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Effects of Greywater Organomineral Liquid Fertilizer on the Growth, Yield Performance, and Proximate Composition of Chili (*Capsicum annum* L.)

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ABSTRACT

The production cost of chili in the fertigation system has increased recently due to the high cost of water-soluble fertilizers used in the system. Laundry greywater and biodegradable vegetable waste are rich in nutrients essential for plant growth. Thus, this research aims to investigate the effects of greywater organomineral fertilizer (OMF) on the chili plants' growth and yield performance in the fertigation system. The experiment was laid out in a completely randomized design under the rain shelter. OMF produced from laundry water and vegetable waste was applied with chemical fertilizer (CF) in different ratios, including 100% CF (T1, control), 75% CF + 25% OMF (T2), 50% CF + 50% OMF (T3), 25% CF + 75% OMF (T4), and 100% OMF (T5). Results showed that the combined use of CF and OMF produced non-significantly different chili plants from those solely treated by CF. Interestingly, chili plants treated with 50% CF and 50% OMF increased the yield by 4.71% compared to CF. Chili plants treated with 25% and 50% OMF showed non-significantly different plant height, stem diameter, plant dry weight, fruit number, and proximate composition of fruits over those treated with 100% CF. Solely application of OMF produced similar chili as CF in terms of fruit quality. The present study shows that plant performance and yield of chili were improved after the application of CF and OMF at a ratio of 50:50. It can be concluded that OMF has the potential to be used as an alternative for replacing 50% of chemical fertilizer in chili fertigation system without affecting its growth and yield.

Keywords: Chili, fertigation, greywater organomineral fertilizer, proximate composition, yield performance

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INTRODUCTION

Chili (*Capsicum annum* L.) is an economic crop from the Solanaceae family (Tripodi & Kumar, 2019). It is a global spice and vegetable used in various cuisines, especially in Asian countries like Malaysia, India, and Bangladesh (A. K. Singh et al., 2021). Chili cultivation generates high revenues for producers (Karungi et al., 2013). In Malaysia, red chili (Cili Kulai) is one of the main varieties produced on commercial farms. It is usually cultivated conventionally or in a fertigation system (in open or under shelter) at the lowland (Suhaimi et al., 2016). Malaysian red chili contains high value of vitamin C, calcium, iron, fiber, and protein (Fudholi et al., 2013).

According to the Department of Statistics Malaysia, local chili production cannot meet market demand despite its economic and cultural value. In 2020, a total estimation of 28,264 tonnes of red chili was produced in Malaysia, about 54.75% less than those yielded five years back in 2016, which was 43,738 tonnes. More chili was imported from neighboring countries like China, India, and Thailand to meet local needs. The importation of chili in Malaysia rose from 49,069 tonnes in 2016 to 66,295 tonnes in 2020 (Department of Statistics Malaysia [DOSM], 2021; Sarobo, 2019).

The reduction in chili yield may cause by the instability of market value, diseases, expensive and low-quality inputs, and poor extension services (Arain, 2019). Nevertheless, the fertigation system was more financially feasible than conventional farming by increasing on-farm income and reducing weed control and fertilizer application management costs. The fertigation system provides continuous macro- and micro-nutrients to improve the growth and yield of chili plants on tin-mined land by about 130% compared to conventional nitrogen, phosphorus, and potassium (NPK) fertilizer (Subiksa et al., 2019). Balanced nutrition is the most crucial factor which ensures chili growth and yield performance. However, fertilizer cost becomes the major constraint among chili growers as water-soluble fertilizers such as potassium nitrate, monopotassium phosphate, calcium nitrate, and sulfate of potash have relatively costly compared to conventional fertilizers such as urea, diammonium phosphate, and muriate of potash (Rajput et al., 2007; Reddy & Hebbar, 2018).

On the other hand, the combined use of organic and inorganic fertilizers with biofertilizers successfully improved the plants' growth and obtained a better yield of chili (Stan et al., 2021). Organomineral fertilizer (OMF), formulated from mineral fertilizer and organic waste, is an alternative that provides the good attributes of organic and mineral fertilizer (Sá et al., 2017). The application of bio-organo mineral fertilizer enhanced chili plants' germination, growth, and yield (Nofiyanto et al., 2018). The integrated use of organic and mineral fertilizers on tomato plants significantly enhanced plant development and improved the number of clusters and fruits per plant (Tonfack et al., 2009). Furthermore, organomineral fertilizers can potentially improve soil structure more than conventional organic fertilizers (Bautista et al., 2020). The application of OMF built up nutrient retention and structural stability of the soil and ensured the continued availability of nutrients by its organic constituents (Egbuchua & Enujeke, 2013).

The present study involved liquid OMF from commercial waste (laundry greywater) and agriculture residues (dried vegetable wastes). Laundry greywater (LGW) is wastewater from commercial and urbanized clothes-washing processes. LGW mainly comprises cations: calcium, magnesium, and potassium, as well as anions such as nitrate, sulfate, carbonate, and chloride, along with organic micropollutants (OMPs) raised from the detergents (Chan et al., 2014; Mohamed et al., 2014). LGW can be reused by diverting it into gardens and lawns without treatment (Jeppesen, 1996) as its salts and nutrient contents benefit plants (Misra et al., 2010). Furthermore, vegetable waste is a biodegradable material that includes rotten peels, shells, and scraped portions of vegetables or slurries (A. Singh et al., 2012). It is a potential organic amendment owing to its high nutrient content, such as fiber, nitrogen, potassium, phosphorus, and other nutrients, and its low hazardous pollutants (Kim et al., 2018; Matthews & Maruthaipillai, 2016; Morales et al., 2016).

Considering chili is one of the essential commodities in Malaysia, there is an apparent necessity to study the effects of OMF on chili production. Despite the nutrients in LGW and vegetable waste, the product is expected to have great potential in improving chili plants' performance from their gradual release of nutrients. Therefore, this study aims to evaluate the effects of greywater OMF on chili plants' growth and yield performance in the fertigation system.

MATERIALS AND METHODS

Pot Experiment

The pot experiment was conducted under a rain shelter that allowed full sunlight for plant establishment at Agrotechnology Section, Putra Agriculture Centre, Universiti Putra Malaysia (2°58'54.5"N, 101°42'53.9"E). Chili seeds (Sakata Hot Pepper F1 Hybrid SJ1-461, India) were sown in peat moss in the nursery for 24 days. The homogenous seedlings showing better growth were selected for transplanting into the polyethylene bags of size (0.4 m width x 0.4 m height) filled with cocopeat as cultivation media under a rain shelter. The liquid OMF formulated from vegetable waste and laundry greywater was applied to chili plants (*Capsicum annum* L.) using a drip irrigation system and liquid chemical fertilizer in different ratios.

Production of Organomineral Fertilizer

Liquid OMF was prepared by mixing grounded vegetable waste and LGW in a container with a cap at a ratio of 1:10 to obtain a biological suspension. The suspension was shaken using an orbital shaker at 180 rpm for 30 min and further incubated for 12 days at room temperature. Upon reaching the respective incubation period, the fermented suspension was filtered to remove the remaining particles of the biological humus to obtain the liquid fertilizer (Rosidi, 2018). The composition of OMF is shown in Table 1.

Preparation of Chemical Fertilizer

The liquid chemical fertilizer was ready-made by Dsyira Enterprise (Malaysia). It consisted of Fertilizer A and Fertilizer B. The composition of each fertilizer is given in Table 2. Fertilizers A and B were stored in separate containers with lids under shade to prevent coagulation and precipitation of the elements. A similar amount of both CF was mixed gradually into a water tank to get a nutrient solution with the preferred electrical conductivity (EC) level. The nutrient solution was then given to the chili plants through a dripping system.

Experimental Design

The experiment was conducted in a completely randomized design (CRD), with ten replications per treatment. The treatments were 100% CF (T1, control), 75% CF + 25% OMF (T2), 50% CF + 50% OMF (T3), 25% CF + 75% OMF (T4), and 100% OMF (T5), prepared in volume basis. The treatment was given to plants by setting the EC of nutrient solution at 1.5 mS.cm^{-1} at 1 to 3 weeks after transplanting (WAT), EC 2 mS/cm at vegetative phase (6-8 WAT), and EC 3 mS/cm at generative phase (8–12 WAT). Each nutrient tank was filled up with water every morning. Then, the treatment fertilizer (T1 to T5) was poured gradually and stirred thoroughly into the respective tank until the EC meter showed its appropriate reading, as stated above.

Table 1
Composition of organomineral fertilizer

Element	Concentration (mg/L)
Nitrogen	376.00
Phosphorus	55.20
Potassium	4,139.00
Calcium	848.67
Magnesium	273.32
Sodium	397.27
Manganese	2.99
Iron	14.20
Zinc	2.07

Table 2
Composition of chemical Fertilizer A and B

Element	Composition % (w/v)
Fertilizer A	
Calcium	15.50
Nitrate nitrogen	19.00
Iron	0.05
Fertilizer B	
Nitrate nitrogen	9.00
Available phosphate	7.00
Soluble Potash	37.00
Boron	0.09
Copper	0.05
Iron	0.50
Manganese	0.19
Molybdenum	0.01
Zinc	0.19

Growth Measurements

The plant height, stem diameter, root length, and dry weight of chili plants were determined at the end of the experiment. The root length was determined with measuring tape after removing it from the growing media and washing off the loose cocopeat. The plant samples were then oven-dried at 60°C for 72 hr to obtain dry weight.

Yield

Upon the maturity stage of plants, chili fruits were continuously harvested at weekly intervals from 8 to 12 WAT. At the end of the harvest, yield (12 WAT), fruit number and weight were determined.

Proximate Composition

The quality of fruits was determined by analyzing their respective proximate composition. Moisture content was determined by drying the fruits in an oven at 105°C for 24 hr. Ash content was measured by placing the sample in the muffle furnace at 450°C for 12 hr. The total nitrogen (N) content of the fruit was determined by the Kjeldhal method (Bremner, 1965). Protein content was determined by multiplying the N content by a conversion factor (6.25) (Akhand et al., 2021).

Crude Fiber Content

Approximately 2 g of fruit sample was added into a flask with 100 ml of 1.25% sulfuric acid (H_2SO_4) (Fisher Scientific, USA). The mixture was heated at 60°C for 35 min. The flask was swirled to prevent particles from adhering to the inner surface of the flask. Next, the sample was filtered and transferred into a flask with 100 ml of 1.25% sodium hydroxide (NaOH) (Fisher Scientific, USA). The flask was again heated at 60°C for 35 min. The sample was then filtered, dried, and transferred into a crucible. The weight of the dried residue with the crucible was taken. Later, the crucibles with samples were calcined in a furnace at 450°C for 4 hr. The weight of the crucible with ash was taken, and crude fiber content was determined (Akhand et al., 2021).

Fat Content

The chili fruit was dried in an oven at 102°C for 5 hr. About 5 g of dried chili was weighed into a thimble. A piece of cotton wool was plugged into the opening of the thimble. The thimble with the sample was inserted in a Soxhlet liquid extractor. Later, the weight of a round bottom flask was taken. Next, 90 ml of petroleum ether (Sigma-Aldrich, USA) was measured and added to the flask. The extraction unit was assembled, connected to a condenser, and placed over an electrothermal extraction unit. Extraction was continued for 8 hr. After extraction, the round bottom flask was detached and removed from the heat source. The flask was then placed in a steam bath to evaporate off the residual petroleum ether. The flask was heated in an oven set at 105°C for one hour and then cooled in a desiccator. The weight was recorded, and fat content (%) was calculated according to Nielsen (2017) methods.

Data Analysis

The collected data were analyzed by one-way analysis of variance (ANOVA) using Statistical Analytical System (SAS 9.4). The treatment means were compared by Tukey's test at a 5% significant level. All analyzed parameters were subjected to a principal component analysis in order to determine which parameters largely discriminated among the different ratios of OMF using Origin software (Version 2022, Origin Lab Corporation, USA).

RESULTS AND DISCUSSION

Plant Growth

Based on Figure 1A, chili plants in T1 showed the highest plant height (66.50 cm), while T4 recorded the lowest value (50.80 cm). However, plant heights of T1, T2, T3, and T5 were not significantly different. Khandaker et al. (2017) reported that chili Kulai plants grown without fertilizer recorded a height of 42.12 cm. Besides, Figure 1B indicates that the average stem diameter of plants in T4 was significantly lower (96 mm) than T2 but statistically comparable to the rest of the treatments. Hence, applying OMF and CF have improved the growth performance of chili plant height.

Results revealed no significant difference in the root length of chili plants under five different fertilizer treatments (Figure 1C). Root length is a crucial parameter in absorbing water and plant nutrients that essential for plant growth and

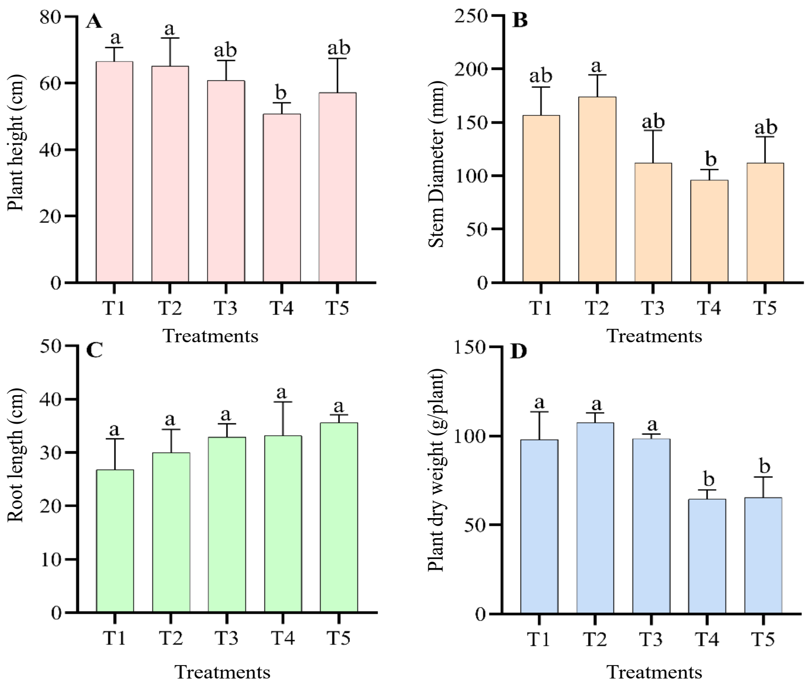

Figure 1. Effect of organomineral fertilizer (OMF) on plant height (A), stem diameter (B), root length (C), and plant dry weight (D). Vertical bars (standard deviation) with different letters are significantly different at $p \leq 0.05$ level according to Tukey's test. T1 = 100% CF; T2 = 75% CF + 25% OMF; T3 = 50% CF + 50% OMF; T4 = 25% CF + 75% OMF; T5 = 100% OMF

development (Prradhiepan et al., 2018). In this study, though no significant differences were observed among treatments in root length, plants grown under 100% OMF showed higher values.

In this experiment, the substitution of 50% recommended CF by OMF sustained all the growth parameters measured (Figure 1). Interestingly, 100% OMF showed no significant different in plant height, stem diameter, and root length to 100% recommended CF (Figures 1A, 1B & 1C). Our results are similar to the findings of Prradhiepan et al. (2018), where the combination of inorganic fertilizer and organic manure increased the root length of chili plants compared to the sole application of inorganic fertilizer (Semida et al., 2014). Further, OMF acts as a reservoir of nutrients, released slowly into substrate solution or directly to plant roots (Rady, 2012). It might be the reason which explains the higher root length in chili plants grown under 100% OMF.

However, plant dry weight was significantly lower in both 25% (T4) and 100% (T5) OMF treatments (Figure 1D) compared to the control (T1, 100% CF). As the concentration of OMF increased, the plant dry weight decreased. On the contrary, Oliveira et al. (2017) found that the dry weight of sorghum linearly increased with increasing doses of OMF. Plant growth could be attributed to different fertilizers' nutrient content encouraging vegetative growth (Atere & Olayinka, 2012). Hence, a single application of OMF could not provide enough nutrients to enhance the vegetative growth of chili plants.

The results show that the combined use of CF and OMF (25% and 50% OMF) produced chili plants with not significantly different plant height, stem diameter, and root length from those solely treated with CF and OMF. Studies revealed that mineral fertilizer is highly soluble, facilitating nutrient uptake. As a result, it promotes better crop growth during the early stages of plant development (Lourenço et al., 2013). Conversely, organic fertilizer and OMF have slow nutrient release characteristics because of their residual effect (Silva et al., 2015). As a consequence, the chili plants solely treated with OMF obtained lower plant dry weight.

Yield Performance

The results showed a significant difference in chili yield and fruit number among the treatments (Figures 2A and 2B). Chili plants under T1, T2, and T3 recorded non-significant yields, while T4 and T5 had lower yields.

The highest fruit number (145 fruits/plant) was observed in T2, which is non-significant to T1 and T3, while T4 and T5 recorded significantly lower fruit numbers. These results are similar to the finding of Olaniyi et al. (2010) in okra, where the highest fruit number and yield were recorded in the treatment with the combination of NPK fertilizer and OMF. Nevertheless, our results contradict the reported studies in which the combined use of chemical or inorganic fertilizer and organic manure enhanced the yield, fruit number, and average fruit weight of chili plants compared to a single application of

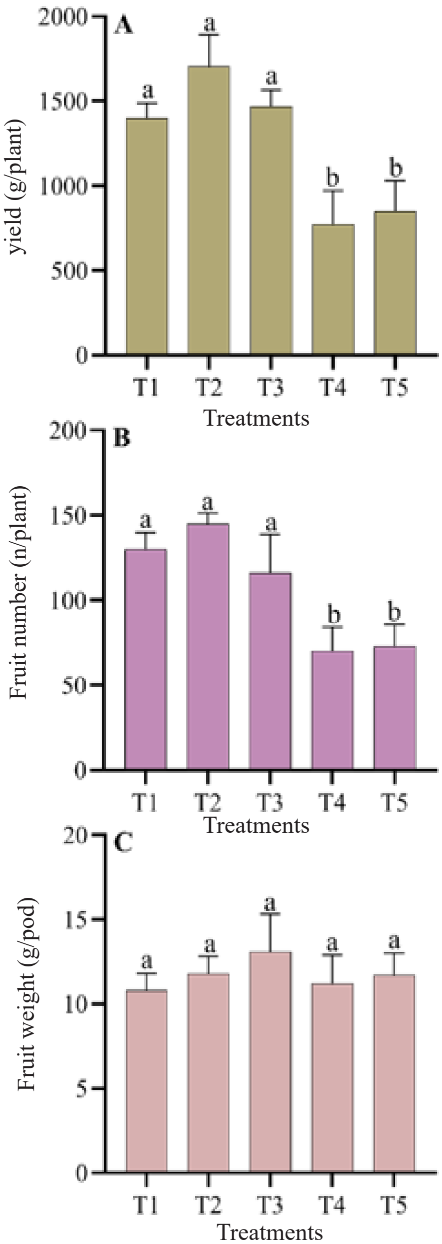

Figure 2. Effect of OMF on chili yield (A), fruit number (B), and fruit weight (C). Vertical bars (standard deviation) with different letters are significantly different at $p \leq 0.05$ level according to Tukey's test. T1 = 100% CF; T2 = 75% CF + 25% OMF; T3 = 50% CF + 50% OMF; T4 = 25% CF + 75% OMF; T5 = 100% OMF

each fertilizer (Prradhiepan et al., 2018; Stan et al., 2021). The use of OMF statistically improved the mean crop yields of forage maize, oilseed rape, and wheat more than conventional fertilizer (Deeks et al., 2013). However, OMF is sustainable due to its slow nutrients releasing nature throughout the plant growing period (Ogunlade et al., 2011). A previous study reported that N from compost was released eventually and made available evenly during OMF treatment for three consecutive years (Paul & Beauchamp, 1993). Nevertheless, it is important to note that, in annual crops, more than the amount of nutrients supplied by OMF may be needed to maintain a yield similar to chemical fertilizer.

Fruit weight showed no significant variation among treatments (Figure 2C). The results (Figures 2A and 2B) are similar to the previous studies in which the mean yield of winter wheat that received OMF treatment was approximately 20% lower than the crop yield from the conventional fertilizer plots (Deeks et al., 2013). However, a comparison of the weight of 1,000 grains of wheat showed no significant difference.

Proximate Composition

In this study, the composition of chili fruits to determine their quality and nutritional value is analyzed (Table 3).

Data revealed that the moisture content of chili samples in T2 was significantly lower than in other treatments. The moisture content was measured as it may have a marked impact on the taste, texture, appearance, shape, and weight of chili

Table 3
Effect of organomineral fertilizer on proximate composition of chili fruits

Treatment	Moisture content (%)	Ash content (%)	Nitrogen (%)	Protein (%)	Crude fiber (%)	Fat (%)
T1	87.77±0.28 ab	0.57±0.04 b	0.21±0.01	1.30±0.01	3.73±0.32 a	0.55±0.16
T2	86.29±1.22 b	0.01±0.01 c	0.21±0.01	1.33±0.02	2.31±0.21 b	0.55±0.08
T3	87.77±0.97 a	0.85±0.14 a	0.23±0.01	1.41±0.04	2.37±0.17 b	0.74±0.16
T4	87.92±1.18 a	0.85±0.10 a	0.23±0.01	1.43±0.07	2.36±0.15 b	0.45±0.10
T5	88.94±0.51 a	0.86±0.02 a	0.23±0.01	1.45±0.05	2.36±0.08 b	0.32±0.14
p-value	0.0738	<0.0001	0.1532	0.0368	0.0001	0.1014
F-value	2.98	41.96	2.69	6.09	19.09	2.59
CV (%)	1.142	15.65	4.41	4.37	9.31	31.71

Note. Columns with different letters are significantly different at $p < 0.05$ level. CV = Coefficient of variation; T1 = 100% CF; T2 = 75% CF + 25% OMF; T3 = 50% CF + 50% OMF; T4 = 25% CF + 75% OMF; T5 = 100% OMF

(Hurst et al., 2018). This result contradicts the finding that the sole application of mineral fertilizer on *Corchorus olitorius* (L.) recorded the significantly highest water content compared to those treated with the combination of organic poultry manure and mineral fertilizer (Ayinla et al., 2018).

The ash content of chili samples was measured to determine the number of minerals present within chili from each treatment (Bakkali et al., 2009). Based on Table 2, the ash content of chili samples increased significantly with increasing OMF. It might be caused by the increase of minerals received by chili plants under these treatments increased, as OMF produced from greywater and vegetable waste exhibits a wide range of minerals and elements (Chan et al., 2014; Matthews & Maruthaipillai, 2016).

The overall proximate composition of chili fruits collected from five treatments showed no significant differences in nitrogen, protein, and fat contents. The results were similar to the previous study that showed no differences in protein content in melon fruits among mineral and OMF treatments (Fernandes et al., 2003). It was reported that using organic poultry manure with inorganic fertilizer effectively combines the advantages of organic and inorganic fertilizers (Okunlola et al., 2011). Hence, it can be said that the OMF produced from vegetable waste and laundry water is compatible with commercial chemical liquid fertilizer, yielding a similar quality of fruits.

There was no significant difference observed in the fat content of chili samples. The characteristic of chili fruits having relatively low-fat content aligns with the findings that reported vegetables are not credible fat sources (Ejoh et al., 1996). Every 100 g of raw red chili is reported to contain 0.40 g of total fat (United States Department of Agriculture [USDA], 2019).

Principal Component Analysis

A comprehensive view of the growth attributes, yield, and proximate composition of chili fruit in response to different ratios of organomineral fertilizer was obtained using principal component analysis (PCA). Several scientific articles have demonstrated the effectiveness of PCA plotting for evaluating the growth enhancement, mineral nutrition, yield and quality traits of several crops (Colla et al., 2017; Raguraj et al., 2022; Rouphael et al., 2017, 2021). The first two principal components were associated with eigenvalues > 1 and explained 85.08% of the total cumulative variance, with PC1 and PC2 accounting for 64.12% and 20.96%, respectively (Figure 3). In this study, PCA scores presented in Figure 3 provide coordinated information on the growth, yield and proximate composition of chili fruit in relation to different ratios of OMF. The PC1 and PC2 score plot divides and classifies different ratios of OMF treatments into four groups. The upper right quadrant of the positive side of PC1 included 25 and 50% of OMF treatments and showed higher yield, fruit number, fruit weight, plant height, stem diameter, plant dry weight, and fat content in fruits. The lower right quadrant depicted 100% CF (Control) fertilizer treatment had higher crude fiber content. OMF 75% and 100% treatments were clustered on the negative side of the PC1. The PCA analysis conducted in the present study might provide the basis for a more in-depth investigation of the effects of different ratios of OMF treatments on the growth, yield and composition of chili fruit.

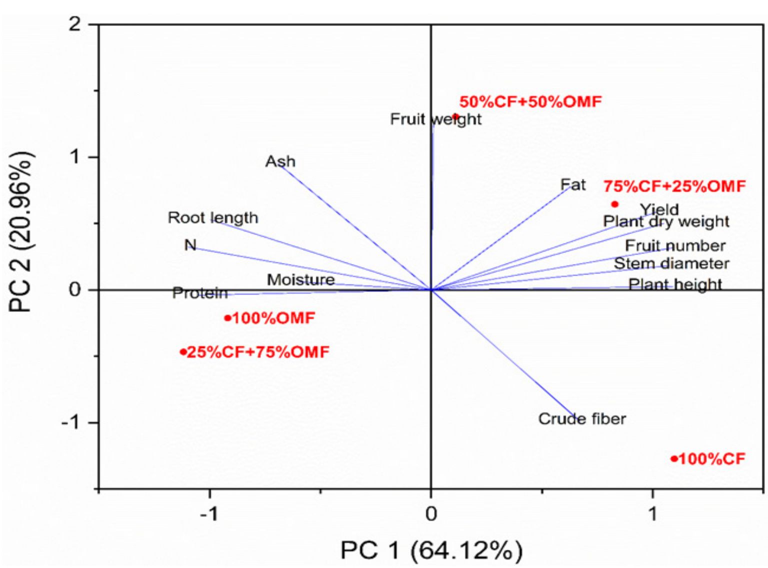

Figure 3. Principal component analysis biplot of growth attributes, yield parameters, and proximate composition of chili in response to different ratios of organomineral fertilizer

Note. CF = Chemical fertilizer; OMF = Organomineral fertilizer

CONCLUSION

Greywater liquid organomineral fertilizer is a potential material to reduce the need for commercial chemical liquid fertilizer in fertigation. The production of this fertilizer encourages nutrient recycling from urban waste into the agricultural ecosystem. Greywater organomineral fertilizer has a slow nutrient-releasing nature making them less effective in sole application. In this study, chili plants receiving 100% OMF showed comparatively lower growth and yield performance than chemical fertilizers. However, the combined use of chemical and organomineral fertilizers in chili produced yields and fruit quality similar to chemical fertilizers. Thus, it could significantly minimize chemical fertilizer costs and improve the sustainability of chili cultivation. Finally, it is suggested to use 50% of CF and 50% of OMF in the fertigation system to obtain better yield performance of chili plants.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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