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Effect of black soldier fly digested organic manures on physico-chemical properties and nutrient status of soil in okra (*Abelmoschus esculentus* L.)

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Abstract
This study investigates the effect of black soldier fly digested organic manures on physico-chemical properties and nutrient status of soil in okra (*Abelmoschus esculentus* L.). The field experiment was laid out in factorial randomized block design (FRBD) included nine treatments and two varieties with 18 treatment combinations replicated thrice. The two varieties tested were Parbhani Kranti, Kashi Lalima and the organic manures used for testing were Aerobic decomposed poultry manure (@7.5 ton/acre, @ 5 ton/acre, @ 2.5 ton/acre) Black solider fly digested poultry manure (@ 7.5 ton/acre, @ 5 ton/acre, @ 2.5 ton/acre) FYM@10 ton/acre, Vermicompost @5 ton/acre, RDF (NPK) (48:24:24) and their combinations were investigated.

The application of Black solider fly digested poultry manure @ 7.5 ton/acre registered significantly reduced the pH (8.14), EC was significantly increased (0.57dS/m), decreased Bulk density (1.15g/cc) and increased organic carbon (0.53%).

The application of Black solider fly digested poultry manure @ 7.5 ton/acre significantly increased available Nitrogen (223.36 kg/ha), available phosphorus (64.17 kg/ha) and available Potassium recorded (382.63 kg/ha). Among the varieties Parbhani Kranti was recorded with highest available Nitrogen (188.24 kg/ha), available phosphorus (51.69 kg/ha) and available Potassium (341.81 kg/ha). The interaction effect of Black solider fly digested poultry manure @ 7.5 ton/acre along with Parbhani Kranti was recorded maximum growth in okra and improved the physico-chemical properties and nutrient status of soil like highest available Nitrogen (235.20 kg/ha), available phosphorus (66.22 kg/ha) and available Potassium (381.93 kg/ha).

Keywords: Black soldier fly digested poultry manure, Aerobic decomposed poultry manure, FYM, NPK, pH, EC, Bulk density and organic carbon

Introduction

Okra (*Abelmoschus esculentus* L.) is a popular vegetable which belongs to the Malvaceae family (Maurya *et al*., 2013) [14]. It originated in Africa and expanded throughout the tropics, subtropics and milder temperate regions. India is the world's largest producer of okra, India accounts for around 72.9% of global production.

Okra is a nutritious vegetable that provides vitamins, minerals, 33 calories, and amino acids. It is rich in carbohydrates (7.5 g), protein (1.9 g), vitamin A (23 mg), vitamin C (36 mcg). This versatile vegetable can be used in various ways, including raw or cooked consumption, as animal feed, and for medical and industrial purposes (Farinde *et al*., 2007) [9]. Okra is high in iodine as well as other essential vitamins and minerals. Polysaccharides, such as galacturonic and glucuronic acids, make up the mucilage in Okra fruit (Farinde *et al.*, 2007) [9]. Okra is utilized as a traditional medicine in a few countries as an antiulcerogenic, gastroprotective and diuretic medication (Gurbuz, 2003) [10]. It is also a good source of minerals like calcium and potassium. The application of organic manure helps to ameliorate acidic condition of soils to improve crop production (Akande *et al*., 2004) [4]. The Black Soldier Fly, also known as *Hermetia illucens*, has a unique feature of converting manure and other organic waste into a biomass rich in protein and fat.

The use of BSFL maximizes the reduction of waste leading to the production of insect biomass. Being rich in macronutrients, micronutrients and organic matter, Black Soldier Fly Larva frass (BSFLF) could increase the organic matter content of intensively cultivated soils. BSF organic fertilizer is a new type of bio-organic fertilizer produced by environmental insects to transform livestock and poultry manure. The feces organic fertilizer is rich in organic matter, which is beneficial to microbial populations, and its effect higher than that of poultry and animal manure (Liu *et al*., 2019) [13] studies found that BSF transform pig dung into feces, which meets the standard of organic fertilizer, and using BSF feces can improve the growth quality of cabbage found that the application of BSF frass could increase the yield of tomato (Wu *et al*., 2020) [22].

Materials and Methods
The field study was conducted during the summer season from February to April, 2024 at PG research block, Department of Vegetable Science, College of Horticulture, Mojerla, SKLTGHU. The experiment with nine treatments and the two varieties tested were Parbhani Kranti, Kashi Lalima was laid out in a factorial randomized block design (FRBD) with three replications. Seeds were sown at a spacing of 45 x 30 cm. The field experiment was laid out in factorial randomized block design (FRBD) included nine treatments and two varieties with 18 treatment combinations replicated thrice. The two varieties tested were Parbhani Kranti, Kashi Lalima and the organic manures used for testing were T_1- Aerobic decomposed poultry manure @7.5 ton/acre, T_2 -Aerobic decomposed poultry manure @ 5 ton/acre, T_3 - Aerobic decomposed poultry manure @ 2.5 ton/acre, T_4 - Black solider fly digested poultry manure @ 7.5 ton/acre, T_5 - Black solider fly digested poultry manure @ 5 ton/acre, T_6 - Black solider fly digested poultry manure @ 2.5 ton/acre, T_7 - FYM@10 ton/acre, T_8 - Vermicompost @5 ton/acre, T_9 - RDF (NPK) (48:24:24) and their combinations were investigated.

The soil parameters like soil pH, EC, Bulk density, organic carbon, available Nitrogen, available Phosphorus, available Potassium after harvest was recorded. Soil pH was determined in 1: 2.5 soil water suspension with a glass electrode pH meter, Electrical Conductivity (dS/m) (Jackson, 1973) [11], Bulk Density (g/cc) worked out by Core sampler method, Organic carbon (%) was determined by wet digestion method (Walkley and Black, 1934) [18], Available Nitrogen (kg ha^{-1}) was determined using alkaline potassium permanganate method (Subbaiah and Asija, 1956) [16], Available phosphorus (kg ha^{-1}) was determined by the Olsens method (Olsen *et al*., 1954) [15], Available potassium (kg ha^{-1}) by flame photo meter methods as suggested by Jackson (1973) [11] was used for the interpretation of the results.

Results and Discussion
Soil Analysis
pH (Soil: Water, 1:2.5 ratio)
The lowest soil pH (8.14) was recorded in T_4 with (Black solider fly digested poultry manure @ 7.5 ton/acre) which was decreased than the initial pH of soil (8.6), T_8 (8.16) was at par with T_4. The highest soil pH (8.65) was recorded in T_9 RDF (NPK) (48:24:24). There was no significant difference found among the varieties with respect to soil pH. The interactive effect of organic manures and varieties on soil pH has no significance. The lowest soil pH of 8.14 was recorded in treatment T_4 with Black Soldier Fly digested poultry manure at 7.5 tons per acre. The decrease in soil pH might be due to the acids produced by the microorganisms at the time of organic manure decomposition into the soil, these acids may decrease the soil pH.

Electrical Conductivity (dS/m)
It is revealed from the data that the application of organic manures significantly affected the electrical conductivity of soil. The highest soil EC (0.63 dS/m) was recorded in T_9 with (RDF (NPK) (48:24:24) this might be due to the release of salts into the soil from the inorganic fertilizers. There was no significant difference found among varieties with respect to soil EC. The interactive effect of organic manures and varieties on soil EC has no significance. The increase in EC in treatment T_9 with (RDF (NPK) (48:24:24) may be due to the release of more salts from the high application of an only source of inorganic fertilizers.

Bulk density (g/cc)
The bulk density of soil was significantly decreased by the application of organic manures. The maximum readings of bulk density (1.58 g/cc) was recorded in T_9 with (RDF (NPK) (48:24:24). The lowest readings of bulk density (1.15 g/cc) were recorded in T_4 (Black solider fly digested poultry manure @ 7.5 ton/acre). The pore space increases due to the addition of organic manures so the bulk density decreases. There was no significant difference found in varieties with respect to bulk density. The interactive effect of organic manures and varieties on soil EC has no significance. The results are consistent with previous findings, showing that soils under organic farming systems had lower bulk density compared to those under conventional farming systems. As a result, organic soils had better aeration and, consequently, higher biological activity (Arun, 2004).

Organic Carbon (%)
The organic carbon per cent of soil significantly increased by the application of organic manures. The maximum organic carbon was recorded with treatment T_4 (0.53 per cent) with (Black solider fly digested poultry manure @ 7.5 ton/acre) it was significantly higher than control. It was followed by T_5 (0.47 per cent) with (Black solider fly digested poultry manure @ 5 ton/acre). The minimum organic carbon of soil (0.36 percent) was reported in T_9 RDF (NPK) (48:24:24). There was no significant difference found among varieties concerning soil organic carbon per cent. The interactive effect of organic manures and varieties on organic carbon per cent has no significant effect.

The maximum organic carbon was recorded with treatment T_4 (0.53 per cent) with (Black solider fly digested poultry manure @ 7.5 ton/acre). The results may be due to BSF (Black Soldier Fly) and BSF frass contributing organic matter to the soil. This organic matter can enhance soil structure, which affects how water moves through the soil and improves overall soil aeration. Agustiyani *et al*. (2021) [3]. In the present study, the application of organic manures led to an increase in soil organic carbon content. This significant rise is primarily due to the direct incorporation of organic matter into the soil. Additionally, the addition of organic manures likely stimulated the growth and activity of microorganisms, which further contributed to the higher soil organic carbon levels. The incorporation of organic manures also enhances carbon sequestration in the soil, potentially leading to increased root yields and the addition of substantial organic biomass. These results conform with Agbede and Adekiya (2012) [2] Kumar *et al*. (2017) [12].

Available Nitrogen (Kg/ha)

The maximum available nitrogen in the soil (223.36 kg/ha) was recorded with treatment T_4 (Black solider fly digested poultry manure @ 7.5 ton/acre). It was significantly higher. However, it was followed by treatment T_9 RDF (NPK) (48:24:24) with (212.20 kg/ha). The minimum available nitrogen (155.70kg/ha) was reported in T_3 (Aerobic decomposed poultry manure @2.5 tons/acre). The available nitrogen in varieties was significantly affected by the application of different organic manures. The maximum available nitrogen i.e. (188.24 kg/ha) was observed in Parbhani Kranti when compared with Kashi Lalima.

The interactive effect of organic manures and varieties on the available nitrogen content of soil observed was significant. However, the available nitrogen content was recorded maximum *i.e.* 235.20 kg/ha under T_4V_1 kg/ha, followed by T_9V_1 214.53 Kg/ha while, the minimum available nitrogen content *i.e.* 152.93 kg/ha was observed inT_3V_2 treatment. The results shown are may be due to the significant increase in mineral nitrogen (N). The BSF frass fertilizer had a 2.4 times higher mineral N concentration. Black soldier fly larvae (BSFL) frass consists of excretions, substrate residue, and shed exoskeletons of the larvae. This frass contains 1.68% total nitrogen (N), 8870.19 mg/kg ammonium, and 5453.20 mg/kg nitrate. These high nutrient levels support plant growth, making BSFL frass an effective organic fertilizer. BSF feces (feces after BSF transforms chicken manure), its component content is as follows: organic matter content is 64.00%, total nitrogen content is 2.66%, total phosphorus (P_2O_5) Content is 5.03%, total potassium (K_2O) content is 3.80% which enhances the crop growth and improves the crop productivity. The similar results have been reported by (Visvini *et al.* 2022) [17] and Beesigamukama *et al*. (2020) [5].

Available Phosphorus (Kg/ha)

The data on available phosphorus (kg/ha) of soil increased significantly by the application of organic manures than the initial range. The maximum available phosphorus (kg/ha) of soil 64.17 kg/ha was recorded with T_4 (Black solider fly digested poultry manure @ 7.5 ton/acre) it was significantly higher over 58.34 kg/ha from T_9 RDF. The minimum available phosphorus of soil 35.39 kg/ha was reported in T_3 (Aerobic decomposed poultry manure @ 2.5ton/acre). The available phosphorus of soil on varieties was significantly affected by the application of different organic manures. The maximum available phosphorus i.e. (51.69 kg/ha) was observed in Parbhani Kranti when compared with Kashi Lalima. The interactive effect of organic manures and varieties on available phosphorus content of soil observed significant. The available phosphorus was recorded maximum *i.e.* (66.22 kg/ha) under T_4V_1 followed by T_4V_2 (66.12 Kg/ha). While, the minimum available phosphorus content i.e. (31.99 kg/ha) was observed inT_3V_2 treatment.

The similar findings were supported by Beesigamukama *et al*. (2020) [5] in maize Using BSF frass fertilizer significantly increased the total phosphorus (P) accumulated. The increased P could be due to Nutrient Enrichment by addition of BSF frass provides phosphorus (P) and potassium (K), which are often deficient in typical soils. The availability of these nutrients supports plant health and productivity. Overall, using BSF frass as organic fertilizers helps improve soil fertility and structure, leading to better plant growth and yield. BSF feces (feces after BSF transforms chicken manure), its component content is as follows: organic matter content 64.00%, total nitrogen content 2.66%, total phosphorus (P_2O_5) Content is 5.03%, total potassium (K_2O) content is 3.80% which enhances the crop growth and improves the crop productivity.

Available Potassium (Kg/ha)

It is reflected from the evaluation of data that available potassium (kg/ha) of soil increased significantly by the application of organic manures than the initial range. The maximum available potassium 382.63kg/ha was recorded with T_4 (Black solider fly digested poultry manure @ 7.5 ton/acre) it was significantly higher 376.16 kg/ha from RDF. The minimum available potassium of soil 293.517 kg/ha was reported in T_3 (Aerobic decomposed poultry manure @ 2.5ton/acre). The available potassium of soil on varieties was significantly affected by the application of different organic manures. The maximum available potassium i.e. (341.81 kg/ha) was observed in Parbhani Kranti when compared with Kashi Lalima. The interactive effect of organic manures and varieties on available potassium content of soil observed significant. The available potassium was recorded maximum i.e. (381.93 kg/ha) under T_4V_1 followed by T_4V_2 (381.93 Kg/ha). While, the minimum available potassium content *i.e.* (291.70 kg/ha) was observed in the T_3V_2 treatment. These findings are in conformity with those of Adekiya *et al.* (2020) [1]. Poultry manure increased N, P, K, Ca and Mg compared with other manures. This was because poultry manure was low in C: N ratio, lignin and lignin/N and high in N, P, K, Ca and Mg compared with other manures. Due to the high quality of this amendment, it decomposes quickly and releases nutrients to the soil. The significant increase in soil nutrients especially OM, N, P and K in organic amendments compared with NPK fertilizer was due to leaching in NPK fertilizers.

Table 1: Physico-chemical analysis of the soil before sowing:

Sr. No.	Particular	Value observed
1	pH	8.6
2	EC (ds/m)	0.62
3	Bulk density (g/cc)	1.46
4	Organic carbon (%)	0.42
5	Available nitrogen (kg/ha)	150.9
6	Available phosphorus (kg/ha)	42.85
7	Available potassium (kg/ha)	328.2

Table 2: Physico-chemical analysis of the soil after harvest:

Treatments	Soil pH	EC (ds/m)	Bulk density (g/cc)	Organic carbon (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
Organic manure							
T_1- Aerobic decomposed poultry manure @7.5 ton/acre	8.24	0.52	1.36	0.45	199.66	55.26	352.30
T_2 -Aerobic decomposed poultry manure @ 5 ton/acre	8.44	0.54	1.34	0.43	183.76	44.62	334.13
T_3 - Aerobic decomposed poultry manure @ 2.5 ton/acre	8.54	0.54	1.48	0.43	155.70	35.39	293.51
T_4 - Black solider fly digested poultry manure @ 7.5 ton/acre	8.14	0.57	1.15	0.53	223.36	64.17	382.63
T_5 - Black solider fly digested poultry manure @ 5 ton/acre	8.32	0.56	1.28	0.47	191.53	55.26	352.30
T_6 - Black solider fly digested poultry manure @ 2.5 ton/acre	8.53	0.54	1.44	0.43	159.00	44.52	324.10
T_7 - FYM@10 ton/acre	8.25	0.53	1.42	0.43	163.80	41.68	318.40
T_8 - Vermicompost @5 ton/acre	8.16	0.53	1.47	0.42	172.66	42.74	322.73
T_9 - RDF (NPK) (48:24:24)	8.65	0.63	1.58	0.36	212.20	58.34	376.16
SE(m)	0.009	0.02	0.02	0.01	0.28	0.33	0.25
CD (5%)	0.02	0.06	0.05	0.04	0.82	0.96	0.72
Varieties							
Parbhani Kranti (Green)	8.36	0.56	1.40	0.45	188.24	51.69	341.81
Kashi Lalima (Purple)	8.37	0.54	1.39	0.43	181.02	46.53	337.35
SE(m)	0.004	0.01	0.01	0.007	0.13	0.15	0.11
CD (5%)	N/S	N/s	N/s	N/s	0.38	0.45	0.34
Interactions							
T_1V_1	8.24	0.55	1.37	0.453	202.60	58.51	355.66
T_1V_2	8.24	0.50	1.36	0.45	196.73	52.02	348.93
T_2V_1	8.43	0.57	1.35	0.44	185.93	47.53	335.40
T_2V_2	8.44	0.51	1.33	0.42	181.60	41.70	332.86
T_3V_1	8.54	0.55	1.49	0.45	158.46	38.78	295.33
T_3V_2	8.54	0.53	1.47	0.41	152.93	31.99	291.70
T_4V_1	8.14	0.56	1.17	0.53	235.20	66.22	383.33
T_4V_2	8.14	0.59	1.14	0.54	211.53	62.12	381.93
T_5V_1	8.32	0.57	1.28	0.48	193.26	58.51	355.66
T_5V_2	8.33	0.56	1.28	0.47	189.80	52.02	348.93
T_6V_1	8.54	0.57	1.45	0.45	161.86	46.66	326.80
T_6V_2	8.53	0.52	1.44	0.42	156.13	42.38	321.40
T_7V_1	8.26	0.53	1.41	0.43	166.66	43.72	318.40
T_7V_2	8.25	0.54	1.44	0.42	160.93	39.64	318.40
T_8V_1	8.16	0.54	1.47	0.45	175.66	44.68	325.40
T_8V_2	8.15	0.53	1.47	0.40	169.66	40.80	320.06
T_9V_1	8.63	0.63	1.59	0.37	214.53	60.61	380.33
T_9V_2	8.67	0.63	1.56	0.36	209.86	56.08	372.00
SE(m)	0.01	0.03	0.02	0.02	0.40	0.47	0.35
CD (5%)	N/s	N/s	N/s	N/s	1.16	1.36	1.02

N/s- Non significant

Conclusions

The application of Black solider fly digested poultry manure @ 7.5 ton/acre (T_4) registered significantly reduced the pH (8.14), EC was significantly increased (0.57 dS/m), decreased Bulk density (1.15 g/cc) and increased organic carbon (0.53%). However the varieties and the interaction effect of treatment were found to be non-significant for pH, EC, Bulk density and organic carbon. The application of Black solider fly digested poultry manure @ 7.5 ton/acre (T_4) significantly increased available Nitrogen (223.36 kg/ha), available phosphorus (64.17 kg/ha), maximum available Potassium was recorded (382.63 kg/ha). The interaction effect of Black solider fly digested poultry manure @ 7.5 ton/acre along with Parbhani Kranti (T_4V_1) recorded the highest available Nitrogen (235.20 kg/ha), highest available phosphorus (66.22 kg/ha), highest available Potassium (381.93 kg/ha).

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