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Effects of foliar and soil-applied liquid organic fertilizers on the growth of *Basella alba* L. and *Centella asiatica* L.

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ABSTRACT

Purpose: *Environmental-friendly organic fertilizers reduce the adverse impacts of chemical fertilizers. This study was conducted to formulate organic liquid fertilizers using selected plant materials i.e., Tithonia diversifolia, Mikania scandens, Chromolaena odorata and Gliricidia sepium with selected organic wastes to compare the efficacies of foliar and soil-applications over the growth of leafy vegetables; Basella alba and Centella asiatica.*

Research Method: *Selected plant materials were allowed to decompose for two months and thereafter fish waste was hydrolyzed separately with fruit wastes of Carica papaya, Ananas comosus and (1:1 w/w) mixture of both were mixed and nutrients analyzed. Fertilizers were foliar and soil-applied separately on C. asiatica and B. alba in RCBD in pot trials.*

Findings: *Fertilizer formulated with decomposed plants + fish waste hydrolyzed with C. papaya significantly recorded the highest N (0.57%), P (0.06%) and highest growth of C. asiatica and B. alba over both soil and foliar applications followed by the fertilizer formulated with decomposed plants + fish waste hydrolyzed with C. papaya + A. comosus. Foliar-application of B. alba significantly showed the highest growth than the soil-application [shoot height (36.6±3.4 cm vs 30.0±1.5 cm), number of leaves per plant (21.7±1.4 vs 17.5±0.8) and plant fresh-weight (61.5±1.8 vs 55.6±0.9 g)] whereas, C. asiatica indicated no significant difference considering both fertilizer application methods.*

Research limitation: *Pot experiments were carried out to provide uniform soil conditions for the experiment which was the main limitation compared to field trials.*

Originality/value: *The formulated novel fertilizers could be utilized effectively in organic farming for safe and healthy leafy vegetables which reduce the adverse impacts of chemical fertilizers.*

Keywords: *Basella alba, Centella asiatica, foliar application, leafy vegetables, liquid organic fertilizers.*

INTRODUCTION

The increasing demand for organic fertilizers, organic farming and organic foods are becoming more popular globally due to the foremost public concern on food safety and security. Most of the multifaceted environmental and health issues are associated with excessive use of chemical fertilizers i.e., deterioration of soil, loss of soil fertility, loss of organic matter, increased soil acidity, reduction of biodiversity, contamination of groundwater (Herath *et al.*, 2014; Ranaweera *et al.*, 2010) and health problems such as chronic kidney disease, methemoglobinemia etc (Jayasumana, *et al.*, 2015; Sutharsiny *et al.*, 2014). These issues could be mitigated by the adoption of organic agricultural practices.

The basis of sustainable organic farming is the use of locally produced and low-cost biomass resources to rebuild and maintain soil productivity (Jensen *et al.*, 2006). As reported by many researchers, the addition of organic materials provides many beneficial effects on soil physical properties i.e. increasing water infiltration capacity, water holding capacity, aeration, porosity and permeability, water-

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stable soil aggregation and rooting depth while decreasing soil crusting, bulk density, runoff and erosion (Haynes and Naidu, 1998; Dahama, 1997) improving the soil texture and structure by enhancing chemical and biological properties in a sustainable way (Smith, 1999; De costa and Sangakkara, 2006). Organic fertilizers are derived from plant-based raw materials i.e., crop residues, green manures, wood ash, fruit waste, domestic waste, woodland litter, seagrass, etc. and/ or animal-based materials such as livestock manure, bird dropping, fish waste and bone meals, etc. (Burnett *et al*., 2016; Wakui, 2009). Fast-growing nutrient-rich plants i.e., *Tithonia diversifolia, Mikania scandens, Chromolaena odorata* etc. that are available in the vicinity of agricultural fields also show great potential in the preparation of organic fertilizers due to their high nutrient contents (Ranasinghe *et al*., 2019a; Suthar and Singh, 2008). In addition to their nutrient values, *T. diversifolia, C. odorata, Lantana camara* and *Croton aromaticus* plant extracts possess antibacterial, fungicidal, nematocidal and insecticidal effects against vast crop-damaging pests and diseases (Odeyemi *et al.*, 2014; Ngatimin *et al*., 2014; Ahamad *et al*., 2010; Malahlela *et al*., 2019; Kuri *et al*., 2011; Dilhani *et al*., 2016). Hence, they also provide additional values as an eco-friendly botanical alternative to synthetic agrochemicals.

Soil application of organic fertilizers as classic solid compost, fresh or digested organic materials (Carrera *et al*., 2007) are the most common method of supplying essential nutrients to plants that are facilitating the absorption of applied nutrients by the roots. Moreover, the plant can absorb nutrients via plant foliage comprising leaves, stems, inflorescences, and fruits (Pandey *et al*., 2013). Foliar application of fertilizers is practiced since 1844 to overcome the chlorosis by foliar spraying of iron (Oosterhuis, 2009) and this technique is practiced for the productive and sustainable management of crops (Fernandez and Brown, 2013). Liquid compost tea derived from aqueous extraction of solid compost in aerated or anaerobic conditions is also used for the foliar applications (Zaccardelli *et al*., 2018, Netpai 2012). These liquid organic fertilizers are more homogeneous and provide soluble and easily available nutrients for effective nutrient uptake and plant growth. The application of undigested solid organic fertilizers takes a longer time to decompose, mineralize and release nutrients. Hence, it was found that only 50% of N, P and K mineralized were within the three months of the crop life cycle (Fahruuozi *et al*., 2016; Foth and Ellis, 1997) or mostly less than 10% of the initial N in composts mineralized within 4-6 months (Hartz *et al*., 2000). Timing to release nutrients to the soil depends on the C/N ratio of the organic materials, moisture content, diversity and density of soil macro and microorganisms. Therefore, many studies were conducted and recommended on the use of organic fertilizers as digested liquid forms i.e., compost extracts, aerated compost teas, herbal extracts, vermicompost extracts, food stillages which are applied on to foliage or into the soil or both (Canfora *et al*., 2015, Kim *et al*., 2015; Jayasundara *et al*., 2016).

Moreover, agricultural production is highly affected by climate and weather changes i.e., climate extremes and constraints due to unpredicted rains and other natural perils which will remarkably reduce agricultural production (Pradhan *et al*., 2015). This has led the government to increase the focus of the public in maintaining their home gardens, which are under the control against natural disasters as well as undue effects of chemical fertilizers. Hence, there will be a higher possibility for most people to start their cultivations in their home gardens. Especially during the COVID-19 incidence in 2020, most Sri Lankans tried to cultivate their home gardens. Furthermore, the prevalence of chronic kidney disease in the major parts of the country discourage farmers to use synthetic agrochemicals in agriculture (Weeraratna, 2013). As a remedial measure to the above problems, home gardens or commercial agriculture needs to introduce cost-effective and environmentally friendly fertilizers. Currently, the Sri Lankan government has launched a national programme named "One million of prosperous home gardens" (*Saubhagya gewathu dasalakshayak*) in April 2020 during the global COVID-19 virus pandemic condition to strengthen and popularize the home-gardening concept which aimed to stabilize the country's economy being self-sufficient in essential food i.e., vegetables, leafy vegetables, fruits, and cereals. Growing leafy vegetables in home gardens are comparatively easy and much popular as they grow faster within a shorter period. The interest in cultivation and the consumption of leafy vegetables i.e., *Centella asiatica, Alternanthera sessilis, Basella alba, Amaranthus viridis, Trianthema portulacastrum* etc. are also high among Sri Lankans due to the presence of high nutrients i.e., calcium, iron, phosphorus and micro-nutrients, fibers, vitamin A, C and K, carotenoids, folate and a wide range of antioxidants and flavonoids (Kananke *et al*., 2014; Nadeeshani., 2018). Moreover, the use of organic methods in agriculture is of great significance in producing healthy, nutrient-rich, and safe foods (Mie *et al*., 2017).

Among different organic materials, the weeds i.e., M. *scandens* (N 3.44%, P 0.35%, and K 3.30%), T. *diversifolia* (N 3.39%, P 0.37%, and K 2.53%) and C. *odorata* (N 2.94%, P 0.28%, and K 1.62%) possessed higher macronutrients (Ranasinghe *et al*., 2019 b). Fish waste is another potential organic waste to enhance the nitrogen content as the growth of leafy vegetables preferentially required a higher nitrogen content for their vegetative growth (Shormin and Kibria, 2018).

Moreover, studies on the comparison of efficacies of both foliar and soil applications of the same liquid fertilizers are scarce. Hence, the aims of the present study were: 1) to formulate organic liquid fertilizers from easily available organic waste materials and 2) to compare the efficacies of both foliar and soil-applied liquid organic fertilizers over the growth of two leafy vegetables *Basella alba* and *Centella asiatica*. The findings of this study would allow identifying the agronomically efficient and environmentally friendly liquid organic fertilizers formulated with widely available weeds and other potential organic wastes.

MATERIALS AND METHODS

Formulation of organic liquid fertilizers

Eight kilograms of fresh plant leaves and tender shoots of the common plant species i.e., *Tithonia diversifolia, Mikania scandens, Chromolaena odorata* and *Gliricidia sepium* (1:1:1:1 w/w) were collected from non-cultivated areas away from the roadsides in Gampaha district, Sri Lanka. Those were rinsed with distilled water twice to remove any contaminants or dust particles present on plant materials and cut into small pieces and mixed with 200 g of topsoil evenly with 5 L of distilled water in plastic containers that were covered with double layered 2 mm nylon mesh. The mixtures were decomposed for eight weeks.

The procedure developed by Ranasinghe *et al*. (2019) b was used to hydrolyze the fish waste samples. Accordingly, 400 g of fish waste samples were digested separately using three different combinations of proteases i.e., crude bromelain extracted from A. *comosus* (fruit peels + crown); crude papain extracted from C. *papaya* (ripe fruits peels + leaves) and the mixture of both enzymes (1:1w/w) for 48 hrs. Crude proteases were prepared by extracting 1:1:5 w/w/v of each plant component in distilled water. Thereafter, digested fish waste samples were mixed separately with the decomposed plant materials and allowed to decompose further two weeks with regular aeration. Those three combinations of liquid extracts were enriched by adding aqueous extracts of fresh leaves of *Croton aromaticus* and *Lantana camara* of 500 g of each (1:1 w/v) that soaked for 72 hrs in distilled water and 50 g of coconut husk ash separately to formulate three different combinations of liquid fertilizers as shown in the below (Table 01). Three replicates were conducted for each fertilizer combination and finally, those were filtered through a 2 mm plastic sieve and a muslin cloth to remove the undigested plant debris.

Table 01: The composition of the formulated liquid fertilizers

<table>
<tr><th>Fertilizer</th><th>Common components for all fertilizer combinations</th><th>Specific components for each fertilizer</th></tr>
<tr><td>FT1</td><td rowspan="3">Decomposed plant materials
T. diversifolia (2 kg)
M. scandens (2 kg)
C. odorata (2 kg)
G. sepium (2 kg)
Topsoil (0.2 kg)
Distilled water (5 L)
Aqueous extracts of fresh leaves of *Croton aromaticus and Lantana camara* (0.5 kg of each)
Coconut husk ash (0.05 kg)</td><td>Powdered fish waste (0.4 kg) hydrolyzed with aqueous extract of *C. papaya* (ripe peel + leaves)</td></tr>
<tr><td>FT2</td><td>Powdered fish waste (0.4 kg) hydrolyzed with aqueous extract of *A. comosus* (ripe peel + crown)</td></tr>
<tr><td>FT3</td><td>Powdered fish waste (0.4 kg) hydrolyzed with (1:1 aqueous extract of *A. comosus* + *C. papaya*)</td></tr>
</table>

Nutrient analysis of liquid fertilizers

All fertilizer formulations were subjected to the following nutrient analysis. The total nitrogen content was determined following the Kjeldahl method (Motsara and Roy, 2008). Phosphorus content was determined following the Vando-molybdate method, and the contents of potassium, calcium, magnesium, iron, zinc, manganese, and copper were determined using atomic absorption spectrophotometry (Varian Spectra A-110) following a tri acid digestion using a mixture of HNO_3, H_2SO_4 and $HClO_4$ acids in 9:4:1 ratio (Motsara and Roy, 2008). The presence of *Escherichia coli* was determined growing on Eosin Methylene Blue agar (EMB) medium. As the control, the pure culture of *E. coli* was grown separately on EMB.

Determination of the effectiveness of the liquid fertilizers on the growth performances of the selected leafy vegetables by foliar application

The formulated liquid fertilizers were applied on leafy vegetables, i.e., *Basella alba* (variety: Green spinach) and *Centella asiatica* (variety: Paduru Gotukola) on pot trials in Kelaniya, Sri Lanka (6° 95' 59.16" N, 79° 94' 43.11" E) during February 2018 to Aug 2018 to evaluate their growth performances. Seeds of *B. alba* obtained from the Department of Agriculture, Sri Lanka were allowed to germinate for two weeks in a nursery and a healthy single plantlet of the same size was transplanted separately in plastic pots filled with sieved garden soil. Similarly, individual healthy *C. asiatica* plantlets of the same maturity were collected from the Botanical Garden of the University of Kelaniya, Sri Lanka and a single plantlet was planted separately in plastic pots. Both *B. alba* and *C. asiatica* plants were kept for a week to acclimatize before the commencement of fertilizer treatments. For each treatment, six replicates with single plantlets were used and arranged in a completely randomized block design. Five milliliters of 1:5 diluted fertilizers of FT1, FT2 and FT3 were foliar sprayed twice a week for three months on both leafy vegetables. In all foliar applications, liquid fertilizers were sprayed carefully on the surfaces of plant leaves and stem parts. Moreover, the topsoil layers of the pots were covered with a circular-shaped transparent plastic sheet that matched with the diameter of the pot to avoid any spillages to the soil in the pot. Distilled water was used as the negative control and the selected commercially available seaweed liquid fertilizer (M) was used as the positive control. The growth parameters measured in this study were the shoot height, number of leaves, leaf area, plant fresh and dry weights of whole plants at the end of three months.

Determination of the effectiveness of the liquid fertilizers on the growth performances of the selected leafy vegetables by soil application

Similarly, to foliar application, five milliliters of 1:5 diluted fertilizers of FT1, FT2 and FT3 were soil-applied twice a week for three months on *B. alba* and *C. asiatica* plants grown in pots. Distilled water was used as the negative control and the selected commercially available seaweed liquid fertilizer (M) was used as the positive control. For each treatment, six replicates were used and arranged in a completely randomized block design. Shoot height, the number of leaves, leaf area, plant fresh and dry weights were measured at the end of three months of fertilizer treatments as growth parameters in both crops.

Statistical analysis

Data with respect to nutrient contents were analyzed statistically using one-way analysis of variance (ANOVA, $p<0.05$) and plant growth performances of five treatments over two application methods were analyzed statistically using two-way analysis of variance (ANOVA, $p<0.05$). If the interaction effect was significant ($p<0.05$) one-way ANOVA was conducted. All the statistical analyses were performed using the IBM SPSS software package (SPSS version 20 for Windows).

RESULTS AND DISCUSSION

Nutrient contents of the formulated liquid organic fertilizers

Formulated fertilizer FT1 (decomposed plant materials + fish waste hydrolyzed with aqueous extract of *C. papaya* (ripe peel + leaves) + coconut husk ash) recorded the highest ($p<0.05$) amount of N and P contents (5.7±0.2 and 0.5±0 g L^{-1}) followed by FT2 and FT3, whereas the positive control (M) showed the lowest contents of N and P (2.4±0 and 0.09±0 g L^{-1} respectively) (Figure 1). However, significantly the highest potassium content was observed in the positive control (M) (3.0±0.0 g L^{-1}) followed by FT1 and FT2 whereas the FT3 fertilizer recorded the lowest (2.2±0.0 g L^{-1}). Moreover, significantly the highest calcium content was observed in FT1 (1.5±0.0 g L^{-1}) followed by FT3 (1.0±0 g L-1) and the least was recorded for the positive control (M) (0.08±3.7 mg L^{-1}). There were no significant differences in Mg content in all fertilizer mixtures (Fig. 01).

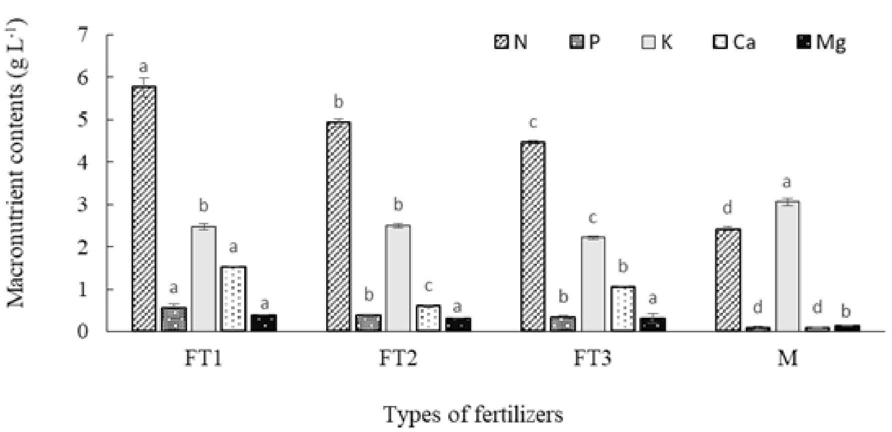


Figure 01: Macronutrient contents of the enriched liquid fertilizers

(FT1: decomposed plant materials + fish waste hydrolyzed with proteases from *C. papaya;* FT2: decomposed plant materials + fish waste hydrolyzed with proteases from *A. comosus* and FT3: decomposed plant materials + fish waste hydrolyzed with proteases from *C. papaya* and *A. comosus*; C: negative control and M: positive control).

Means sharing a common letter(s) in each treatment at a given time are not significantly different by Tukey's multiple comparison test ($p<0.05$). Each data point represents the mean of three replicates ± standard deviation.

As shown in Figure 02, the highest Cu content was recorded in FT1 and FT3 fertilizers (0.9±0 and 0.8±0 mg L^{-1}) whereas the positive control (M) possessed the minimum (0.33±0.05 mg L^{-1}). There were no significant differences between Mn contents. However, significant higher Fe content was recorded in FT3 fertilizer followed by FT1 (53.1±0.9 and 48.5±0.0 mg L^{-1}). Significantly, higher Zn content was recorded in FT3 and FT1 (15.5±0 and 13.4±0.2 mg L^{-1} respectively) whereas the lowest was recorded for the FT2 fertilizer (1.8±0.1 and 3.3±0.7 mg L^{-1}).

Protein-rich fish wastes were enzymatically hydrolyzed using plant-based crude proteases of papain and bromelain extracted from the fruit wastes of *C. papaya* and *A. comosus* respectively to increase the available nitrogen to the plants (Wisuthiphaet and Kongruang, 2015; Gioseffi *et al*., 2012). Similarly, amino acid liquid fertilizer formulated from the acid hydrolysis of pig hairs recorded high total amino acid and nitrogen contents (Wang *et al*., 2019). Coconut husk ash was incorporated as the main potassium source (K 9.28%) and topsoil with decaying litter was used as an inoculant of the favorable microbes to accelerate the degradation of organic materials throughout the preparation of liquid organic fertilizers.

Microbial parameters in formulated liquid organic fertilizers

All the formulated liquid organic fertilizers were free from *E. coli*. The isolated pure culture of *E. coli* that grew on EMB as the control produces small colonies with a metallic sheen.

Effect of the formulated organic liquid fertilizers on the growth of selected leafy vegetables

Effect of foliar and soil applications of organic liquid fertilizers on the growth of Basella alba

Fertilizing methods and the different fertilizers significantly affect the shoot height, the number of leaves, leaf area and plant fresh weight of *B. alba*. Moreover, there were significant interactions between the fertilizing methods x fertilizers on shoot height, number of leaves, plant fresh and dry weights of *B. alba* (Table 02).

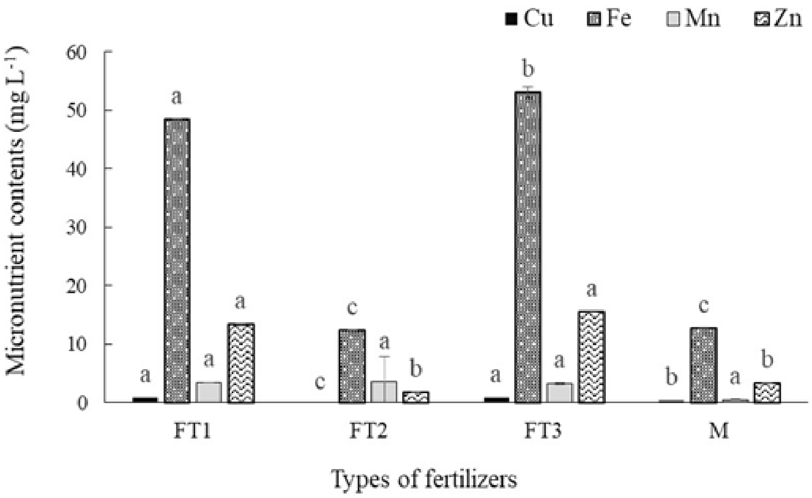


Figure 02: Micronutrient contents of the enriched liquid fertilizers

(FT1: decomposed plant materials + fish waste hydrolyzed with proteases from *C. papaya*; FT2: decomposed plant materials + fish waste hydrolyzed with proteases from *A. comosus* and FT3: decomposed plant materials + fish waste hydrolyzed with proteases from *C. papaya* and *A. comosus*; C: negative control and M: positive control).

Means sharing a common letter(s) in each treatment at a given time are not significantly different by Tukey's multiple comparison test ($p<0.05$). Each data point represents the mean of three replicates ± standard deviation.

Table 02: Growth parameters of *B. alba* over foliar and soil applications of different organic liquid fertilizers

Growth parameter	Fertilizing method		Fertilizer		Fertilizing method x fertilizer	
	P value	F value	P value	F value	P value	F value
Shoot height	0.000	41.398	0.000	73.664	0.004	4.376
No. of leaves	0.000	70.638	0.000	125.393	0.000	6.061
Leaf area	0.037	4.568	0.000	219.219	0.070	73.368
Plant fresh weight	0.000	23.809	0.000	127.242	0.000	47.296
Plant dry weight	0.077	3.269	0.000	30.815	0.000	14.713

Means having a p-value greater than 0.05 (p>0.05) is not significantly different by Turkeys multiple comparison test.

As shown in Figure 03a the foliar application of organic liquid fertilizers during the twelve weeks, the highest average shoot heights of *B. alba* were obtained for FT1 fertilizer followed by FT3 and positive control (M) (36.6±3.4, 29.4±2.4 and 27.7±0.9 cm respectively) whereas the lowest was recorded for the negative control (C) (21.7±1.8 cm). Similarly, the highest number of leaves per plant of *B. alba* resulted in the FT1 fertilizer (21.7±1.4) followed by FT3 (20.0±1.3) whereas the negative control (C) possessed the minimum (11.0±1.3) (Figure 03-b). However, there was no significant difference in the leaf area of *B. alba* plants treated with FT1, FT3 and positive control (M) (71.7±1.2, 71.1±1.6 and 68.6±2.1 cm^2 respectively) (Figure 03-c). The highest plant fresh and dry weights (61.5±1.8 and 5.81±0.6 g respectively) were observed for the FT1 and the lowest was recorded for the control (41.7±1.0 and 3.8±0.1 g respectively) (Figure 03- d and e). In accordance with these results, Shormin and Kibria (2018) also reported that higher nitrogen supply through fertilizers significantly enhances the plant height, the number of leaves per plant, fresh and dry weights of plants of *B. alba*. Furthermore, they stated that the application of nitrogen is highly essential in the growth of leafy vegetables as it involves increased cell division and enlargement resulted in higher number of leaves. Moreover, all the plants treated with foliar-applied formulated fertilizers showed a comparatively higher greenish appearance compared to controls. This could be due to the higher nitrogen content in the formulated fertilizers as it enhances the photosynthesis rate by increasing the chlorophyll content and accumulation of carbohydrates in leaves increasing the plant weights (Shormin and Kibria, 2018). Moreover, this result is agreed with Khan *et al.* (2014) who reported that foliar sprayed vermiwash has improved *Capsicum assamicum* plant growth and nutrient uptake under pot trials. Purwanto *et al.* (2017) also reported that foliar application of liquid organic fertilizers on coconut plants increased the chlorophyll contents of leaves and neera production by enhancing its volume and sugar contents. Moreover, they stated that foliar application facilitates effective nutrient absorption avoiding microbial transformation or nutrient leaching compared to soil application.

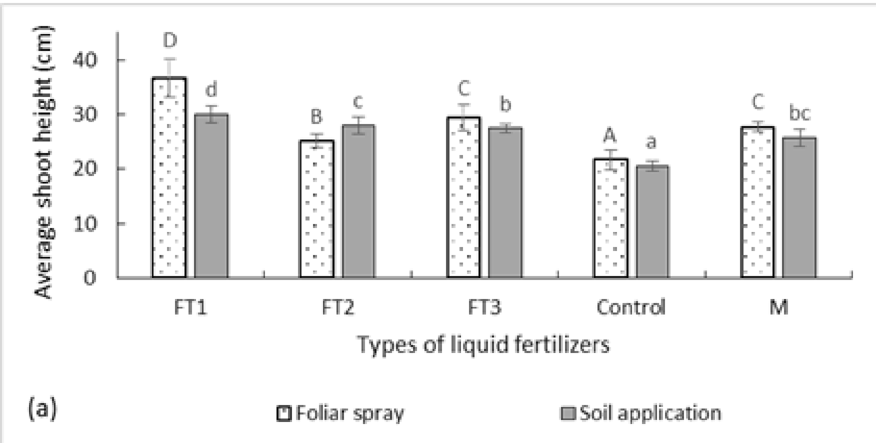
Considering the soil application of liquid fertilizers, the highest average shoot height was recorded for the FT1 fertilizer followed by FT2 fertilizer (30.0±1.6 and 28.0±1.6 cm respectively) however, the negative control (C) showed the lowest (20.5±0.8 cm) (Figure 03-a). The higher number of leaves per plant of *B. alba* was obtained for soil applied FT1, FT3, FT2 and positive control (M) (17.5±0.8, 16.7±1.0, 15.8±0.8 and 16.8±0.8 respectively) showing no significant differences within the formulated fertilizers and the positive control (M). The negative control possessed the significantly lowest number of leaves (10.2±1.5) of *B. alba*

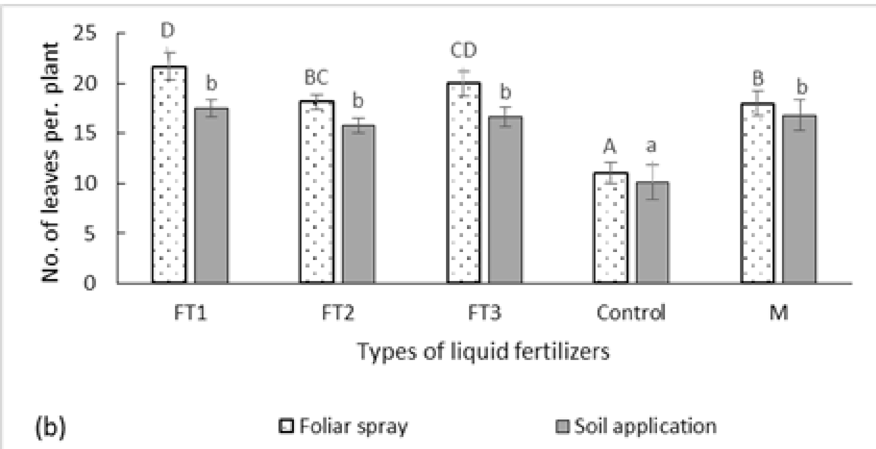
(Figure 03-b). Considering the leaf area, soil-applied FT3 fertilizer significantly resulted in the highest (68.8±0.8 cm^2) followed by FT1and the positive control (67.7±2.3 and 65.9±1.2 cm^2) whereas the negative control possessed the lowest (50.1±2.1 cm^2) (Figure 03-c). Significantly, the higher plant fresh weight was recorded for the FT1, FT3 and the positive control (55.6±0.9, 54.7±1.6 and 51.4±2.6 g respectively) showing no significant differences among them whereas the negative control recorded the lowest (42.0±1.1 g). Similarly, the highest plant dry weight also resulted in soil-applied FT1 fertilizer (5.1±0.2 g) followed by FT3 and the standard (4.9±0.2 and 4.7±0.2 g respectively) while the lowest was recorded in the control (3.9±0.2 g) (Figure 03-d and e).

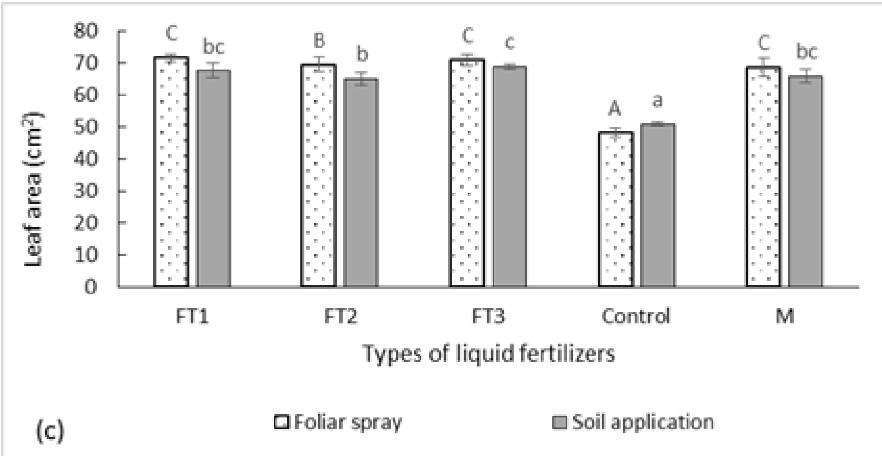
Fertilizer that contained decomposed plant materials + fish waste hydrolyzed using the papain enzymes from *C. papaya* fruit waste (FT1) recorded the highest plant growth performances of *B. alba* with respect to both fertilizing methods as it contained the highest amount of nitrogen and other major nutrients. Foliar-applied amino acid liquid fertilizer formulated from the acid hydrolysis of pig hairs also revealed significantly higher cowpea yields compared to the chemical fertilizer due to the presence of degraded proteins in available form (Wang *et al*., 2019). Soil application of inorganic nitrogen fertilizers also enhanced the plant fresh and dry weights due to the increase of photosynthesis process and accumulation of high carbohydrate contests in leaves (Shromin and Kibria, 2018). Moreover, Michael *et al*. (2010) also revealed that soil application of nitrogen-rich poultry manure increased the number of leaves and accelerated the growth of leaves in leafy vegetables i.e., lettuce.

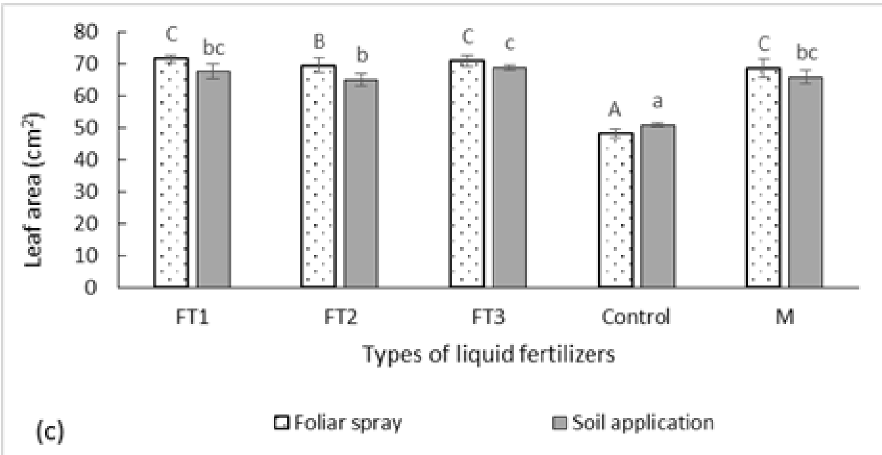
Effect of foliar and soil applications of organic liquid fertilizers on the growth of Centella asiatica in a pot experiment

As shown in Figure 04-a, the foliar application of *C. asiatica,* recorded significantly, the highest average number of leaves for FT1 fertilizer (15.5±0.5) whereas the lowest was recorded for









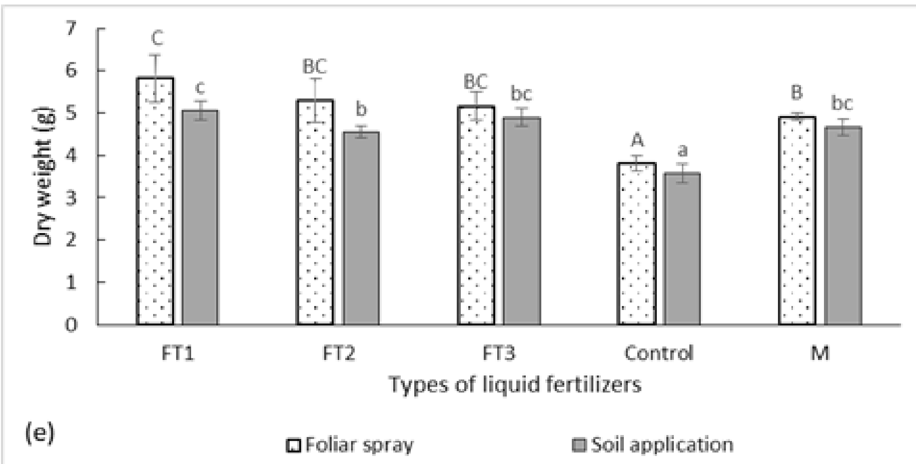


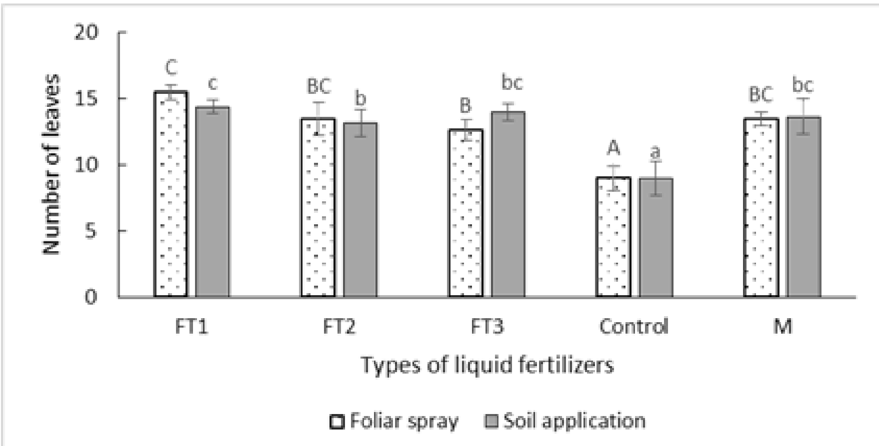
Figure 03: Effect of the enriched fertilizer treatments on growth performances (a) shoot height, (b) number of leaves per plant, (c) leaf area, (d) plant fresh weight and (e) plant dry weight of *B. alba* over foliar spray and soil application.

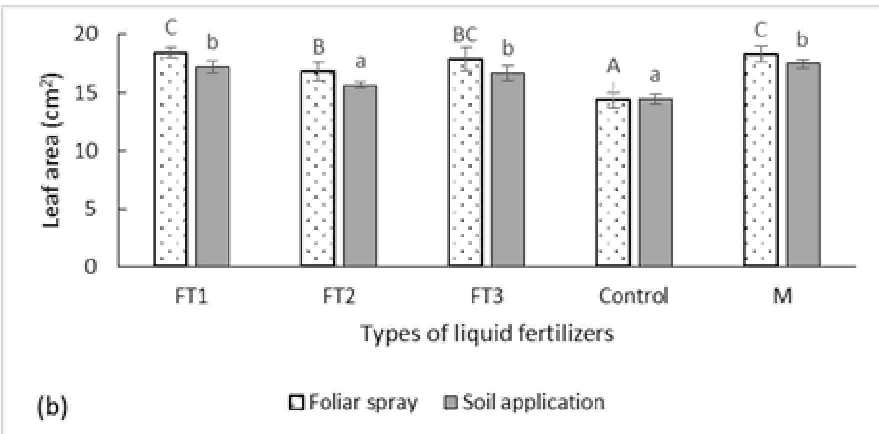
Each data point represents the mean of six replicates ± standard deviation. Means sharing a common letter (s) in each column of a separate treatment are not significantly different p< 0.05 by Tukey's multiple comparison test.

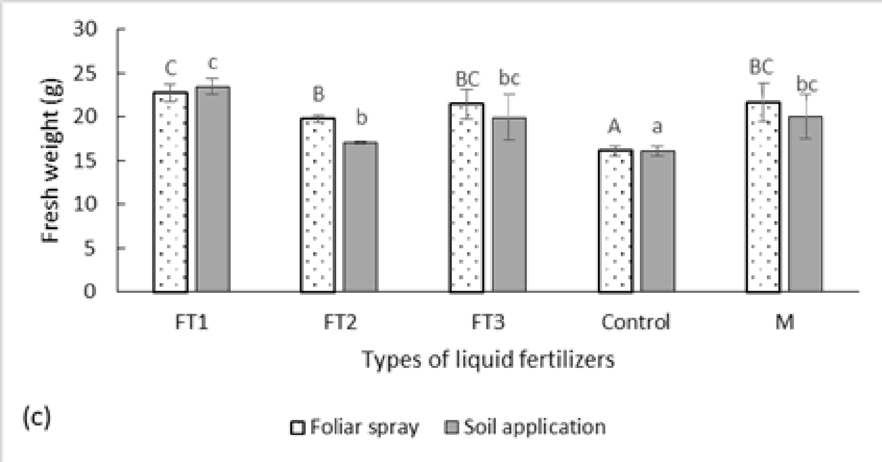
the negative control (9.0±0.9). Similarly and significantly, the highest leaf area of *C. asiatica* resulted in FT1 fertilizer and the positive control (18.4±0.4 and 18.3±0.7 cm^2 respectively) showing no significant differences ($p>0.05$), whereas the negative control recorded the lowest (14.3±0.6 cm^2) (Figure 04-b). Moreover and significantly, the highest plant fresh and dry weights also recorded for the FT1 fertilizer (22.7±1.0 g and 4.7±0.3 g respectively) whereas the control possessed the least (16.1±0.6 g and 3.4±0.3 g respectively) (Figure 04-c and d). As evident from Jayasundara *et al*. (2016), foliar-applied liquid fertilizers formulated with *G. sepium* and poultry manure significantly recorded the highest number of branches, plant length, leaf area and plant fresh weight of leafy vegetable *Alternanthera sessilis*. Similarly, Khalil et al. (2005) stated that high nitrogen contents improve vegetative growth.

Among the soil-applied fertilizers, the highest number of leaves per plant of *C. asiatica* resulted in FT1 fertilizer (14.4±0.6) followed by FT3 and the positive control (14.0±0.6 and 13.7±1.4 respectively) whereas the negative control recorded the lowest (9±1.3) (Figure 04-a). However, there were no significant differences among the soil-applied FT1, FT3 fertilizers and the positive control which showed the leaf areas ranging from 17.4±0.4 - 16.7±0.6 cm^2. Significantly, the highest plant fresh and dry weights were recorded for the FT1 fertilizer (23.4±0.9 and 4.3±0.1 g) followed by the positive control and FT3 fertilizers (Figure 04-c and d).

Moreover, the number of leaves, whole plant fresh and dry weights of *C. asiatica* plants showed a significant effect on different fertilizers and their fertilizing method (Table 03). There were no significant interactions between the fertilizing methods and fertilizers on *C. asiatica* except for the leaf area.







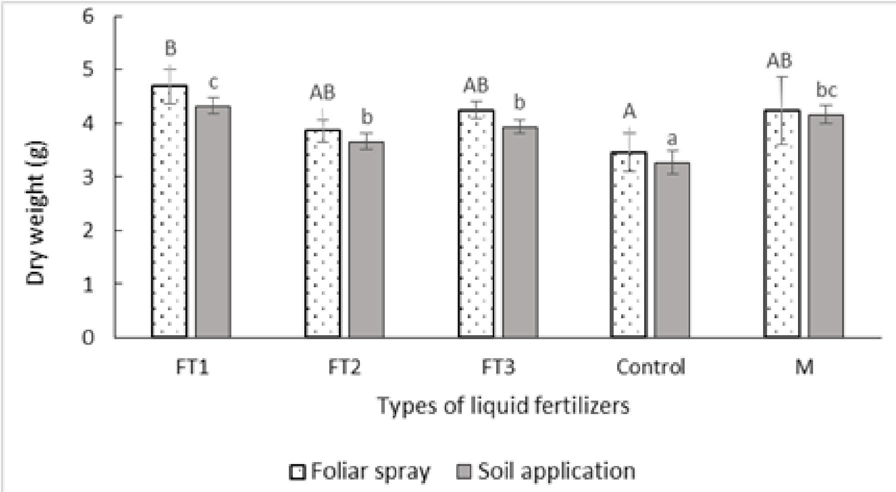


Figure 04: Effect of the enriched fertilizers on growth performances (a) number of leaves per plant, (b) leaf area, (c) plant fresh weight and (d) plant dry weight of *C. asiatica* over foliar spray and soil application.

Each data point represents the mean of six replicates ± standard deviation. Means sharing a common letter (s) in each column of a separate treatment are not significantly different p< 0.05 by Tukey's multiple comparison test.

The research findings were similar to what was reported by Fahrurrozi *et al.* (2019) where both soil and foliar applications of *Tithonia*-enriched liquid fertilizer were similarly effective for the growth of sweet corn. Moreover, they stated that the leaf area also plays a vital role in the effectiveness of foliar application as narrow-leaf structures resulted in lower effectivity than the broader leaves. In this study also, *C. asiatica* that had a comparatively lower leaf area resulted in no significant differences of both soil and foliar applications whereas *B. alba* that had a comparatively higher leaf area recorded a significant effect. Similarly, Hamayun *et al.* (2011) also resulted in a marginally higher mean number of lentil seeds per pod in foliar sprayed with nitrogen followed by soil-applied and soil + foliar-applied nitrogen.

However, locally produced effective organic fertilizers are still not prevailing widely at a commercial scale in the market due to poor understanding in the society and no proper published information on the same subject. This research has successfully shown effective liquid organic fertilizers that can be easily produced even by home gardeners without much of the scientific knowledge for the maintenance of their leafy vegetables and other crops to strengthen the family economy, food safety and health.

Table 03: Growth parameters of *C. asiatica* over foliar and soil applications of different organic liquid fertilizers

Growth parameter	Fertilizing method		Fertilizer		Fertilizing method x fertilizer	
	P value	F value	P value	F value	P value	F value
No. of leaves	0.038	4.558	0.000	57.910	0.071	2.311
Leaf area	0.430	4.295	0.170	3.312	0.009	3.820
Plant fresh weight	0.001	13.134	0.000	16.181	0.101	2.053
Plant dry weight	0.002	11.128	0.000	32.139	0.682	0.575

Means having a p-value greater than 0.05 (p>0.05) is not significantly different by Turkeys multiple comparison test. Each data point represents the mean of six replicates ± standard deviation. Means sharing the same letter in each row are not significantly different at p<0.05 by Tukey's multiple comparison test. (FT1: decomposed plant materials + fish waste hydrolyzed with proteases from C. papaya; FT2: decomposed plant materials + fish waste hydrolyzed with proteases from A. comosus and FT3: decomposed plant materials + fish waste hydrolyzed with proteases from C. papaya and A. comosus; C: negative control and M: positive control).

CONCLUSIONS

Liquid organic fertilizer derived from plant materials (i.e., *T. diversifolia* + *M. scandens* + *C. odorata* + *G. sepium* + *C. aromaticus* + *L. camara*) + topsoil + fish waste + *C. papaya* (ripe peel + leaves) + coconut husk ash (FT1) recorded the highest nutrient contents of N, P and Ca. Foliar-applied liquid organic fertilizers showed significantly higher overall growth performances of *B. alba* than the soil-applied fertilizers. Both foliar and soil-applied liquid organic fertilizers indicate similar growth performances in *C. asiatica.* Considering the overall growth parameters of both foliar and soil-applied liquid fertilizers, FT1 fertilizer recorded the highest growth performances followed by FT3 compared to the standard fertilizer on the growth of *C. asiatica* and *B. alba.* Furthermore, all formulated liquid fertilizers showed significantly higher growth performances compared to the untreated negative control showing their potential to utilize as organic fertilizers in cultivating safe and healthy leafy vegetables at home gardens reducing the adverse impacts of chemical fertilizers. Therefore, it is recommended that correctly formulated organic liquid fertilizers provide higher yields and a sustainable soil health.

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