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Research Article
Liquid Organic Fertilizer Increased Nutrient Uptakes, Growth and Yields of Organically Grown Carrot and Green Onion

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Abstract

Background and Objective: Sustainable supply of organic carrots and green onions must be established to comply with increased market demands by using solid organic fertilizers. The effectiveness of solid organic fertilizer must be amended with liquid organic fertilizer application to improve nutrient uptakes, growth and yields of carrot and green onion. This experiment aimed to determine the effect of liquid organic fertilizer on growth, yields and nutrient uptakes (N, P and K) by organically grown carrots and green onions. **Materials and Methods:** Two parallel experiments (carrot and green onion) were separately arranged in a completely randomized block design with three replicates. Treatments were five levels of liquid organic fertilizer concentrations (0, 25, 50, 75 and 100%). **Results:** Results indicated that the use of liquid organic fertilizer increased N, P and K uptakes by carrots and green onions, increased plant height, shoot dry weight, tuber fresh weight and tuber diameter of carrots and increased shoot fresh weight, root fresh weight, tiller number, shoot dry weight and root dry weight of green onions. Increases in tuber fresh weight of carrots and shoot fresh weight of green onions were related to their increased N, P, K uptakes. **Conclusion:** Results concluded that the use of 50 and 25% of liquid organic fertilizer was considered sufficient to produce high biological yields of tuber fresh weight of carrots and shoot fresh weight of green onion, respectively.

Key words: Carrot, green onion, growth and yields, liquid organic fertilizer, nutrient uptakes, organic farming, vegetable production

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Both carrot (*Daucus carota* L.) and green onion (*Allium fistulosum* L.) are among very popular vegetable dishes for many people around the world due to their great sources of nutritious content that benefit human health. Increased consumer demands for organically grown carrots and green onion are inevitable and will go along with the increased demands for overall organic vegetables. Consumer demand for organic fruits and vegetables accounted for almost 40% of the total global market of organic products[1]. A sustainable supply of organic vegetables, including carrots and green onions, must be guaranteed to meet increased market demands without sacrificing land and water resources. Both carrots and green onion have been organically produced around the world by using solid organic fertilizers. Organic carrot has been widely produced in countries like United States[2], Sweden[3], Estonia[4], Pakistan[5], Nepal[6], Brazil[7], India[8] and Indonesia[9] by using solid organic fertilizers. Likewise, the production of organic green onion, also known as welsh onion, spring onion, scallion, scallion and salad onion, has been also broadly practised in many countries, such as in Netherland[10], Poland[11] Japan[12], Taiwan[13], India[14], 2017 and Indonesia[15]. Successfulness of growing organic vegetable production requires a consistent nutrient supply which was mainly provided by the application of organic fertilizers. A proper supply of organic fertilizer is very important since insufficient nutrient supplies in the organic production system might bring about a significant reduction in crop growth and development as well as pest and disease problems.

Crop ability to absorb major nutrients in organically grown vegetables is very important for estimating the number of nutrients that must be provided to support the quality of crop yields and the sustainability of land resources. Solid organic fertilizer application has been commonly practised in organic vegetable production systems since it improves the physical and chemical[16] as well as biological[17] properties of the soil which eventually establishes a more favourable growing environment for cultivated crops. However, the use of solid organic fertilizer must be accompanied by the use of liquid organic fertilizer to improve its effectiveness for organic vegetable production. This supplement was related to the slow-release traits of solid organic fertilizer which can delay the early growth of vegetables[18]. The amendment of liquid organic fertilizer in organic sweet corn production increased nitrogen uptake but not phosphorus and potassium uptakes[19]. The research concluded that potassium uptakes by sweet corn fertilized with liquid organic fertilizer significantly increased shoot dry weight, the weight of husked ear and the yield of sweet corn[20]. Concerning phosphorus uptakes, the application of liquid organic fertilizer significantly increased growth and yields as well as shortened ‘time to tasseling and silking’ of organically grown sweet corn[21]. Yet, nutrient uptakes to particular nutrients among plants might vary among species and genotypes in different growing environments.

There has been increasing interest in the use of homemade (non-commercial) liquid organic fertilizer for the organic production of carrot and green onion in Indonesia. The applications of such liquid organic fertilizers for organic carrot production have been reported[22-24]. So did the use of liquid organic fertilizer for organically grown green onion[25,26]. The effectiveness of liquid organic fertilizer in vegetable production must be improved by understanding how much plants uptake nutrients from this liquid fertilizer. Although pH, ion activities and exchanges in the root zones, nutrient inflow to the cell apoplasm, external and internal nutrient concentrations have been claimed to be responsible for nutrient absorptions by plant roots[27], the addition of liquid organic fertilizer in the organic vegetable production system might change crops performances by increasing nutrient uptakes of major nutrients. Determination of nutrient uptakes was considered a useful part of nutrient management in crop production[28]. However, research on nutrient uptakes for organically grown carrot and green onions under Indonesian ecosystems has been less documented.

The objectives of these experiments were to determine the effect of liquid organic fertilizer on growth and yields as well as on major nutrients (N, P and K) by organically grown carrots and green onions.

MATERIALS AND METHODS

Study area: Two parallel experiments were established in an organic farm at the elevation of 1.054 m above sea level in the highland of Rejang Lebong, Indonesia (3°39'35.1" South latitude, 102°34'23.6" East longitude). For the carrot experiment, planting was conducted on April 5th and harvested on July 26th, 2021. Meanwhile, the green onion experiment was planted on June 22nd and harvested on September 28th, 2021.

Experimental design: Each experiment (carrot and green onion) was arranged in a completely randomized block design with three replicates. Treatments were five levels of liquid organic fertilizer concentrations (0, 25, 50, 75 and 100%).

Production of liquid organic fertilizer: Production of liquid organic fertilizer was established by composting the combinations of dairy cattle's faeces and urine, topsoil and green leaves of *Tithonia diversifolia* (Hemsley) A. Gray and *Ageratum conyzoides* L., EM-4 solution and water[29]. All materials were aerobically composted in a blue plastic container for 5 weeks. Lab analysis indicated that the pH of this liquid organic fertilizer was 7.36 and its N, P_2O_5, K_2O, Ca, Mg, Cu and Zn, were 2.23, 0.03, 0.17, 0.035 and 0.025%, 0.505 and 2.63 ppm, respectively.

Land preparations: At 2 weeks before planting, the experimental sites were ploughed and harrowed and a week before planting 15 soil beds (1 m width×5 m length×0.25 m-height) for each crop were constructed. Each soil bed was separated by 0.75 m within the block and 1.0 m away between the blocks. These two parallel experimental sites were 2 m apart. In addition, a week before planting, 10 t ha^{-1} of vermicompost was uniformly fertilized in each of the experimental plots. This vermicompost contained N, P, K and organic C as much as 2.15, 0.24, 0.55 and 25.6 g kg^{-1}, respectively[30]. Composited soil samples of the experimental site were analyzed and it revealed that the soil pH of this site was 5.03 and its nutrient contents were 0.22% N, 5.24 ppm P, 0.35 me/100 g K and 2.44% organic C.

Planting: Carrot seeds (a well-adapted local variety) were manually sown on April 5th, 2021 in each of three rows in the soil bed. Carrot seedlings were manually thinned in each seeding row on May 5th, 2021, to make plant spacing of 0.10 m within the row and 0.35 m between the rows. The total number of carrot plants per plot was 144 plants. Meanwhile, seedlings of green onion (a well-adapted local variety) were planted on June 22nd, 2021 in each of four rows in the soil bed with a spacing of 0.25 m within the rows and 0.25 m between the rows. The total plant number in each then per plot was 76 plants.

Treatment applications: Both carrots and green onions were fertilized with liquid organic fertilizer with the concentrations treatments at 2, 3, 4, 5 and 6, weeks after thinning (for carrots) or planting (for green onions) with the volume of 50, 100, 200, 300 and 350 mL/plant.

Crop maintenances: In the absence of precipitation for two days, crops were manually irrigated by watering the plants in each row uniformly. Weeds were removed from the experiment plots and soil along the rows was raised to avoid sun exposure for carrots and to prevent plants get uprooted for green onions. In addition, crops were weekly sprayed using bio-fungicide Glio® and bio-pesticide Pestona® to avoid pathogen outbreaks.

Nutrient uptakes analysis: Determination of nutrient N, P, K uptakes of carrots and green onions was conducted by taking the leaf samples from the third leaf of the uppermost developed leaves. Samples were cleaned and dried in the oven at 60-70°C for further nutrient content analysis.

Nutrient uptakes (g/plant) were calculated as[31]:

$$\frac{\text{PNC}}{\text{SDW}}100$$

where, PNC is plant nutrient (%) and SDW is shoot dry weight per plant (g).

Harvesting: Carrots were manually harvested 112 days after sowing (July 26th, 2021) and immediately washed with fresh water. Meanwhile, green onions were harvested 79 days after planting (September 8th, 2021) and immediately cleaned with fresh water.

Data collection: Effects of treatments on carrot growth and yields were observed (20 plant samples $plot^{-1}$) in terms of plant height, the number of leaves, fresh weight of tuber, diameter of tuber, length of tuber and shoot dry weights. Plant height was measured at 14 weeks after sowing by measuring from the tuber base of the plant to the tip of the longest leaf. The number of leaves was done 14 weeks after sowing by counting the number of fully develop compound leaves. Fresh weight tuber was immediately measured after harvesting by weighing the tuber after removing the adhering soil. Tuber diameter was measured at the widest tuber parts using a micro calliper and the length of the tuber was measured from the tuber based on the longest tuber’s tip. Shoot dry weight was counted from dried above-ground parts of carrot after drying it at 60-70°C until reaching a constant weight.

Meanwhile, the effects of treatments on green onion were measured (averaged of 10 plant samples $plot^{-1}$) in terms of shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, leaf number and tiller number. Shoot and root fresh weight was determined by weighing the fresh weight above and below-ground parts of newly harvested green onions after removing the adhering soil. Shoot and root dry weight was counted from dried above and below ground parts after drying it at 60-70°C until reaching a constant weight. The number of leaves and number of tillers were counted as the number of fully developed leaves and several tillers one day before harvesting.

Statistical analysis: Data subjected to homogenous test before analysis of variance by using Statistical Analysis System at $p \leq 0.05$. Data subjected to homogenous test before analysis of variance by using Statistical Analysis System at $p \leq 0.05$. Means of treatment effects were compared using Least Significantly Different test at $p \leq 0.05$. Data on monthly rainfall, relative humidity and air temperatures during the experiment were collected from Meteorology, Climatology and Geophysical Agency Bengkulu (ID WMO: 96255).

RESULTS AND DISCUSSION

Environmental conditions: The averages of monthly rainfall from April-September, 2021 were 250, 220, 138, 251, 97 and 347 mm, respectively. The daily average relative humidity during those months was 86.7, 88.6, 88.7, 85.1, 87.0 and 87.6%, respectively, whilst the daily temperature averages were 24.2, 24.7, 24.7, 23.8, 24.2 and 24.1°C, respectively. These conditions were sufficient enough to support carrot and green onion growths. Although the best daily air temperatures for carrot growth and development ranged from 16-21°C[32], the carrot used in this experiment was a local variety that has been well-adapted to this growing environment. The supply of water from rainfall during this experiment was sufficient to support crop growth since crop requirement from rainfall ranges from 100-200 mm/month is considered sufficient to support carrot growth. Green onions grow well at a mean monthly rainfall of 35-705 and the number of rainy days from 5-26 in a month, with monthly relative humidity ranging from 52-91% at the altitude of 900-1100 m above sea level[14]. The most suitable range of daily air temperatures to support the growth of green onion was 13-25°C and the optimum daily temperature for dry matter accumulation was 19-25°C[11]. Concerning soil pH, it was 5.03 a week before planting, measurement of soil pH at 4 and 10 weeks after first planting indicated that soil pH were 5.32 and 5.42, respectively. This property is expected to increase along with the crop growth and development, since the addition of vermicompost to organic soil is claimed to reduce soil acidity by increasing soil pH[33,34]. So did the application of liquid organic fertilizer in this experiment which has higher pH (7.36) than the soil itself which eventually increase soil pH as the crop grew.

Nutrient uptakes: The use of liquid organic fertilizer significantly influenced N, P and K uptakes by carrots ($p \leq 0.05$ at 0.0450, 0.0190 and 0.0012, respectively). So did in green onions, treatments significantly affected N, P and K uptakes ($p \leq 0.05$ at 0.0060, 0.0380 and 0.0500, respectively). The effects of liquid organic fertilizer concentration on N, P. and K uptakes by carrots and green onions were presented in Fig. 1 and 2, respectively.

This experiment revealed that the concentration of liquid organic fertilizer increased N, P and K uptakes of both carrots (Fig. 1a-c) and green onions (Fig. 2a-c). The highest N, P and K uptakes in carrots were found at 50% application, meanwhile, green onions were achieved at 100%. The different response between these two crops was reasonable since they come from two different crop families. Although nutrient uptakes by plants were genetically controlled[35], different varieties had different patterns in nutrient absorption and had different crop performances when grown in different nutrient management systems[36]. Another research concluded that crop variety (shallot) had different uptake abilities for P and K[37].

Increased N, P and K uptakes by carrots and green onions might have attributed to the increased ability of the plant to absorb nutrients from the rhizosphere. This induction was related to the growth and yield improvement of carrot and green onions due to the amendment of liquid organic fertilizer since plant nutritional status determines nutrient uptakes by plants[27]. Figure 3a-f showed that liquid organic fertilizer increased plant height, shoot dry weight, tuber fresh weight and tuber diameter of carrots (Fig. 3a and c-e) but not 'but not leaf number (Fig. 3b).

Figure 4a-f show that green onion was found to increase tiller number, shoot fresh weight, root fresh weight, shoot dry weight and root dry weight (Fig. 4b-f) but not leaf number (Fig. 4a).

The application of liquid organic fertilizer improved crop health and eventually increased the ability to uptake major nutrients from the soil. Research conducted on carrots concluded that the application of liquid organic fertilizer increased both N, P and K availability in the soil and uptakes by organically grown carrot[38]. Such increases were claimed as attributed to N, P and K releases from both solid and liquid organic fertilizer in the rhizosphere. Satisfactory mobility and activity of nutrients within the plants determined nutrient uptakes by plants[39]. In addition, nutrient uptakes by plants are determined by sufficient available nutrients in the root zone, rapid transport of the nutrients in the soil solution towards the root surface, satisfactory root growth to access available nutrients and continuous nutrient uptakes by plants. In terms of N uptakes, the result of this experiment was in line with other report[19], who found that concluded that the use of liquid organic fertilizer in organic production increased nitrogen uptake by sweet corn. Although crop growth and yields

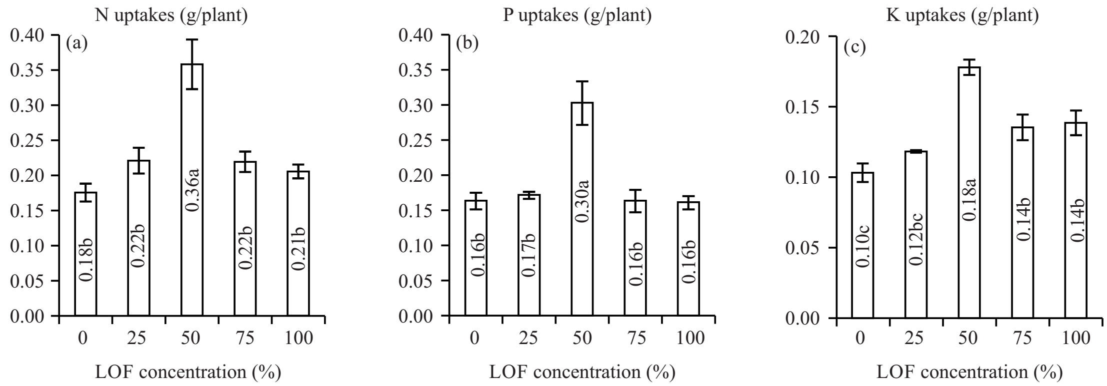

Fig. 1(a-c): Effects of liquid organic fertilizer (LOF) on (a) N uptakes, (b) P uptakes and (c) K uptakes of carrots

Means of treatment followed by the same letter in each figure are not significantly different according to least significant difference $p \leq 0.05$

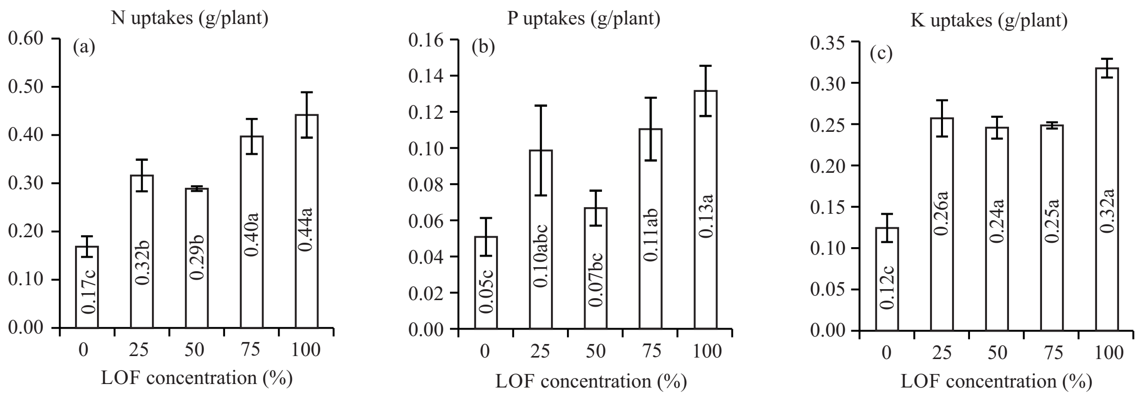

Fig. 2(a-c): Effects of liquid organic fertilizer (LOF) on (a) N uptakes, (b) P uptakes and (c) K uptakes of green onions

Means of treatment followed by the same letter in each figure are not significantly different according to least significant difference $p \leq 0.05$

mostly depend on the combination and concentration of mineral nutrients available in the soil, the ability of carrots and green onions to uptake N, P and K eventually determines their growth and development. Plants with poor nutrient uptakes will lead to nutrient deficiency, resulting in reduced crop yield or reduced yield quality.

Carrot growth and yields: The use of liquid organic fertilizer significantly affected plant height, shoot dry weight, tuber fresh weight and tuber diameter of carrots ($p \leq 0.05$ at 0.0004, 0.0010 and 0.0005, respectively) but not the number of leaves and tuber lengths ($p \leq 0.05$ at 0.0530, 0.0010 and 0.1600). The effects of liquid organic fertilizer concentration on the growth and yields of carrots were presented in Fig. 3.

It appeared that the use of 50% of liquid organic fertilizer has been sufficient enough to increase carrot growth (plant height and shoot dry weight) and yields (tuber fresh weight and tuber diameter) since higher concentration produced lower growth and yields (Fig. 3a, c-e). These increases could have been due to increased N, P and K uptakes by carrots (Fig. 1a-c), which later accelerated photosynthesis and tuber development. For example, for tuber fresh weight, it is found that the correlation coefficient between tuber fresh weight with N, P and K uptakes were 0.694, 0.869 and 0.862, respectively. These strong relationships indicated that an increase in tuber fresh weight was determined by N, P and K uptakes by carrots. Overall effects of liquid organic fertilizer on carrot growth and yields from this study were in line with that found by other researchers[40], in which dry matter, tuber weight and carotenoid contents of carrot fertilized with liquid organic fertilizer were higher than those of fertilized with synthetic fertilizer. Another research[41] also concluded that the application of liquid organic fertilizer increase petiole length, shoot fresh weight and tuber diameter of carrot. In addition, residual effects of yearly vermicompost application to this production site might have played effects to establish a better growing environment as well as tuber development for carrots. Indeed, vermicompost amendment into the soil

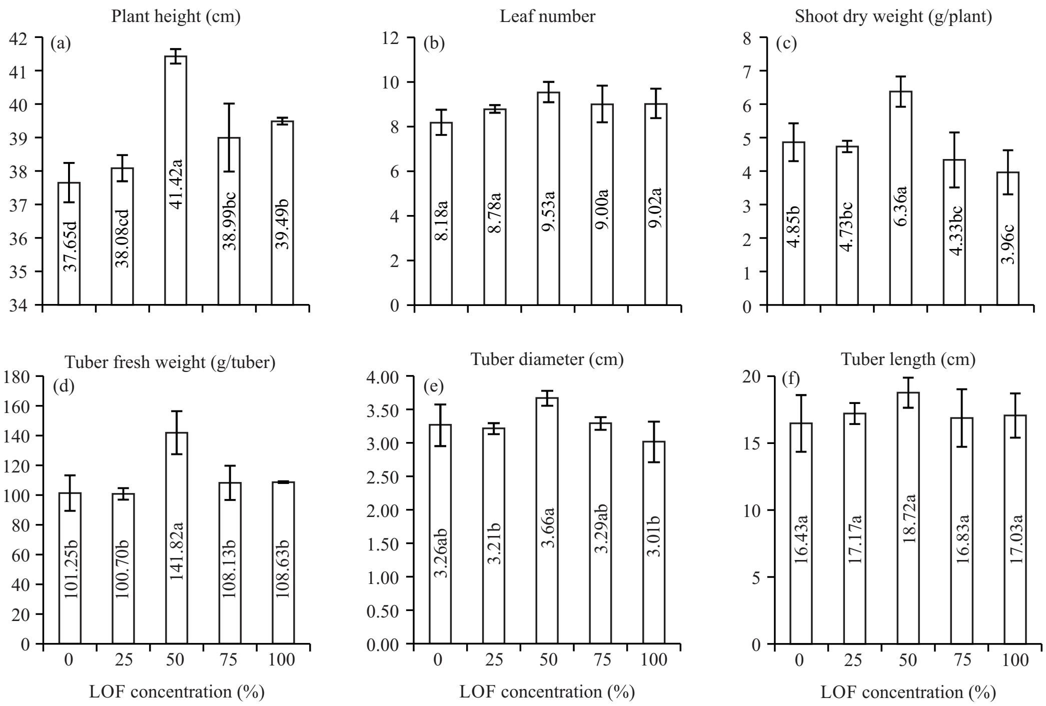

Fig. 3(a-f): Effects of liquid organic fertilizer (LOF) on (a) Plant height, (b) Leaf number, (c) Shoot dry weight, (d) Tuber weight, (e) Tuber diameter and (f) Tuber length of carrots

Means of treatment followed by the same letter in each figure are not significantly different according to least significant difference $p \leq 0.05$

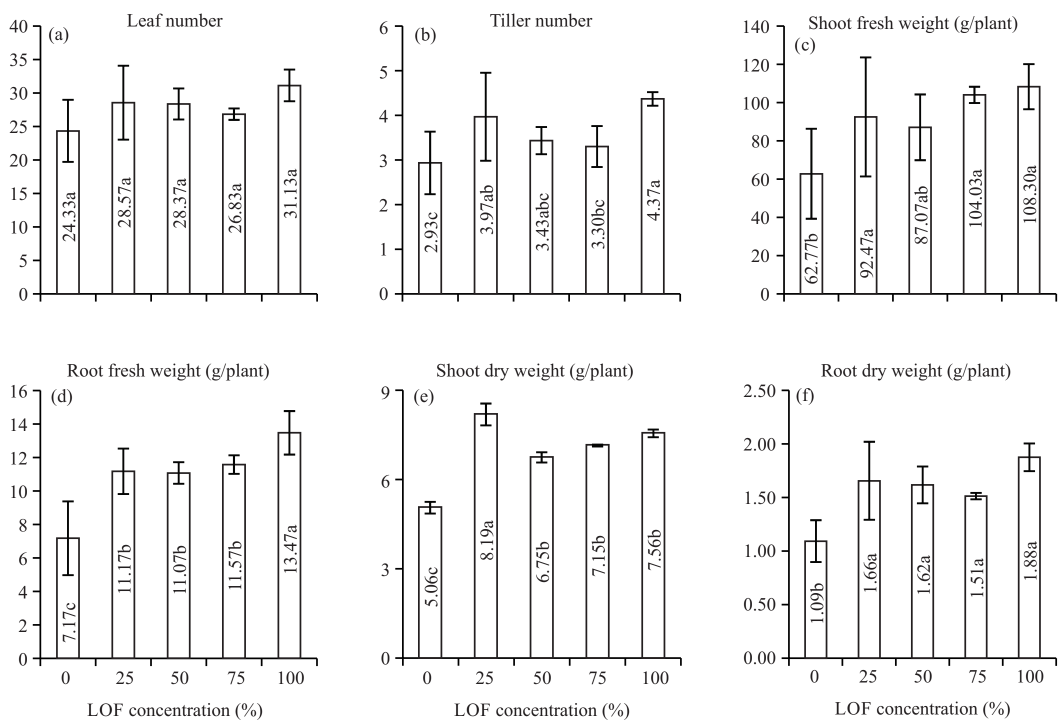

Fig. 4(a-f): Effects of liquid organic fertilizer (LOF) on different parts of green onion, (a) Leaf number, (b) Tiller number, (c) Shoot fresh weight, (d) Root fresh weight, (e) Shoot dry weight and (f) Root dry weight of green onion

Means of treatment followed by the same letter in each figure are not significantly the different according to least significant difference $p \leq 0.05$

improved soil pH, aggregates, bulk density, water-holding capacity, organic matter, micro and macro-nutrients and soil biological properties[34].

Green onion growth and yields: The use of liquid organic fertilizer significantly affected shoot fresh weight, root fresh weight, tiller number, shoot dry weight and root dry weight of green onions ($p \leq 0.05$ at 0.0200, 0.0002, 0.016 and 0.0100, respectively) but not the number of leaves ($p \leq 0.05$ at 0.0800). The effects of liquid organic fertilizer concentration on the growth and yields of green onion are presented in Fig. 4.

Positive effects of liquid organic fertilizer to increase shoot fresh weight, root fresh weight, tiller number, shoot dry weight and root dry weight of green onions (Fig. 4b-f) but not leaf number (Fig. 4a), could have also been related to increased N, P and K uptakes by green onions (Fig. 2a-c). Similar to the case of carrot responses, increased nutrient uptakes by green onions accelerated plant metabolisms and hence increased the growth and yields of green onions. This study revealed that to shoot the fresh weight of green onions, the correlation coefficient between tuber fresh weight with N, P and K uptakes were 0.699, 0.454 and 0.682, respectively. These relationships indicated that increased shoot fresh weight was determined by N, P, K uptakes by green onions. It appeared that the use of 100% liquid organic fertilizer generally increased the growth and yields of green onion. Considering the economic value of green onion relies on its shoot fresh weight, the application of liquid organic fertilizer was sufficient at 25 ppm (Fig. 4c). This result was in line with that concluded by other researchers[26], where green onion fertilized with cow manure liquid organic fertilizer at a 50% concentration had higher fresh weight than those fertilized with 0, 25 and 75% concentration cow manure liquid organic fertilizer. This research also revealed that the use of 25% guava waste liquid organic fertilizer produced a fresh weight of green onion significantly higher than those of fertilized with 0, 50 and 75% concentration guava waste liquid organic fertilizer. 'A similar conclusion was reported[25] that green onion fertilized with 2 mL L^{-1} of liquid fertilizer generally had higher growth and yields than those of 0 and 3 mL L^{-1}. In addition, the use of liquid organic fertilizer has been also reported to increase plant height, leaf number, tiller number and bulb yields of shallot[42].

This research suggested that the use of liquid organic fertilizer in organic vegetable production systems becomes inevitable to improve the effectiveness of solid organic fertilizer application in organic farming. As nutrient supplementation, it is demonstrated that the use of liquid organic fertilizer increased N, P and K uptakes as well as the growth and yield of carrot and green onion, respectively. However, it did not increase the leaf numbers of both carrot (Fig. 3b) and green onion (Fig. 4a). It was also found that the use of 50 and 25% liquid organic fertilizer was able to increase the growth and yield of carrot and green onion, respectively. These results might be not separated from the fact that this experiment was conducted on an organic farm which takes at least three consecutive years of organic farming practices to have established organic growing conditions. Although crop responses to foliar fertilizer are different among species, plant ages and environmental conditions, further research should be addressed on the use of liquid organic fertilizer at lower concentrations and on evaluating the nutrient use efficiency of carrot and green onion in organic production.

CONCLUSION

The use of liquid organic fertilizer increased N, P and K uptakes by carrots and green onions. The use of liquid organic fertilizer increased plant height, shoot dry weight, tuber fresh weight and tuber diameter of carrots. Liquid organic fertilizer with 50% in concentration is sufficient to increase carrot growth and yields. Increased tuber fresh weight of carrots depended on the increase of N, P and K uptakes by carrots. The use of liquid organic fertilizer significantly increased shoot fresh weight, root fresh weight, tiller number, shoot dry weight and root dry weight of green onions. Increased shoot fresh weight of green onions was also largely related to increased N, P, K uptakes by green onions. The use of 25% liquid organic fertilizer was considered sufficient to increase the shoot fresh weight of green onions.

SIGNIFICANCE STATEMENT

This study discloses that under organic production systems the use of liquid organic fertilizer increased N, P, K uptakes of organically grown carrot and green onion. In addition, the use of liquid organic fertilizer improved the effectiveness of solid organic fertilizer application in increasing yields of carrot and green onion. The use of 50 and 25% of local resources-based liquid organic fertilizer was considered sufficient to produce tuber fresh weight of carrots and shoot fresh weight of green onion, respectively. The results of this study convince the organic vegetable farmers that practising organic production benefits farmers by reducing the costs of synthetic fertilizers.

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