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Original Paper

Effect of spent coffee grounds and liquid worm fertilizer on the growth and yield of *Brassica campestris* L.

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Brassica campestris L. plants are widely grown, including in Asian countries where the leaves are used to prepare Chinese sour pickled mustard greens. The potential benefits of the application of organic by-products and organic fertilizers in sustainable agricultural production have been shown in previous studies. Consequently, this study investigated the effectiveness of liquid worm fertilizer (LWF) and spent coffee grounds (SCG) individually and in combination on the growth of *B. campestris*. The results showed that LWF at the highest dose had positive effects on the growth and yield of *B. campestris*, but SGC had inhibitory effects. The treatment consisting of composted SCG + triple of the standard dose of LWF resulted in the best plot yield with 3,866.7 $g.plot^{-1}$, followed by the treatment of fresh SCG + triple of the standard dose of LWF, which produced a yield of 3,766.7 $g.plot^{-1}$. The lowest yield (2,100.0 $g.plot^{-1}$) was observed in the treatment of 1 $kg.m^{-2}$ fresh SCG + no LWF. The interaction effect between SCG and LWF on the plot yield of *B. campestris* L. was significant ($F_{(4,18)} = 4.6$; $p = 0.01$) demonstrating enhanced yield when both SCG and LWF were used in combination.

Keywords: *Brassica campestris* L., coffee grounds, liquid worm fertilizer, pickled mustard greens

1 Introduction

The intensive use of inorganic fertilizers in agricultural cultivation has promoted increased crop yields, allowing food production to keep pace with the rapidly growing human population; hence, ensuring food security for humanity. However, the long-term impacts on crops are not sustainable. Farmers overuse inorganic fertilizers to raise productivity, which has adversely affected the soil, crops, the environment, useful microorganisms, and human health (Bisht & Chauhan, 2020). Most chemical fertilizers are derived from acids, so they will reduce the soil pH, they also are frequently contaminated with heavy metals and disrupt the soil structure (Bisht & Chauhan, 2020). It is well-acknowledged that biofertilizers have demonstrated their potential to replace chemical fertilizers (Chang et al., 2010; Zhang et al., 2012; Lin et al., 2019; Bisht & Chauhan, 2020). The use of organic fertilizers can not only enhance crop yield and soil properties, but also restrain pests and diseases due to their alleviating soil acidification, improving soil fertility, improving soil structure, and promoting long-term positive effects on crop growth (Lin et al., 2019; Bisht & Chauhan, 2020).

Organic fertilizers are derived from natural sources such as manure, plant residues, biogas residue, agricultural by-products, and liquid organic fertilizers fermented and extracted from natural sources. Furthermore, reusing these by-products in agricultural production can have not only a positive impact on environmental pollution, but also increase economic benefits in the circular economy. Spent coffee grounds (SCG) are a residue from coffee brewing produced in massive quantities. It is estimated that more than 15 million tons are produced annually (Kamil et al., 2019; Cervera-Mata et al., 2022). SCG contains notable amounts of macro- and micro-nutrients and organic carbon (Ballesteros et al., 2014), potentially making it a useful soil amendment/fertilizer. Yamane et al. (2014) tested the effects of fresh SCG on the growth

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of alfalfa, guinea grass, crotalaria, sorghum, sunflower, oat, barley, and rye at the field scale. The result showed negative impacts of SCG in the first cropping season when applied at rates of 1 and 10 $kg.m^{-2}$ of SCG. However, after the second cropping season, the inhibitory effect clearly diminished. Interestingly, at the application of 10 $kg.m^{-2}$ of SCG, the growth of guinea grass, sorghum, and sunflower increased 2-fold in comparison with the control (Yamane et al., 2014). It was demonstrated that both fresh and composted SCG had positive effects on lettuce growth and have the potential for use as fertilizer in agriculture (Gomes et al., 2014). Consequently, whilst SCG had the effect of stimulating crop growth, this was dependent on the particular species (Yamane et al., 2014). Yamane et al. (2014) further showed that the inhibitory effect on crops found with SCG amendments could be moderated by the additional application of horse manure at 10 $kg.m^{-2}$. Hence, the mixing of SCG with another organic fertilizers has the potential to overcome the initial negative impacts of SCG on crops.

Liquid worm fertilizer (LWF) is an organic fertilizer produced by the fermentation process from earthworms. In Vietnam, *Perionyx excavates* earthworms have been cultured popularly from manure or from other agricultural by-products; hence, the worm is an abundant resource to produce LWF. Recently, the benefits of organic fertilizers related to worms such as vermicompost and worm-casting tea in stimulating crop growth and yield are well-acknowledged (Prisa, 2019; Alkobaisy et al., 2021; Koskey et al., 2023), but the effect of liquid worm fertilizer extracted from earthworms on plant growth is yet to be established.

Vegetables, including *Brassica campestris* L. are an important part of a healthy diet. They are an important source of nutrients, including amino acids, vitamins, bioactive phytochemicals, and dietary fiber (Ülger et al., 2018). The fibre content especially brings great potential benefits to human health; a generous intake of dietary fiber decreases the risk of developing several diseases, such as cardiovascular disease, stroke, hypertension, diabetes, obesity, and certain gastrointestinal disorders. In addition, increased dietary fiber consumption improves serum lipid concentrations, blood glucose, and immune function, lowers blood pressure, helps to control diabetes, promotes regularity, and aids in weight loss (Anderson et al., 2009).

Brassica campestris L. originated in China (Centre Data of Vietnam Botany, 2023) and remains a popular crop in Vietnam and other Asian countries in both fresh and in the form of sour pickled mustard greens. The aim of the present study was to determine whether the yields of this important crop could be enhanced by using SCG and/or LWF and whether there was a positive interaction between SCG and LWF on the yield of *B. campestris*. The results of the present study could be referenced by farmers to select the appropriate cultivation method to improve crop productivity while protecting the environment and human health.

2 Material and methods

2.1 Materials

Fresh spent coffee grounds (SCG) were collected from coffee shops in Tra Vinh province, Vietnam. These were then dried and stored until use. Both fresh and composted SCG were compared in the present study to test if composting increased the effectiveness of SCG as a soil amendment.

For fresh SCG: The collected SCG (Figure1A) was mixed with *Trichoderma* sp. (10^9 $CFU.g^{-1}$) at a ratio of 100 coffee grounds: 1 *Trichoderma* sp. (w/w). This was then applied directly to the soil in the experimental plots.

For composted SCG: The collected SCG was mixed with peanut leaves and branches in the ratio of 10 : 1 (w/w), respectively, and then 1% *Trichoderma* sp. was added. The mixture was then pressed into a Styrofoam box, covered with a thin heavy soil layer to maintain the temperature and moisture of compost during the incubation process. The compost was drenched by watering and covered by a box lid. After 10 days of the composting process, the compost was watered again. Composting continued for 45 days in total by which point the peanut leaves were decomposed (Figure 1B).

Brassica campestris L. seeds: The F1 seeds of *B. campestris* was obtained from a commercial supplier (Trang Nong Co. Ltd, Ho Chi Minh City, Viet Nam).

The commercial liquid worm fertilizer (Vermi Max, Tanixa Technology Co., Ltd, Long An, Vietnam), consisted of 60% liquid worm extract, which contained 2% Chitosan, 3,000 ppm Zn, and minor elements of Fe, Cu and Ca. The doses of the organic fertilizer used in the present study were 0, the standard dose and X3 the standard dose.

2.2 Experimental set-up under Greenhouse conditions

A two-level factorial experiment of Randomized Complete Block Design (RCBD) with three replicates was conducted in order to assess the effect of spent coffee grounds and liquid worm fertilizer on *B. campestris* growth (Table 1).

The experiment, which started on April 2022 to June 2022, was carried out in a net house of Tra Vinh University, Vietnam. In total, the experiment included nine treatments (as shown in Table 1) with each treatment

Figure 1 Fresh (A) and composted (B) spent coffee grounds

replicated three times. Consequently, twenty-seven 1 m^2 plots were set up in the soil within the net house (clay soil and pH ~6). In preparation, the experimental area was cleared of weeds and tilled. A pre-plant fertilizer application was then applied to the soil consisting of cow manure and superphosphate (Table 2). A lime application was also made to adjust soil pH to a pH range of 6.5–7.0. Twelve *B. campestris* plants were then planted as seedlings (3 true leaves and 6-8 cm in height) directly into the soil of each experimental plot of 1 m^2. Between days 1 to 5 after planting, watering was conducted three times per day as the roots of the seedlings were developing. After day 5, watering was carried out once per day in the early morning or late afternoon. All plots received small fertiliser additions on day 7 (urea) and day 12 (NPK and urea) to ensure that nutrient is sufficient for plant growth.

Fresh and composted SCG treatments were applied manually by top dressing around the plant base three times at the period of 10, 20 and 30 days after planting. The total quantity of three application times was equal to 1 $kg.m^{-2}$.

Liquid worm fertilizer was sprayed onto the soil every 7 days for the first 35 days after planting at the standard recommended dose and X3 dose depending on the particular treatment. The application of LWF consisted of 0.1 mL or 0.3 mL of LWF, for the X1 and X3 dose respectively, diluted in 50 mL water, which was then sprayed on to the respective plots.

All growth and yield parameters were determined 42 days after planting. Seven out of the twelve plants were randomly selected to collect the data. The harvested plants were used to investigate individual growth parameters, including plant height, individual foliage diameter, and the number of mature leaves (leaves had spread out and were no longer tightly coiled). All seven selected plants were harvested on the same day, yellow leaves were removed along with the roots and the remaining shoots were weighed in order to determine individual plant fresh biomass. In addition, the total plant mass of plants from each plot was then evaluated by calculating the weight of all twelve plants of each plot.

Table 1 Experimental design to determine the effect of spent coffee ground and liquid worm fertilizer on the growth of *Brassica campestris* when applied both signgly and in combination

SCG / LWF	0	Fresh SCG (1 $kg.m^{-2}$)	Composted SCG (1 $kg.m^{-2}$)
0	LS	LoSf	LoSc
X1 (0.1 $mL.m^{-2}$)	LS	L1Sf	L1Sc
X3 (0.3 $mL.m^{-2}$)	LS	L3Sf	L3Sc

SCG – spent coffee grounds; LWF – liquid worm fertilizer; X1 – standard dose; X3 – triple of standard dose. LoSo – control (no LWF+ no SCG); LoSf: no LWF + 1 $kg.m^{-2}$ fresh SCG; LoSc – no LWF + 1 $kg.m^{-2}$ composted SCG; L1So – X1 of LWF + no SCG; L1Sf – X1 of LWF + 1 $kg.m^{-2}$ fresh SCG; L1Sc – X1 of LWF + 1 $kg.m^{-2}$ composted SCG; L3So – X3 of LWF + no SCG; L3Sf – X3 of LWF + 1 $kg.m^{-2}$ fresh SCG; L3Sc – X3 of LWF + 1 $kg.m^{-2}$ composted SCG

Table 2 Fertilizer formula used for *Brassica campestris* L.

Days after planting	Fertilizing method	Amount of fertilizer (kg.1,000 m^{-2})				
		$CaCO_3$	16-16-8 N-P-K	urea	superphosphate (16% P_2O_5)	cow manure
In pre-planted preriod	basic manuring	30	–	–	30	2,000
7	spraying	–	–	5	–	–
12	spraying	–	7.5	5	–	–

Source: Nguyen Thi Hong Tham, 2016

2.3 Statistical analysis

A two-way ANOVA was conducted for all statistical analyses in this study to find differences in the impacts of SCG and LWF on the growth and yield of *B. campestris* L. plants. Duncan post-hoc test was used to find out which main effect treatment were different in two-way ANOVA. Data sets were analysed for homogeneity of variance with Levene's test prior to comparing means by two-way ANOVA. Also, different effects in plant growth parameters amongst treatments were determined by one-way ANOVA and Duncan post-hoc test.

4 Results and discussion

Effects of spent coffee grounds and liquid worm fertilizer on the growth parameters

There were big differences in the height, the number of leaves and forlia diameter of *Brassica campestris* L. amongst the treatments after 42 days of planting (Tables 3–5).

The plant height in the treatments that used liquid worm fertilizer (LWF) at both standard and triple standard doses was improved in comparison with the other treatments. In contrast, adding fresh and composted spent coffee grounds without LWF slightly, but not significantly, inhibited the growth of *B. campestris* especially for fresh SCG (Table 3). The best growth in terms of plant height was found in the treatments with the X3 dose of LWF. The addition of fresh or composted SCG had very little effect on plant height. This was confirmed by two-way ANOVA, which showed only the main effect of LWF had a significant effect on the plant height ($F_{(2,18)} = 22.67$; $p < 0.001$) and SCG did not ($F_{(2,18)} = 0.69$; $p = 0.52$). Additionally, no significant interaction effect between SCG and LWF was found ($F_{(4,18)} = 1.31$; $p = 0.30$), showing that there was no difference in the response of the plant to LWF by SCG.

Table 3 Effects of spent coffee grounds (SCG) and liquid worm fertilizer (LWF) on the height (cm) of *B. campestris* (mean ±1 SD)

SCG / LWF	0	Fresh SCG	Composted SCG	Mean of LWF
0	24.76 ±1.27^{cd}	22.87 ±2.54^{d}	24.73 ±1.88^{cd}	24.12 ±1.95^{C}
X1	25.60 ±1.42^{bc}	26.40 ±0.61^{abc}	27.57 ±1.06^{ab}	26.52 ±1.27^{B}
X3	28.60 ±1.48^{a}	29.10 ±0.86^{a}	28.40 ±0.87^{a}	28.71 ±1.02^{A}
Mean of SCG	26.32 ±2.12	26.13 ±3.05	26.90 ±2.03	

SCG – spent coffee grounds; LWF – liquid worm fertilizer; X1 – standard dose (0.1 mL.m^{-2}); X3 – triple of standard dose (0.3 mL.m^{-2}). Treatment of no SCG and no LWF used as control; the treatments with the same letter were not significantly different; whilts different lowercase letters showed differences among treatments, capital letters showed differences among main effects

Table 4 Effects of spent coffee grounds (SCG) and liquid worm fertilizer (LWF) on the number of mature leaves of *B. campestris* (mean ±1 SD)

SCG / LWF	0	Fresh SCG	Composted SCG	Mean of LWF
0	10.23 ±0.32^{b}	10.27 ±0.35^{b}	10.17 ±0.90^{b}	10.22 ±0.51^{B}
X1	10.17 ±1.07^{b}	10.37 ±1.23^{b}	11.13 ±0.23^{ab}	10.56 ±0.94^{B}
X3	11.36 ±0.35^{ab}	11.73 ±0.35^{a}	11.63 ±0.35^{a}	11.58 ±0.35^{A}
Mean of SCG	10.59 ±0.83	10.79 ±0.97	10.98 ±0.82	

SCG – spent coffee grounds; LWF – liquid worm fertilizer; X1 – standard dose (0.1 mL.m^{-2}); X3 – triple of standard dose (0.3 mL.m^{-2}). Treatment of no SCG and no LWF used as control; the treatments with the same letter were not significantly different; whilts different lowercase letters showed differences among treatments, capital letters showed differences among main effects

Table 5 Effects of spent coffee grounds (SCG) and liquid worm fertilizer (LWF) on the foliage diameter (cm) of *B. campestris* L. (mean ±1 SD)

SCG / LWF	0	Fresh SCG	Composted SCG	Mean of LWF
0	38.67 ±2.68^{cd}	36.97 ±3.54^{d}	39.30 ±1.93^{cd}	37.31 ±2.24^{C}
X1	42.13 ±0.87^{bc}	41.10 ±2.49^{cd}	45.57 ±1.27^{ab}	42.93 ±2.50^{B}
X3	46.63 ±1.72^{a}	46.63 ±2.46^{a}	47.00 ±3.05^{a}	46.76 ±2.15^{A}
Mean of SCG	42.48 ±0.83	41.57 ±4.88	43.96 ±4.02	

SCG – spent coffee grounds; LWF – liquid worm fertilizer; X1 – standard dose (0.1 mL.m^{-2}); X3 – triple of standard dose (0.3 mL.m^{-2}). Treatment of no SCG and no LWF used as control; The treatments with the same letter were not significantly different; Whilts different lowercase letters showed differences among treatments, capital letters showed differences among main effects

A similar effect was found in the number of mature leaves per plant (Table 4). The application of LWF at standard and triple standard doses increased the number of leaves of the *Brassica campestris* L. plant in treatments added with fresh and composted SCG was slightly higher than that in treatments added no SCG. The highest number of leaves was found for the plants in the X3 dose of LWF with/without SCG. A two-way ANOVA found that LWF application had a significant effect on the mean number of leaves per plant ($F_{(2,18)}$ = 9.79; p = 0.001), but SCG did not ($F_{(2,18)}$ = 0.74; p = 0.49). The interaction term (LWF*SCG) was also not significant ($F_{(4,18)}$ = 0.61; p = 0.66).

Differences in the effects of treatments on the foliage diameter of *Brassica campestris* L. plants were recorded. Fresh SCG had a small negative effect on the foliage diameter, but a slightly positive effect was found for composted SCG when compared to the control (Table 5). An increase in the applied dose of LWF significantly improved the foliage diameter of the plant, especially in the treatments which had a combination of LWF and composted SCG (Table 5). A significant main effect of LWF on the foliage diameter was shown in the two-way ANOVA ($F_{(2,18)}$ = 28.79; p <0.001), but the main effect of SCG on the foliage diameter was not significant ($F_{(2,18)}$ = 2.34; p = 0.13). The interaction term between SCG and LWF was also non-significant ($F_{(4,18)}$ = 0.70; p = 0.60), showing there was no difference in the effect of LWF on the foliage diameter by SGC (Table 5).

3.2 Effects of spent coffee grounds and liquid worm fertilizer on the yield parameters

Differences in the mean mass of *Brassica campestris* plants were noted between treatments (Table 6, Figures 2–3). In the treatment without LWF both fresh and composted SCG reduced the mass of individual plants in comparison with the control, whilst a positive effect of the combination of SCG and LWF amendments was apparent (Table 6, Figures 2&3). Two-way ANOVA analysis showed that LWF significantly affected the individual weight of the plant, but SCG application did not ($F_{(2,18)}$ = 35.38; p <0.001 and $F_{(2,18)}$ = 1.07; p = 0.37, respectively for LWF and SCG). The interaction term between SCG and LWF was also not significant ($F_{(4,18)}$ = 1.92; p = 0.15). Consequently, only LWF application had a statistically significant effect on *B. campestris* yield.

In terms of the yield of *B. campestris* from each experimental plot, the highest yield was found in the treatment compromising the X3 dose of LWF and composted SCG (the L3Sc treatment), which achieved a yield of 3866.7 g.plot^{-1}and the lowest yield was recorded in the treatment of LoSf (no LWF + 1 kg.m^{-2} fresh SCG) with only 2100.0 g.plot^{-1} (Table 7). Subsequent two-way ANOVA analysis found that both SCG and LWF main effects had a significant effect on the total yield of each experimental plot ($F_{(2,18)}$ = 3.93; p = 0.04 and $F_{(2,18)}$ = 69.86; p <0.001 for SCG and LWF, respectively). A significant

Table 6 Effects of spent coffee grounds (SCG) and liquid worm fertilizer (LWF) on the individual yield of *B. campestris* L. (g.plant^{-1}; mean ±1 SD)

SCG / LWF	0	Fresh SCG	Composted SCG	Mean of LWF
0	232.8 ±24.5^{cd}	189.8 ±24.4^{d}	204.8 ±37.0^{d}	209.1 ±31.8^{C}
X1	222.0 ±21.3^{cd}	235.3 ±24.1^{cd}	269.7 ±17.1^{bc}	242.3 ±28.0^{B}
X3	304.0 ±5.2^{ab}	346.8 ±64.1^{a}	347.5 ±36.0^{a}	332.8 ±42.7^{A}
Mean of SCG	252.9 ±42.0	257.3 ±78.8	274.0 ±67.7	

SCG – spent coffee grounds; LWF – liquid worm fertilizer; X1 – standard dose (0.1 mL.m^{-2}); X3 – triple of standard dose (0.3 mL.m^{-2}). Treatment of no SCG and no LWF used as control; the treatments with the same letter were not significantly different; whilts different lowercase letters showed differences among treatments, capital letters showed differences among main effects

Figure 2 Size of *Brassica campestris* L. plants in experiment treatments of LoSc – no LWF + 1 kg.m^{-2} composted SCG (A); L1Sc – X1 of LWF + 1 kg.m^{-2} composted SCG (B); L3Sc – X3 of LWF + 1 kg.m^{-2} composted SCG (C)

interaction term between SCG and LWF was also found ($F_{(4,18)}$ = 4.6; p = 0.01), indicating that combining the two amendments significantly affected yield at the plot level.

Research into the effect of organic fertilizers, including vermicompost and earthworm extracted fertilizers on crop cultivation are quite abundant. It is well-acknowledged that using organic fertilizers can bring many benefits to not only crops but also the environment (Chang et al., 2010; Zhang et al., 2012; Lin et al., 2019; Prisa, 2019; Bisht & Chauhan, 2020; Alkobaisy et al., 2021; Koskey et al., 2023). In terms of spent coffee grounds (SCG), several studies found an adverse effect of SCG application on plant growth (Kitou & Yoshida, 1997; Vardon et al., 2013; Gomes et al., 2014; Yamane et al., 2014; Hardgrove & Livesley, 2016), but this is species dependent (Yamane et al., 2014; Hardgrove & Livesley, 2016). Growth

Figure 3 Size of *Brassica campestris* L. plants in experiment treatments of LoSf: no LWF + 1 kg.m^{-2} fresh SCG (A); LoSf: X1 of LWF + 1 kg.m^{-2} fresh SCG (B); L3Sf: X3 of LWF + 1 kg.m^{-2} fresh SCG (C)

Table 7 Effects of spent coffee grounds (SCG) and liquid worm fertilizer (LWF) on the plot yield of *B. campestris* L. (g.plot^{-1}; mean ±1 SD)

SCG / LWF	0	Fresh SCG	Composted SCG	Mean of LWF
0	2,633.0 ±230.9^{c}	2,100.0 ±264.6^{d}	2,266.7 ±230.9^{cd}	2,333.3 ±316.2^{C}
X1	2,500.0 ±200.0^{cd}	2,566.7 ±305.5^{cd}	3,266.7 ±152.8^{b}	2,777.8 ±417.7^{B}
X3	3,533.3 ±57.7^{ab}	3,766.7 ±450.9^{a}	3,866.7 ±208.2^{a}	3,722.2 ±290.6^{A}
Mean of SCG	2,888.9 ±511.0^{Y}	2,811.1 ±803.8^{XY}	3,133.3 ±721.1^{X}	

SCG – spent coffee grounds; LWF – liquid worm fertilizer; X1 – standard dose (0.1 mL.m^{-2}); X3 – triple of standard dose (0.3 mL.m^{-2}). Treatment of no SCG and no LWF used as control; the treatments with the same letter were not significantly different; whilts different lowercase letters showed differences among treatments, capital letters showed differences among main effects

inhibition may be attributed to N immobilization, the multiplication of pathogenic fungi or the presence of phytotoxic allelochemicals remaining in SCG, such as caffeine, tannins and polyphenols (Kitou & Yoshida, 1997; Pandey et al., 2000). In contrast, incorporation of this residue improved soil physical, chemical and biological properties (Pérez-Burillo et al., 2022). In addition, using a fertilizer with SCG application can help alleviate growth inhibition in crops (Vardon et al., 2013; Yamane et al., 2014).

In this present study, wide variations in the parameters related to the growth and yield of *Brassica campestris* were found with different applications of liquid worm fertilizer (LWF) and forms of SCG. The present study confirmed that fresh SCG could have an inhibitory impact on *B. campestris* growth parameters. The factors of plant height, foliage diameter, the mean individual plant weight, and the total plot yield in the LoSf treatment (which applied 1 kg.m^{-2} fresh SCG, but no used LWF) were lower than that of the control. Indeed, the yield of the LoSf treatment was decreased compared to that of the control by 20.24% (2,100.0 g.plot^{-1} compared with 2,633.0 g.plot^{-1}, respectively; Table 7). Although the detrimental effects of composted SCG were not found in growth parameters such as the plant height and foliage diameter when compared to the control, the average individual weight and total plot yield in this treatment (LoSc: no LWF + 1 kg.m^{-2} composted SCG) were much lower than that in the control (Tables 6–7). The adverse effects of both fresh and composted SCG on crops are in agreement with other studies (Kitou and Yoshida, 1997; Vardon et al., 2013; Gomes et al., 2014; Yamane et al., 2014; Hardgrove and Livesley, 2016; Pérez-Burillo et al., 2022). By contrast, the application of LWF improved the growth and yield parameters of *Brassica campestris*, with a triple dose of LWF (without SCG) increasing the plot yield by 34.19% in comparison with the control.

A combination of LWF and fresh and composted SCG improved the yield of *B. campestris* in comparison to the corresponding treatment group of no SCG application in the present study. At the standard and triple of LWF, adding composted SCG increased the total plot yields, by 30.67% and 9.43%, respectively, in comparison with the corresponding treatment of no SCG and other growth parameters (increases in plant height, the number of leaves per plant, plant foliage diameter and average individual weight) were also improved, although non-significantly. The increased plot yield appeared to result from the combined increase in these factors.

The study of Yamane et al. (2014) demonstrated that adding horse manure at a rate of 10 kg.m^{-2} effectively alleviated the inhibitory effects of spent coffee grounds at both low and high application rates of 1 kg and 10 kg.m^{-2}. A further study showed that applying N fertilizer in combination with treatments of fresh SCG and SCG by-products (defatted grounds, spent ground biochar and defatted ground biochar) increased Sorghum-sudangrass biomass in comparison with the control (Vardon et al., 2013). The results of the present study were fully compatible with these previous findings in that co-application of fertilizer mitigated the negative effects of SCG. This is important as the application of SCG has been shown to improve soil physical, chemical and biological properties (Pérez-Burillo et al., 2022), such as a decreased bulk density and increased water holding capacity, aggregate stability, nutrient element content (including C, N, K, Mg, Zn, and Cu) and microbial diversity. The application of SCG on its own can cause a detrimental effect on plant growth due to its presence of potentially phytotoxic compounds (Kitou & Yoshida, 1997; Pandey et al., 2000). However, in combination with N fertilizer, SCG residues can act as bio-chelates able to keep available nutrients for biofortification of edible plants (Pérez-Burillo et al., 2022); hence, the plant can mediate the status of N immobilization caused by SCG applications. Consequently, growth and yield parameters in this present study improve by adding both LWF and SCG. Composted SCG before application appeared to be benficial, probably due to the effect of composting on the levels of allelochemicals present (Jiao et al., 2021).

4 Conclusions

Applying seperately liquid worm fertilizer (LWF) at the highest dose had significantly positive effects on the growth and yield of *Brassica campestris* L., but SGC had inhibitory effects when applied as a top dressing with fresh SCG significantly decreasing plot yield by 20.24% compared to the control. However, the combination of both LWF and SCG improved plot yield over the individual treatments, apparently by promoting increases in plant height, the number of leaves, plant foliage diameter, and average individual weight of *B. campestris* plants. Consequently, the findings of this present study demonstrated that fresh and composted SCG have the potential to be used as fertilizer in agricultural cultivation, but SCG should be used with an effective fertilizer such as LWF until potentially phytotoxic compounds in the SCG have degraded. Pre-treating the SCG by composting appears to be an effective way to speed up this degradation.

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