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Influence of Black Soldier Fly Frass Fertilizer on Growth and Southern Blight Disease Development in Okra (*Abelmoschus Esculentus* (L.) Moench)

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ABSTRACT

Black Soldier fly (*Hermetia illucens*) larval (BSFL) frass is gradually becoming a source of organic fertilizer in cropping systems because of its role in improving crop growth and development as well as suppressing the growth of fungal pathogens. This study evaluated the effect of Black Soldier Fly Frass Fertilizer (BSFFF) on the growth of Okra (*Abelmoschus esculentus*) plant and development of southern blight disease during its growth. The BSFFF was applied at the rate of 10g, 15g, and 20g per 3kg of heat pasteurized soil in (5 litre capacity and 20 cm-diameter at the top and 15 cm height) plastic pots. No BSFFF application served as control while NPK 20:10:10 was applied at the rate of 30 kg ha^{-1} to serve as a check. Results showed no significant difference (p=0.05) in the growth parameters on BSFFF-treated okra plants regardless of level of application. From the second to fifth weeks after sowing (WAS), the growth parameters of okra plants treated with BSFFF at all levels were significantly different (p = 0.00001) from those of untreated and NPK-treated plants. Plant heights in the first and sixth WAS ranged from 15.95±0.53 to 37.65±2.63 cm, respectively. From the second to fifth WAS, stem girth of okra plants treated with BSFFF at all levels was significantly wider (p = 0.00001) than that of untreated and NPK-treated plants. At two WAS, the number of leaves (6.56 ± 0.24) on okra $BSFFF_{20}$ treated plants was significantly (p = 0.0098) more than that of control plants (5.20± 0.13). However, from 3 WAS, there was a steady reduction in the number of leaves on okra plants irrespective of the treatment received, probably due to the onset of disease symptoms. At 4 WAS, the number of leaves on $BSFFF_{20}$ (5.67± 0.33) treated plants was again significantly more (p = 0.0003) than that of untreated plants despite the moderate incidence of disease symptoms on plants. The findings in this study demonstrate that integration of BSFFF into the okra cropping system would improve the growth and development of the okra plant and boost its tolerance to southern blight disease.

Keywords: Black soldier fly; Frass; southern blight disease; Okra; Disease.

INTRODUCTION

Okra (*Abelmoschus esculentus*) is a commercial vegetable crop that belongs to the Family Malvaceae and the Genus *Abelmoschus*. It is cultivated all over the world in tropical, subtropical, and warm-temperature regions with warm temperatures. It is a good source of protein, vitamins, calcium, minerals, enzymes, and potassium (Singh *et al.*, 2014; Aboyeji *et al.*, 2021). Several biotic

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and abiotic factors affect the production of okra. One of the biotic factors is a soil-borne fungus, *Sclerotium rolfsii* (the cause of Southern blight disease). This disease affects a wide variety of plants and usually infects the lower stem near the soil surface. With some plants, the roots may become infected. The disease occurs worldwide, but predominantly in warm climates (Mullen, 2001).

Management measures such as cultural, biological and plant extracts have been used in controlling the disease in okra in order to bring about improved yield (Amadi *et al.*, 2014). *Sclerotium rolfsii* has, however, proved difficult to control without the use of synthetic fungicides (Ekundayo *et al.*, 2018). Nevertheless, prolonged application of such fungicides is potentially toxic to the environment and humans (Ekundayo *et al.*, 2018), hence the need for a more eco-friendly approach for effective control of the disease on okra.

There are many beneficial soil microbes with plant protection capabilities that make them suitable as environmentally safe alternatives to synthetic pesticides (Cawoy *et al.*, 2011). Plant growth-promoting rhizobacteria (PGPR), for instance, have been reported to promote plants' resistance to pests and diseases (Pineda *et al.*, 2010; Pieterse *et al.*, 2014). Similarly, *Bacillus cereus* and *B. subtilis* are two root-colonising bacteria that can promote plant growth, induce systemic resistance, and inhibit the activities of a wide range of phytopathogens and insect pests (Gadhave and Gange, 2016). The use of insect frass as soil amendment has been reported to enhance the growth and activity of these and other beneficial soil microbes (Mazzola and Freilich, 2017). Frass is a nutrient-rich mix of insect faeces, shed exuviae, and undigested feed (Fowles and Nansen, 2020). The insect exoskeleton or exuviae is made up of mainly chitin and proteins and is a rich source of nitrogen for plant growth. Since plants cannot by themselves access nitrogen in chitin, they depend on the enzymatic activities of beneficial soil microbes to help break down the complex polysaccharide (Shamshina *et al.*, 2020). Thus, when added to the soil, insect frass indirectly promotes plant growth, stimulates tolerance, and systemic resistance to pests and diseases (Barragan-Fonseca *et al.*, 2022). According to Randall *et al.* (2020) and Andreo-Jimenez *et al.* (2021), chitin-rich amendments like frass resulted in the reduction of the incidence of diseases caused by root-infecting fungi like *Fusarium oxysporum* and *Rhizoctonia solani* in the greenhouse and field. Nevertheless, reports show that the effect of insect frass on plant resistance against pests and diseases depends on the crop species being treated, the insect species from which frass was obtained, and the plant part treated with the frass. Consequently, this study investigated the effect of frass from the Black Soldier Fly larvae as a soil amendment on the growth of okra and the development of southern blight disease on the plant. It was hypothesized in the study that the application of Black Soldier Fly Frass Fertilizer (BSFFF) as soil amendment would enhance increased growth of okra while suppressing the incidence and severity of southern blight disease of the plant.

MATERIALS AND METHODS

Study Location

This study was carried out in the laboratory and screen house of the Department of Crop Protection, Faculty of Agriculture, University of Ilorin, Nigeria. The University is located in the North-Central part of Nigeria (8.4928° N, 4.5962° E). The climatic condition is friendly for okra cultivation with annual rainfall ranging from 800 mm to 1500 mm, minimum temperature of 21.1 °C - 25 °C, average maximum of 30 °C – 35 °C, relative humidity of 75% – 80%, 6.5 – 7.7 hours of daily sunshine from November – May (Oriola & Oyeniyi, 2017).

Source of Okra Seeds

Okra seeds (Variety: F1 Pure Lucky) are a commonly grown okra variety in Ilorin. The seeds were obtained from Premier Seeds store located in the Sango area close to the Ministry of Agriculture and Natural Resources in Ilorin, Nigeria.

Source and Preparation of Fungal Inoculum

Sclerotium rolfsii culture was obtained from the Nigeria Horticultural Research Institute (NIHORT), Ibadan, Oyo State. Mycelia suspension was prepared by transferring fifteen 5mm diameter punches from a 5-day-old culture of the fungus into 100ml of sterile water using a sterile cork borer. The mixture was comminuted in a Waring blender for 5 minutes. The mixture was then stored in a corked Erlenmeyer flask. Inoculum meal was prepared by pouring 5ml of the suspension prepared earlier into 100g of previously sterilized wheat powder and incubating the mixture for 2 weeks at ambient laboratory conditions of 25 ^{0}C ±2 ^{0}C and a 12-hour photoperiod.

Soil Pasteurization and Inoculation

Sandy loam top soil was collected from the farm site around the Department of Agronomy Faculty of Agriculture University of Ilorin and steam pasteurized according to the modified Susilo *et al.* (2010) procedure in a drum at 65 – 80 °C for at least 10 hours. Three kilograms of the pasteurized soil were then measured into perforated plastic pots (PPP) for the potted experiment. Two days before planting, *Sclerotium rolfsii* inoculum was added to the sterilized soil at the rate of 10 g per 3 kg of soil.

Production of Black Soldier Fly Frass Fertilizer

Black Soldier Fly Frass Fertilizer (BSFFF) was produced by larval composting of municipal organic wastes. Briefly, BSF eggs obtained from a local BSF farm were hatched under ambient conditions of (29.6±0.8ºC °C, 69.5±7.5 % relative humidity, 12 hours light and 12 hours dark) in the Entomology laboratory of the Department of Crop Protection, University of Ilorin. The newly hatched larvae were reared for six days on commercial chicken feed mash (with 70-80% moisture) and thereafter split into two groups. The first group of BSFL was transferred into a large rearing bowl (10 L volume; 22.5 mm base diameter and 13.6 mm height) containing a slurry mash of restaurant food wastes, mainly remnants of cooked rice, fish, meat, yams, plantain, and flour doughs.

The second group was transferred into a similar rearing bowl that contained fruit wastes comprising mainly watermelon peels and rinds, as well as orange and pineapple peels. In both bowls, approximately 2000 six-day-old BSF larvae were reared on 1200 g of the mashed organic wastes for thirteen days (Spranghers *et al.*, 2017). During this time, the waste-based substrates were turned every other day to enhance proper ventilation. The frass fertilizer (dry and crumbly residue mixed with insect exuviae and droppings) was collected at the end of rearing when the larvae had begun to pre-pupate. The BSFFF produced from food wastes and fruit wastes were separately air-dried to a constant moisture content level of 11% for three days and then stored in separate Ziploc bags in the refrigerator at 4 °C until needed for experimentation.

Experiments and Treatments

The experiment to investigate the effect of soil amendment with BSFFF produced from food wastes on the growth and the development of southern blight disease on okra plants was laid out in a completely randomized design in the screen house. Experimental units comprised pots (5 litre capacity and 20 cm-diameter at the top and 15 cm height) containing 3 kg of steam pasteurized soil that had been inoculated with *S. rolfsii* as earlier described. Five seeds of okra were sown in each soil-filled pot, and the emerged plants were thinned to two stands one week after sowing. Two weeks after sowing (i.e., one week after thinning), treatments were applied to the pots in a randomized fashion. Treatments comprised: no BSFFF amendment (NF), 10 g $BSFFF_{FOW}$ per 3 Kg of soil ($BSFFF_{10}$), 15 g $BSFFF_{FOW}$ per 3 Kg of soil ($BSFFF_{15}$), 20 g $BSFFF_{FOW}$ per 3 Kg of soil ($BSFFF_{20}$), and NPK 20-10-10 fertilizer (NPK) at the recommended rate of 200 kg/ha. All five treatments were replicated five times each to give a total of 25 experimental units.

Data Collection and Analysis

Each of the two plants in a pot was assessed during data collection. Data was collected weekly on the number of leaves, plant height (cm), and stem girth (cm) from the first to the sixth week after sowing. The number of leaves was assessed by counting all the leaves on a plant, and plant height was measured with a tape rule from the point where the stem touched the soil to the point where the highest leaf was attached. Stem girth was measured using a digital Vernier caliper (0.1 mm precision). In addition, okra plants were visually assessed for Southern blight disease incidence and severity at the fourth and fifth week after sowing. Disease incidence was calculated using the formula:

Disease incidence (%) =

$$\frac{\text{Number of infected plants per pot}}{\text{Total number of units assessed}} \times 100$$

Southern blight disease severity of okra plants was evaluated using the modified scale of Le *et al.* (2020) as shown below (Table 1). Generally, data on plant growth, disease incidence, and severity were submitted to a one-way Analysis of Variance (ANOVA) test at 5% level of significance. Where necessary, mean separation was done using Tukey's HSD. All descriptive and inferential statistical analysis was done using packages and functions in R (V.4.3.1).

Table 1: Southern blight disease severity ratings based on visible symptoms on okra plants grown in sterilized soils infested with *Sclerotium rolfsii*

Severity Score	Description
1	No symptoms; plant is healthy
2	Gray water-soaked lesions present on the stem above the soil, but no visible fungal outgrowth
3	Visible fungal outgrowth on the stem base, characterized by silky-white mycelia or sclerotia that gradually darken
4	Partial wilting, where younger leaves begin to wilt and stems begin to shrivel
5	Complete wilting, desiccation, and browning of leaves and stem; plant collapse and death (rot)
6	Pre-emergence damping-off; complete seed rot, with no sign of germination, or evidence of germination hampered by fungal colonization

Le *et al.*, (2012)

RESULTS

The number of leaves on okra plants increased steadily within the first two weeks after sowing (Table 2). At two weeks after sowing (WAS), the number of leaves (6.56 ± 0.24) on okra $BSFFF_{20}$ treated plants was significantly (p = 0.0098) more than that of control plants (5.20± 0.13). However, from 3 WAS, there was a steady reduction in the number of leaves on okra plants irrespective of the treatment received, probably due to the onset of disease symptoms. At 4 WAS, the number of leaves on $BSFFF_{20}$ (5.67± 0.33) treated plants was again significantly more (p = 0.0003) than that of untreated plants, despite the moderate incidence of disease symptoms on plants. Compared to the second week after sowing, a sharp decline was observed in the number of leaves on all BSFFF-treated plants at 6 WAS when disease incidence and severity were generally high. Consequently, the number of leaves on untreated plants (3.80 ± 0.20) and those fertilized with NPK (3.40 ± 0.22) was significantly more (p = 0.00001) than on the BSFFF-treated plants. In all weeks of assessment, no significant difference (p = 0.05) was found in the number of leaves on BSFFF-treated okra plants regardless of the level of application.

Table 2: Number of Leaves of Okra Plants Grown in Soils Amended with Black Soldier Fly Frass Fertilizer

Treatment	1 WAS	2 WAS	3 WAS	4 WAS	5 WAS	6 WAS
$BSFFF_{10}$	4.40 ± 0.16^{a}	5.60 ± 0.40^{ab}	5.33 ± 0.37^{a}	5.55 ± 0.50^{a}	5.44 ± 0.41^{a}	1.11 ± 0.39^{b}
$BSFFF_{15}$	4.60 ± 0.22^{a}	6.10 ± 0.31^{ab}	5.70 ± 0.26^{a}	5.40 ± 0.34^{ab}	5.30 ± 0.50^{a}	1.40 ± 0.60^{b}

$BSFFF_{20}$	4.80± 0.25[a]	6.56 ± 0.24[a]	6.33± 0.37[a]	5.67± 0.33[a]	5.11± 0.45[ab]	0.44± 0.24[b]
NF	4.20± 0.13[a]	5.20± 0.13[b]	5.10 ± 0.38[a]	4.30± 0.32[bc]	4.1 ± 0.23[ab]	3.80 ± 0.20[a]
NPK	4.70± 0.15[a]	5.50± 0.17[ab]	5.10± 0.35[a]	3.90± 0.18[c]	3.7 ± 0.26[b]	3.40 ± 0.22[a]
	$F_{(4, 45)}$ =1.62	$F_{(4, 45)}$ =3.80	$F_{(4, 45)}$ =2.18	$F_{(4, 45)}$ =6.51	$F_{(4, 45)}$ =4.23	$F_{(4, 45)}$ =16.30
	p = 0.1850	p = 0.0098	p = 0.0878	p = 0.0003	p = 0.0056	p = 0.00001

Values are means of 5 replicates ± Standard deviations. Mean values followed by the same superscript letters in each column are not significantly different at 5% level of significance. $BSFFF_{10}$ = frass applied as a soil amendment at 10g/3kg of soil. $BSFFF_{15}$ = frass applied as a soil amendment at 15g/3kg of soil. $BSFFF_{20}$ = frass applied as a soil amendment at 20g/3kg of soil. NF = No application of frass, i.e., Control. NPK = Commercial fertilizer added at the recommended rate of 200 kg/ha. WAS: Weeks After Sowing

The height of okra plants that received NPK treatments increased steadily from the first (17.62±0.75) to the sixth (41.00±2.81) week after sowing (Table 3). A similar trend was observed with untreated plants, where heights, though lower, ranged from 15.95±0.53 to 37.65±2.63 in the first and sixth week after sowing, respectively. While okra plants treated with BSFFF also had increasingly higher plant heights in the first five weeks after sowing, a marked decline was observed at 6 WAS when the incidence and severity of disease were already very high. Nevertheless, no significant difference (p = 0.0611) was observed in the height of plants treated with BSFFF and those treated with NPK at all weeks of assessment.

Table 3: Height of Okra Plants Grown in Soils Amended with Black Soldier Fly Frass Fertilizer

Treatment	1 WAS	2 WAS	3 WAS	4 WAS	5 WAS	6 WAS
$BSFFF_{10}$	16.91±1.24[a]	25.53±1.79[ab]	37.07±2.96[a]	44.91±3.47[ab]	51.04±4.64[ab]	47.62±4.20[a]
$BSFFF_{15}$	16.48±0.98[a]	28.28±1.84[ab]	38.16±2.40[a]	47.16±2.95[a]	53.27±3.52[a]	46.36±2.99[a]
$BSFFF_{20}$	17.58±1.49[a]	30.37±2.45[a]	37.83±2.76[a]	45.98±3.69[a]	50.97±5.04[ab]	46.36±5.26[a]
NF	15.95±0.53[a]	23.23±1.06[b]	28.67±2.59[a]	34.12±1.78[b]	37.54±2.23[b]	37.65±2.63[b]
NPK	17.62±0.75[a]	25.74±0.94[ab]	31.6±1.71[a]	37.26±2.46[ab]	40.65±2.77[ab]	41.00±2.81[a]
	$F_{(4,45)}$ =0.48	$F_{(4, 45)}$ =2.57	$F_{(4, 45)}$ =0.52	$F_{(4, 45)}$ =4.12	$F_{(4, 45)}$ =3.76	$F_{(4, 45)}$ =2.44
	p = 0.752	p = 0.0509	p = 0.724	p = 0.00648	p = 0.0104	p = 0.0611

Values are means of 5 replicates ± Standard deviations. Mean values followed by the same superscript letters in each column are not significantly different at 5% level of significance. $BSFFF_{10}$ = frass applied as a soil amendment at 10g/3kg of soil. $BSFFF_{15}$ = frass applied as a soil amendment at 15g/3kg of soil. $BSFFF_{20}$ = frass applied as a soil amendment at 20g/3kg of soil. NF = No application of frass, i.e., Control. NPK = Commercial fertilizer added at the recommended rate of 200 kg/ha. WAS: Weeks After Sowing

A steady increase was generally observed in the stem girth of okra plants from the first to the fifth week after sowing (WAS). This was, however, followed by a reduction in stem girth at the sixth week (Table 4). From the second to fifth WAS, stem girth of okra plants treated with BSFFF at all levels was significantly wider (p = 0.00001) than that of untreated and NPK-treated plants. ALSO, as with other growth parameters in the present study, the level of application of BSFFF did not significantly affect the stem girth of okra plants treated with the organic amendment.

In this study, the incidence and severity of the southern blight disease on okra plants were assessed at the fourth and fifth WAS (Figure 1). Generally, soil amendment with BSFFF treatments or NPK 20-10-10 fertilizer did not prevent the onset or progression of the disease in plants. Incidence and severity of the disease on plants that received BSFFF (p = 0.563 and p = 0.908) and those that received NPK (p = 0.748 and p = 0.942) at 4

WAS and 5 WAS, respectively, were not different from NPK-treated plants or the untreated control plants. Also, in both weeks, no difference was observed in the incidence and severity of disease on okra plants treated with BSFFF, irrespective of the level of application.

Table 4: Stem Girth of Okra Plants Grown in Soils Amended with Black Soldier Fly Frass Fertilizer

Treatment	1 WAS	2 WAS	3 WAS	4 WAS	5 WAS	6 WAS
$BSFFF_{10}$	1.27 ± 0.07^{ab}	1.75 ± 0.08^{ab}	2.22 ± 0.12^{a}	2.42 ± 0.12^{a}	2.41 ± 0.11^{a}	2.41 ± 0.13^{a}
$BSFFF_{15}$	1.14 ± 0.08^{ab}	1.94 ± 0.12^{a}	2.28 ± 0.13^{a}	2.53 ± 0.11^{a}	2.53 ± 0.11^{a}	2.4 ± 0.12^{a}
$BSFFF_{20}$	1.32 ± 0.10^{a}	1.99 ± 0.11^{a}	2.44 ± 0.13^{a}	2.54 ± 0.14^{a}	2.74 ± 0.14^{a}	2.34 ± 0.09^{ab}
NF	1.01 ± 0.04^{b}	1.12 ± 0.06^{c}	1.57 ± 0.06^{b}	1.68 ± 0.07^{b}	1.8 ± 0.04^{b}	1.77 ± 0.04^{c}
NPK	1.24 ± 0.06^{ab}	1.42 ± 0.05^{bc}	1.75 ± 0.05^{b}	1.87 ± 0.04^{b}	2.01 ± 0.06^{b}	1.94 ± 0.11^{bc}
	$F_{(4,45)} = 2.92$	$F_{(4, 45)} = 17.87$	$F_{(4, 45)} = 16.44$	$F_{(4, 45)} = 16.38$	$F_{(4, 45)} = 16.80$	$F_{(4, 45)} = 8.407$
	$p = 0.0315$	$p = 0.00001$	$p = 0.00001$	$p = 0.00001$	$p = 0.00001$	$p = 0.00004$

Values are means of 5 replicates ± Standard deviations. Mean values followed by the same superscript letters in each column are not significantly different at 5% level of significance. $BSFFF_{10}$ = frass applied as a soil amendment at 10g/3kg of soil. $BSFFF_{15}$ = frass applied as a soil amendment at 15g/3kg of soil. $BSFFF_{20}$ = frass applied as a soil amendment at 20g/3kg of soil. NF = No application of frass i.e. Control. NPK = Commercial fertilizer added at recommended rate of 200 kg/ha. WAS: Weeks After Sowing

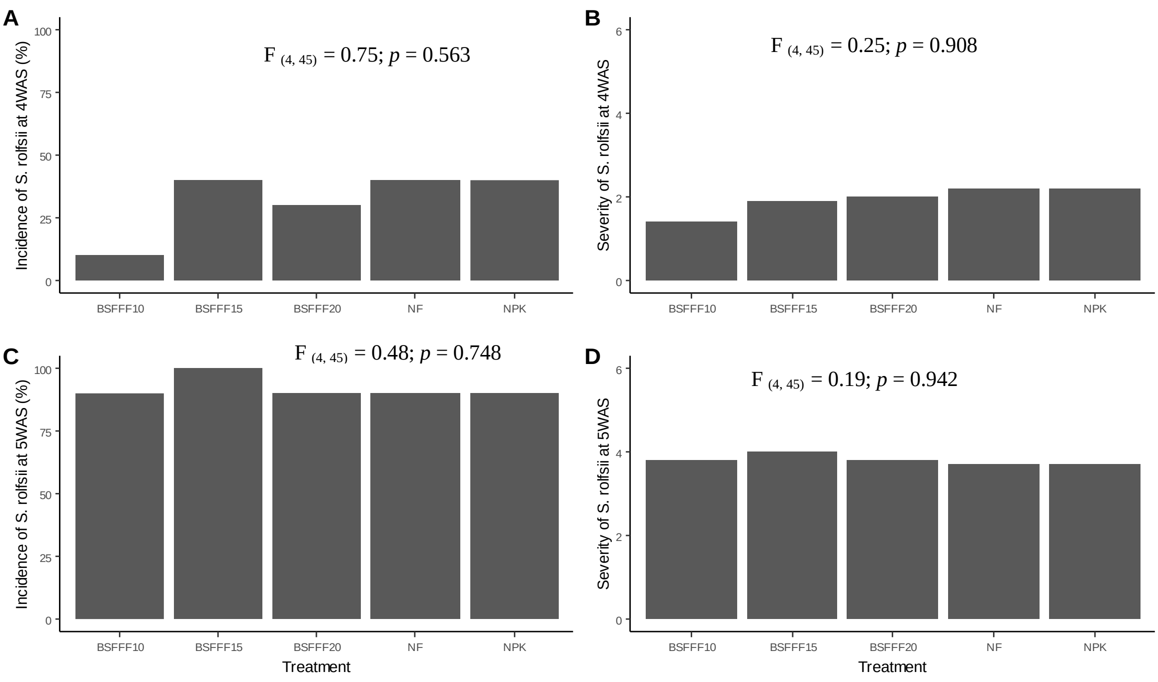

Figure 1: Effect of Black Soldier Fly Frass Fertilizer (BSFFF) on incidence and severity of okra plants infected with *Sclerotium rolfsii* at 4 and 5 weeks after sowing (WAS). $BSFFF_{10}$ = BSFFF applied as soil amendment at 10g/3kg of soil; $BSFFF_{15}$ = BSFFF applied as a soil amendment at 15g/3kg of soil. $BSFFF_{20}$ = frass applied as a soil amendment at 20g/3kg of soil. NF = No application of frass i.e. Control. NPK = Commercial fertilizer added at recommended rate of 200 kg/ha.

DISCUSSION

Rearing of insects for food and feed is gradually becoming a desirable alternative in the animal breeding industry. Frass, a key byproduct of the insect rearing process, is now known to play vital role in crop production, especially as a valuable organic fertilizer source for sustainable organic crop production. BSFL is reared on a mixture of locally available organic wastes to produce beneficial organic fertilizer (frass). The role of BSFL as an efficient recycler of organic wastes into nutrient-rich organic fertilizer for crop production (Beesigamukama *et al.*, 2021) is well demonstrated in this study. The integration of frass fertiliser into cropping practices has also been shown by previous studies (Alattar *et al.*, 2016; Beesigamukama *et al.*, 2020b; Green and Popa, 2012; Quilliam *et al.*, 2020; Zahn, 2017) to demonstrate the potential for improving soil fertility, crop yield and plant health. The frass fertilizer returns nutrients back into the soil and increases farm productivity through reduced inorganic fertilizer inputs.

The findings in this study show that plant height, number of leaves, and stem girth improved as a result of the addition of BSFL frass. This is contrary to the report by Alattar *et al.* (2016), who observed that the development of plant height and leaves in maize was inhibited by the use of BSFL frass. This was ascribed to the limited porosity of larval wastes, which perhaps resulted in anaerobic conditions. They claim that insufficient oxygen delivery can occur when frass contains a high amount of moisture and is not properly processed thereafter. It is important to reiterate here that the frass used in this study had a moisture content of 11%. This could be the reason for the difference in the outcome of both studies.

In all weeks of assessment, there was no significant difference in the growth parameters under consideration on BSFFF-treated okra plants regardless of the level of application. This observation is in line with the findings of Klammsteiner *et al.* (2020), who reported that the addition of frass did not lead to significant differences in plant growth compared to the mineral fertilizer. This, according to them, could be because the nutrients from frass are readily available for uptake, and it had no detrimental effect on the plant growth.

The number of leaves increased in magnitude from the first WAS to the second WAS, while plant height and stem girth increased from the first to the fifth WAS compared to untreated control and NPK-treated plants. Thereafter, at 6 WAS, the growth parameters all experienced a decline in BSLFFF-treated plants with a corresponding increase in values recorded for untreated control NPK-treated plants. This shows that the different levels of BSFFF treatments compared to the control and NPK at the early stage of growth of okra plants in this study are an indication of a higher level of nutrient availability and supply from the introduced frass fertilizer (Beesigamukama *et al.*, 2020).

In a meta-analysis conducted on 57 articles to identify the way plant disease severity of fungal pathogen-induced infection is modified following fertilization, it was found that in the vast majority of instances, N fertilization increased disease severity (Veresoglou *et al.,* 2014). It was, however, concluded in that study that the potential of some plant species, such as *Solanum* spp., to show reduced disease severity following N fertilization requires further investigation. Evidence of biocontrol potential of BSFL frass was provided by Arabzadeh *et al.* (2023), in which the study carried out revealed the antagonistic activity of BSFL frass against many plant pathogenic fungi, and this was attributed to the presence of *Bacillus valezensis* in the Gainesville diet used for rearing the BSFL. This discovery points to the importance of the inherent microbial characteristics of the feedstock for rearing BSFL on the fungicidal activity of the frass. In this study, the inability of the frass to produce a significant reduction in the incidence and severity of southern blight disease of the okra plant might be related to the microbial characteristics of the frass, which may not contain *Bacillus valezensis*.

Studies on the utilization of black soldier fly-derived materials as soil amendments come with different limitations, which include environmental, methodological, biological, practical, chemical, physical, and data-related constraints. With particular reference to this study, results are specific to the encountered soil types or qualities and may not be generalizable to other soils. Also, the findings may have been influenced by the prevailing climate and weather conditions, which may not be representative of other regions or seasons. The sample size used is limited, and the selection of crops/soil types does not represent the broader agricultural industry. There is no evidence that the experimental design used is adequate enough to account for all potential variables or confounding factors that could influence the results. The composition and quality of the household waste used to feed the black soldier fly may not be representative of other types of waste, and the findings will only be specific to the crop/plant species used in this study and may not be generalizable to other crops. These limitations may impact the study's generalizability and accuracy and highlight areas for future research and improvement.

CONCLUSION

This study shows that the use of BSFFF as an organic soil amendment has the potential to reduce overreliance on mineral fertilizers with the attendant negative effect on the soil structure, improve crop growth and development in a way to helps promote tolerance to disease development. However, it is recommended that the adoption of large-scale and extensive use will require further study into modalities for producing BSFFF with factors that will enhance the development of tolerance to crop diseases and applicability of BSFFF to different cropping systems and agro-ecological zones.

CONFLICT OF INTEREST

The authors declare no competing interests.

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أثير سماد فضلات ذبابة الجندي الأسود على نمو وتطور مرض اللفحة الجنوبية في البامية (ABELMOSCHUS ESCULENTUS (L.) Moench)

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ملخص

أصبحت فضلات يرقات ذبابة الجندي الأسود (BSFL) (Hermetia illucens) تدريجيًا مصدرًا للأسمدة العضوية في أنظمة الزراعة نظرًا لدورها في تحسين نمو المحاصيل وتطورها، بالإضافة إلى كبح نمو مسببات الأمراض الفطرية. قامت هذه الدراسة بتقييم تأثير سماد فضلات ذبابة الجندي الأسود (BSFFF) على نمو نبات البامية (Abelmoschus esculentus) وتطور مرض اللفحة الجنوبية أثناء نموه. تم تطبيق BSFFF بمعدل 10 جم و15 جم و20 جم لكل 3 كجم من التربة المبسترة بالحرارة في أوعية بلاستيكية (سعة 5 لتر وقطر 20 سم في الأعلى وارتفاع 15 سم). لم يعمل أي تطبيق BSFFF كضابط بينما تم تطبيق NPK 20:10:10 بمعدل 30 كجم هكتار−1 ليكون بمثابة اختبار. أظهرت النتائج عدم وجود فرق كبير ($p = 0.05$) في معايير النمو على نباتات البامية المعالجة بـ BSFFF بغض النظر عن مستوى التطبيق. من الأسبوع الثاني إلى الخامس بعد البذر (WAS) ، كانت معايير نمو نباتات البامية المعالجة بـ BSFFF على جميع المستويات مختلفة بشكل كبير ($p = 0.00001$) عن تلك الخاصة بالنباتات غير المعالجة والمعالجة بـ .NPK تراوحت أطوال النباتات في دراستي WAS الأولى والسادسة بين 15.95±0.53 و37.65±2.63 سم على التوالي. من دراستي WAS الثانية إلى الخامسة، كان محيط ساق نباتات البامية المعالجة بـ BSFFF على جميع المستويات أوسع بشكل ملحوظ ($p = 0.00001$) من محيط ساق النباتات غير المعالجة والمعالجة بـ .NPK في دراستيWAS ، كان عدد الأوراق (6.56±0.24) في نباتات البامية المعالجة بـ BSFFF20 أكبر بشكل ملحوظ ($p = 0.0098$) من عدد أوراق نباتات الشاهد (5.20±0.13). ومع ذلك، بدءًا من دراستي WAS الثالثة، كان هناك انخفاض مطرد في عدد أوراق نباتات البامية بغض النظر عن نوع المعالجة، ويرجع ذلك على الأرجح إلى ظهور أعراض المرض. عند WAS4 ، كان عدد أوراق النباتات المعالجة بـ BSFFF20 (5.67 ± 0.33)أكبر بشكل ملحوظ ($p = 0.0003$) من عدد أوراق النباتات غير المعالجة، على الرغم من اعتدال معدل ظهور أعراض المرض على النباتات. تُظهر نتائج هذه الدراسة أن دمج BSFFF في نظام زراعة البامية من شأنه تحسين نمو وتطور نبات البامية، وتعزيز قدرته على مقاومة مرض اللفحة الجنوبية.

الكلمات الدالة: ذبابة الجندي الأسود؛ الفضلات؛ مرض اللفحة الجنوبية؛ البامية؛ المرض.

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