Ardakani *et al*. (2011), *i.e.*, = PNC/100 SDW, where PNC is plant nutrient (%) and SDW is shoot dry weight per plant (mg).

Data of treatment effects on growth and yields as well as nutrient uptakes of groundnut were subjected to homogenous test before conducting analysis of variance at $P \leq 0.05$. Mean of vermicompost effects were compared using Duncan's Multiple Range Test at $P \leq 0.05$.

Results

The use of vermicompost significantly influenced pod weight ($P \leq 0.05 = 0.00001$), grain weight ($P \leq 0.05 = 0.0001$), N uptakes ($P \leq 0.05 = 0.0051$), P uptakes ($P \leq 0.05 = 0.0269$), and K uptakes ($P \leq 0.05 = 0.0001$) of groundnuts. However, it did not affect root to shoot ratio ($P \leq 0.05 = 0.8777$), and pod number ($P \leq 0.05 = 0.0544$). Application of liquid organic fertilizer significantly affected P uptakes of groundnuts ($P \leq 0.05 = 0.0131$), but insignificantly influenced other observed variables. In addition, there was no interaction effects of liquid organic fertilizer and vermicompost on all observed variables. It appeared that application of 15 Mg ha^{-1} vermicompost was considered as the best dosage for increasing pod weight, grain weight of groundnuts as well as N, P, and K uptakes (Table 1).

Table 1. Effects of vermicompost on growth, yields and nutrient uptakes of groundnut

Variables	**Vermicompost (Mg ha^{-1})**				
	5	10	15	20	25
Root to Shoot ratio	0.172 a	0.166 a	0.168 a	0.178 a	0.183 a
Pod numbers	19.03 a	20.16 a	22.80 a	23.86 a	24.40 a
Pod weight (g plant^{-1})	14.77 c	18.55 b	21.33 a	23.24 a	23.09 a
Seed weight (g plant^{-1})	10.86 b	12.49 b	15.65 a	17.01 a	17.37 a
N uptakes (mg plant^{-1})	0.55 ab	0.50 b	0.63 ab	0.70 ab	0.82 a
P uptakes (mg plant^{-1})	0.012 c	0.014 bc	0.015 abc	0.017 ab	0.018 a
K uptakes (mg plant^{-1})	0.973 c	1.575 b	2.123 a	2.398 a	2.300 a

Note: Means in the same row followed with the same letter are not significantly different according to Duncan's Multiple range Test at $P \leq 0.05$

Results indicated that using liquid organic fertilizer increased phosphorous uptakes by groundnuts (Table 2), but not significantly increased shoot to root ratio, number of pods per plant, pod weight, seed weight, N uptakes, and K uptakes.

Table 2. Effects of liquid organic fertilizer on growth, yields and nutrient uptakes of groundnut

Variables	With Liquid Organic Fertilizer	Without Liquid Organic Fertilizer
Root to shoot ratio	0.180 a	0.160 a
Pod numbers	22.240 a	21.860 a
Pod weight (g $plant^{-1}$)	21.030 a	19.360 a
Seed weight (g $plant^{-1}$)	15.570 a	13.780 a
N uptakes (mg $plant^{-1}$)	0.730 a	0.540 a
P uptakes (mg $plant^{-1}$)	0.016 a	0.014 b
K uptakes (mg $plant^{-1}$)	2.230 a	1.510 a

Note: Means in the same row followed with the same letter are not significantly different according to t-Test at P < 0.05

Although the used of vermicompost tended to increase all observed variables in groundnuts. Results indicated that there were no interaction effects of liquid organic fertilizer and vermicompost on root to shoot ratio, number of pods per plant, pod weight, seed weight, N uptakes, P uptakes and K uptakes.

Discussion

Root to shoot reflects plant healthiness and serves a sensitive indicator of plant adaptation to particular environments (Agathokleous *et al*., 2019). The application of vermicompost was expected to change the root to shoot ratio, but results of this experiment indicated that the use of vermicompost had no effects on root to shoot ratio of groundnuts. Vermicompost treatments produced root to root ratio in the range of 0.166 to 0.183. These values are comparable with the average of eight groundnut genotypes (0.153) grown under well-watered condition (Jagana *et al.,* 2012). Insignificant effects of vermicompost on root to shoot ratio might have related to insignificant effects vermicompost on root dry weight as well as shoot dry weight of groundnuts. In addition, the continuous application of vermicompost in this site might have dwindled the continuous applications of vermicompost since 2011 in the experiment plots with the same rate with the treatments, which later provided sufficient amount of nutrient to support growth of groundnuts, though this result was different to what was concluded by Mycin *et al.* (2010). Similar insignificant effect was also noticed in terms of the pod number per plant. The residual effect of vermicompost was presumably increased C-organic and N soil. According to Ros *et al*. (2006), long-term compost applications (> 12 years) increased organic-C and total-N levels in soils and had positive effects on the soil biota. The ability of legume crops to fixate atmospheric nitrogen through the existence of root number of nodules might have also taken into account. Research on the effects of vermicompost on root nodulations must be further evaluated.

This experiment, however, indicated that both pod weight and seed weight per plant increased due to vermicompost application. The use of 15 Mg ha^{-1} of vermicompost was enough to increase pod weight and seed weight, since the weights were similar to those fertilized with 20 and 25 Mg ha^{-1} of vermicompost. Similar results were previously reported by Kumar *et al*. (2014). Increased pod weight and seed weight per plant might be due to more nutrient available in the soil which was contributed by nutrient content of vermicompost used in this experiment, *i.e.,* 3.06 % N, 2.6 % P, 1.05 % K, 1.79 % Ca, 0.59 % Mg and 7.96 % organic C. Such addition nutrients might have improved soil fertility (physical, chemical and biological) and resulted greater yields of groundnuts (Sengupta *et al.,* 2016). Recently Sharma *et al.* (2020) concluded that increased pod yields groundnut was strongly related to increased N, P, K uptakes.

Results indicated hat in general groundnut fertilized with 15 Mg ha^{-1} of vermicompost was sufficient to increased N, P, K uptakes of groundnut. These results were similar to that of reported by Poonia *et al.* (2013). Increased plant uptakes might be related to increased nutrient availability on the soil (Roy *et al.*, 2006) due to vermicompost application that resulted in increasing soil pH. Continuous application of vermicompost to this experimental site might have led to increased soil pH, through the accumulation of humic substances which creating an organo-complex in soil (Muktamar *et al.,* 1998). At higher soil pH (6.0-6.5), N, P, K availability are generally increased for many plants.

Surprisingly, the use of liquid organic fertilizer did not increased root to shoot ratio, number of pods per plant, pod weight, seed weight, N and K uptakes of groundnut. However, plant fertilized with liquid organic in general had better performances in those characteristics. The application of liquid organic fertilizer only increased P uptakes of groundnuts. Increased P uptakes by groundnut might have related to high pH of liquid organic fertilizer (7.36) increased P availability in the soil through the increasing of soil pH (Muktamar *et al.*, 2015). According to Penn and Camberato. (2019), at lower soil pH (4.5-6.0), P availability was inhibited due to fixation of Ca, Al, and Fe minerals, and P availability was maximum at higher soil pH (6.5).

This experiment found that there was no interaction between the use of liquid organic fertilizer and vermicompost. Previous researches concluded the used of liquid organic fertilizer in combination with vermicompost increased yields of sweet corn (Muktamar *et al.*, 2017) and potato (Fahrurrozi *et al.*, 2019). This combination also increased soil chemical properties and nutrient availability of sweet corn (Muktamar *et al.*, 2017). It appeared that groundnut had different responses combined application of liquid organic fertilizer and vermicompost compared to other vegetable crops (sweet corn and potato). The effects of solid organic fertilizer on groundnut growth and yields are not accelerated by the supplementation of liquid organic fertilizer. As a legume crop, groundnut has an ability to produce root nodules might have contributed to this phenomenon. This plant has smaller nodules with higher nitrogen-fixing activity and are densely filled with rhizobium-infected cells which make groundnuts have higher nitrogen-fixing ability (Tajima *et al.*, 2007). This characteristic of many legume plants, including groundnut, might have eliminated the complementary effects of liquid organic fertilizer in increasing the efficacy vermicompost to increase growth and yields of organically grown groundnuts.

In conclusion, the use of 15 Mg ha^{-1} of vermicompost might be considered as the best dosage to increase the growth and yield of groundnuts. Meanwhile, the use of liquid organic fertilizer did not increase the growth and yields of organically grown groundnuts. The use of liquid organic fertilizer did not improve the effectiveness of solid organic fertilizer in promoting growth and yields of organically grown groundnuts.

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