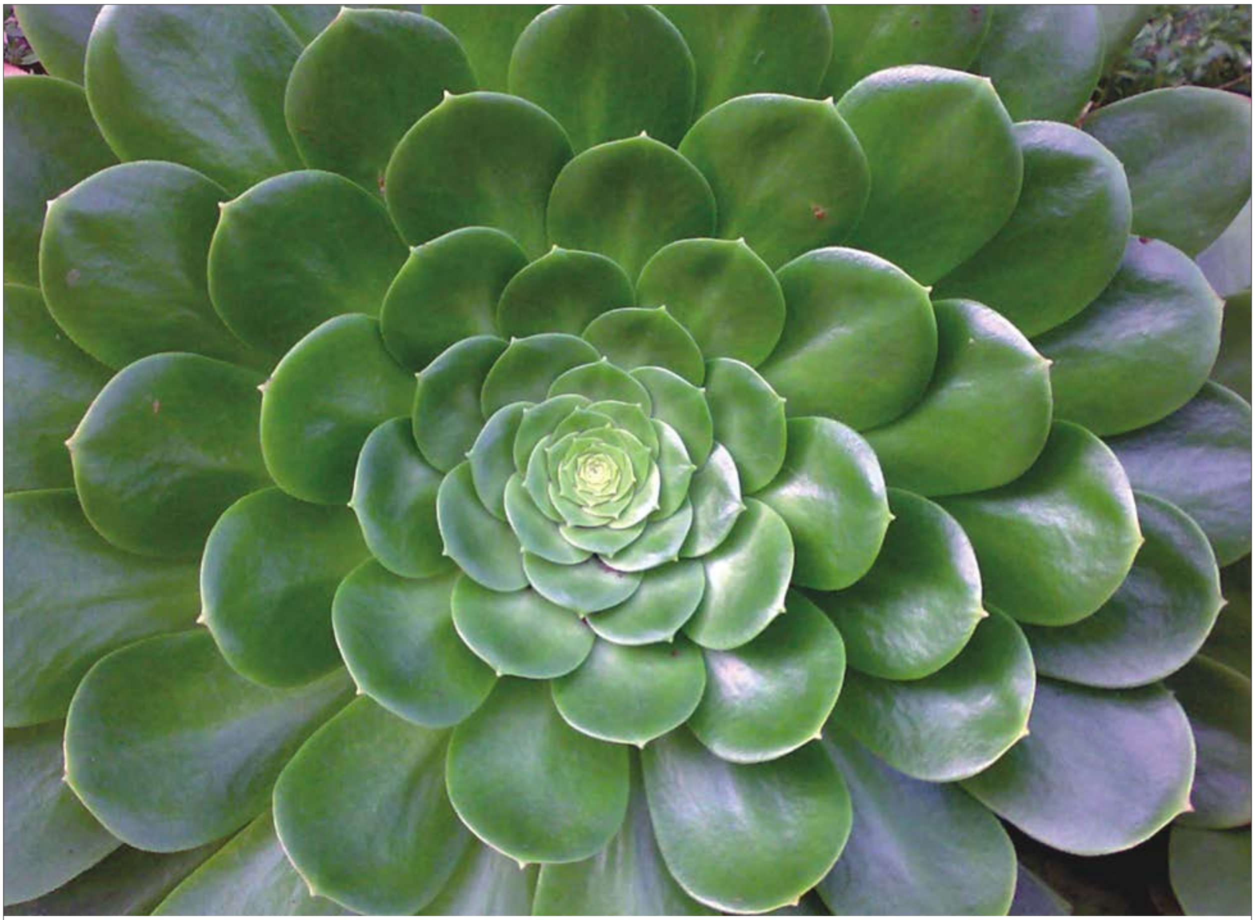

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Research Article

Organic and Mineral Fertilization-Induced Yield and Seed Quality of Okra (*Abelmoschus esculentus* L.)

[1]Sumona Akhter, [2]A.K.M. Ruhul Amin and [2]Abdul Awal Chowdhury Masud

[1]Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh
[2]Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh

Abstract

Background and Objective: Fertilizers provide nutrients to plants that are required for proper crop growth and development. This experiment has been conducted to understand whether the use of organic fertilizers can substantially reduce the use of chemical fertilizers. This study aimed to explore the effect of organic manures (cow dung, compost, vermicompost) and different doses of chemical fertilizers on the yield and seed quality of okra. **Materials and Methods:** A pot experiment was conducted at the net house of the Agronomy Department of Sher-e-Bangla Agricultural University with two factors (organic: 03, inorganic: 04 levels). Cowdung, compost and vermicompost were combined with recommended doses of inorganic fertilizers at different levels. The entire experiment was performed in completely random design (CRD) with three replications. **Results:** Results revealed that both organic and inorganic fertilizers alone or in combination modified the yield and seed quality of okra. Plant growth and yield parameters i.e., plant height, branches number, pod length, pod diameter and green pod yield significantly increased due to the application of organic manure where vermicompost resulted in the best performances. Similarly, the application of inorganic fertilizers at recommended doses showed an increased number and content of the mentioned parameters. However, in combination, vermicompost+25% less of the recommended dose of fertilizer (RDF) resulted in the highest plant and seed quality attributes. **Conclusion:** Hence, it can be concluded that vermicompost application significantly reduced the ¼ amount use of inorganic fertilizers and improved okra yield through cost minimization.

Key words: Organic farming, eco-sustainability, organic amendments, chemical fertilization, soil productivity, vermicompost, plant nutrition

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Corresponding Author: Abdul Awal Chowdhury Masud, Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh

Competing Interest: The authors have declared that no competing interest exists.

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

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is a very popular vegetable all over the world which is commonly known as Lady's finger, Dherosh or Bhindi in different locality of the world[1]. Although it is originated from Africa, in Bangladesh it is considered as one of the most important summer vegetable crops due to its' nature of cultivation under rainfed or irrigated conditions in a wide range of soils[2]. This crop plays an important role in the human diet by supplying carbohydrates, proteins, fats, minerals and vitamins[3]. Tendergreen pods of okra contain approximately protein 17.16%, carbohydrates 60.90%, fat 2.07%, energy 93.32% and also contain important elements such as zinc 51 ppm, iron 371 ppm and calcium 107 ppm[4].

The continued deterioration of land and water resources around the world, as well as diminishing yields due to indiscriminate use of agrochemicals, pose a danger to traditional agriculture's long-term viability. Okra yields are low for a variety of reasons, including a lack of quality seeds of high yielding types at the right time, fertilizer management, disease and insect infestation, inappropriate or inadequate irrigation infrastructure and other necessary agronomic techniques[5].

Inorganic chemical fertilizers pose environmental hazards, such as high prevalence of pests and diseases. As a result, it is considered as necessary to limit the usage of inorganic fertilizers by implementing an appropriate integrated nutrient management system (INMS) that includes farmyard manure (FYM), composts, vermicompost, cow dung and so on. It is worth noting that the use of organic manures not only resulted in the highest and most sustainable crop production but also enhanced soil fertility and productivity[6]. Although organic manures contain fewer plant nutrients than fertilizers, growth-promoting elements such as enzymes and hormones, in addition to plant nutrition, make them effective for increasing soil fertility and production. Manure nutrients are released more slowly and held in the soil for a longer period, resulting in longer residual effects, increased root development and higher crop yields[7]. In recent years, the use of vermicompost in integrated nutrient management (INM) systems in vegetable crops have been promoted.

Aside from mineral fertilization, the use of organic fertilizers has been deemed critical for vegetable production. The idea is to employ this input at the highest yielding doses while supplementing with mineral fertilizers to lower production expenses[8]. A variety of studies on the beneficial effects of organic fertilizers on plant development and yield have been carried out. Organic matter makes soil nutrients easily available for the plant. As a result, it is regarded as the most important and effective component in organic plant nutrition, favouring unconditional plant growth and development[9]. Organic farming approaches can reduce the negative effects of bioavailable heavy metals, as well as the environmental risk of using chemical fertilizers excessively. Organic fertilizers are environmentally friendly and promote a diversified population of beneficial soil microbes by improving soil health, water-holding capacity, high cation exchange capacity and low bulk density[10,11].

Cowdung, compost and vermicompost are well-known among organic fertilizers for their positive properties as a soil supplement. As vermicompost is a low-cost organic amendment made by combining the synergistic effects of earthworms and microorganisms in a bio-oxidation process of organic substrates[12]. Vermicompost improves soil bulk density, water holding capacity, pH and electrical conductivity better than standard compost or raw material[13]. Akhter *et al.*[14] found the highest yield of okra from the combined effect of vermicompost and netting which was 56.74% higher compared to the control treatment combination. Furthermore, using vermicompost as organic amendments greatly reduces heavy metal toxicity from land and it also produces hormone-like compounds, which are credited with accelerating plant growth and resulting in shorter production cycles[10,11].

Due to the overuse of artificial fertilizers, soil fertility is rapidly deteriorating. Thus, combining organic and inorganic fertilizers can assist to enhance yields during hot, sunny seasons of the year. Furthermore, by applying inorganic fertilizers in the field, it may be possible to lower the demand for inorganic fertilizers while improving soil quality. Although various experiments have been undertaken to determine the influence of organic fertilizers on okra yield characteristics. However, a few studies investigated the combined role of organic and inorganic fertilizers on okra productivity and seed quality. Taking this into consideration, the current experiment was designed to assess the interaction of organic and inorganic fertilizer on green vegetables, seed yield and seed quality of okra.

MATERIALS AND METHODS

Experimental site and design: The study was conducted at the net house of the Agronomy Department at Sher-e-Bangla Agricultural University from April-July, 2019. Pots were arranged following a Complete Randomized Design (CRD) with three replications. Factor A: Organic manures (03), M_1 (cowdung, 10 t ha^{-1}), M_2 (ACI compost, 8 t ha^{-1}), M_3 (vermicompost, 5 t ha^{-1}). Factor B: Chemical fertilizer (04 levels), F_0 (no fertilizer, negative control), F_1 (recommended dose of fertilizer, 60-90-60 t ha^{-1}), F_2 (25% less of RDF), F_3 (50% less of RDF).

Crop husbandry: Empty plastic garden pots (specification, 14, 12 and 16 inch diameter on top, bottom and height accordingly) were frequently washed and sundried for 2 days before filling with sundried soil. Organic manure and inorganic fertilizers were incorporated with the soil as per treatment for initial plant growth. Each pot was filled with 20 kg of prepared soil and was ready for seed sowing. After 15 days of pot preparation, four okra seeds were sown in each pot having a depth of 2-3 cm maintaining uniform distance and later were thinned to two seedlings after the germination. Weeding was conducted manually at 15 days after sowing (DAS) and 35 DAS to reduce weed competition. Plant morphological data were started to observe from 20 DAS onwards.

Harvesting, processing and data collection: Harvesting was carried out after two months of sowing by hand-picking of the fresh pods. Out of 2 plants in each pot, all the vegetative data and green pods (vegetable) were collected from one plant and the rest was kept for seed collection. The first harvest of green pods was collected at 65 DAS. Later on, the fruits were picked manually at 10 days intervals when they were green tender and at the marketable size. The picked pods were weighed and subjected to other observations immediately after each picking. Mature pods from the rest of one plant were collected. Later on, seeds were separated from the pods and dried, counted and weighted accordingly. Dried seeds from each treatment were used for seed quality analysis. The following parameters were taken for further analysis.

Statistical analysis: Data accumulated from different parameters were subjected to Analysis of Variance (ANOVA) using the Software Statistics 10. Mean separation was done by Fisher's LSD at a 5% level of significance (Statistix, 2013).

RESULTS

Plant height (cm): Plant height was observed at three intervals after seed sowings, i.e., 20, 40 and 60 DAS. Table 1 showed that organic sources of nutrients increased plant height at 20, 40 and 60 DAS. A significant increase of plant height at 20, 40 and 60 DAS were observed with vermicompost application that is 19.14, 82.28 and 105.79 cm, accordingly. It is also evident from the table that fertilization treatments had a significant effect on the plant height, as the treatment F_2 observed with the highest plant height 17.76, 69.98 and 98.17 cm at 20, 40 and 60 DAS accordingly compared to the F_0 treatment. As for the interaction, it was significant, as the M_3F_2 (vermicompost+25% less of RDF) treatment gave the highest plant height at all three intervals (Table 2).

Number of branches/plant: Organic sources significantly affect the branches number in okra (Table 1). However, the highest number of branches (4.34) was observed with the application of vermicompost followed by 4.02 at ACI compost. Effect of inorganic fertilizers showed significant variation in case of branches number of plants of okra. The result depicts that the highest branches number per plant (4.19) was found at F_1 which is 37% higher than the F_0 (control). The interaction effect of organic and inorganic fertilizers was also found significant in increasing the branches number in the plant (Table 2). The table showed that the highest number of

Table 1: Effect of organic manures and different levels of inorganic fertilizer on plant height (20, 40 and 60 DAS) and branches number per plant

	Plant height (cm)			
Treatments	20 DAS	40 DAS	60 DAS	Number of branches per plant
Organic manures				
M_1	15.24	65.69	90.73	3.77
M_2	16.57	67.33	88.81	4.02
M_3	19.14	82.28	105.79	4.34
LSD (0.05)	0.61	1.42	2.16	0.18
CV (%)	1.27	2.96	4.49	0.37
Fertilizer levels				
F_0	15.51	74.54	90.72	3.83
F_1	18.07	76.92	103.92	4.19
F_2	17.76	69.98	98.17	4.13
F_3	16.59	74.54	87.64	4.01
LSD (0.05)	0.71	1.64	2.50	0.20
CV (%)	1.47	3.41	5.18	0.43

Mean±SD was calculated from three replications for each treatment applying Fisher's LSD test at $p \leq 0.05$ level of significance, M_1: Cowdung, M_2: ACI compost, M_3: Vermicompost, F_0: No fertilizers (control), F_1: Recommended dose of fertilizer (RDF), F_2: 25% less of RDF, F_3: 50% less

Table 2: Interaction effect of organic and inorganic fertilizers on plant height (20, 40 and 60 DAS) and branches number per plant

Treatment combinations	Plant height (cm) 20 DAS	40 DAS	60 DAS	Number of branches per plant
M_1F_0	14.50	61.47	85.58	3.68
M_1F_1	16.29	68.74	102.75	4.00
M_1F_2	15.21	67.27	88.25	3.75
M_1F_3	14.96	65.30	86.33	3.66
M_2F_0	13.50	57.68	80.75	3.58
M_2F_1	18.54	73.33	98.08	4.25
M_2F_2	17.79	72.18	90.33	4.16
M_2F_3	16.46	66.15	86.08	4.08
M_3F_0	18.54	77.76	105.83	4.25
M_3F_1	14.50	81.54	110.92	4.33
M_3F_2	16.29	91.33	115.92	4.50
M_3F_3	15.21	78.49	90.50	4.30
LSD (0.05)	1.23	2.85	4.33	0.36
CV (%)	2.55	5.92	8.98	0.74

Mean±SD was calculated from three replications for each treatment applying Fisher's LSD test at $p\leq 0.05$ level of significance, M_1: Cowdung, M_2: ACI compost, M_3: Vermicompost, F_0: No fertilizers (control), F_1: Recommended dose of fertilizer (RDF), F_2: 25% less of RDF, F_3: 50% less

Table 3: Effect of organic and inorganic fertilizers on yield contributing parameters of okra

Treatments	Pod diameter (cm)	Pod length (cm)	Green pod/ plant (No.)	Green pod yield/ plant (kg)	Seeds pod^{-1} (No.)	100 seed weight (g)	Seed yield/ plant (g)	Seed yield (t ha^{-1})	Shelling (%)
Organic manures									
M_1	3.96	12.59	5.45	0.46	53.99	5.42	5.98	2.98	21.41
M_2	4.05	12.97	6.31	0.45	61.12	5.17	8.18	5.65	31.24
M_3	4.41	14.34	8.00	0.64	67.90	6.98	16.46	7.76	49.87
LSD (0.05)	0.14	0.58	0.48	0.01	1.42	0.61	0.58	0.33	1.31
CV (%)	0.30	1.21	1.00	0.02	2.96	1.26	1.21	0.70	2.72
Fertilizer levels									
F_0	3.99	12.80	4.83	0.47	55.07	4.92	7.58	3.87	20.46
F_1	4.25	13.64	7.19	0.57	64.32	6.59	11.86	6.75	39.63
F_2	4.23	13.56	8.16	0.57	64.06	6.86	11.22	5.80	42.74
F_3	4.09	13.30	6.16	0.45	60.58	5.07	10.18	5.44	33.87
LSD (0.05)	0.16	0.67	0.55	0.01	1.64	0.70	0.67	0.39	1.51
CV (%)	0.35	1.39	1.15	0.03	3.41	1.46	1.40	0.81	3.14

Mean±SD was calculated from three replications for each treatment applying Fisher's LSD test at $p\leq 0.05$ level of significance, M_1: Cowdung, M_2: ACI compost, M_3: Vermicompost, F_0: No fertilizers (control), F_1: Recommended dose of fertilizer (RDF), F_2: 25% less of RDF, F_3: 50% less

branches per plant (4.50) was observed at the M_3F_2 treatment combination whereas the lowest (3.58) was observed at the M_2F_0 combination.

Pod diameter (cm): Pod diameter was highly influenced by the application of different types of organic manures. Although the pod diameter was increased with the application of an increased rate of organic fertilizers, Table 3 showed that among cow dung, ACI compost and vermicompost the application of vermicompost resulted in the highest pod diameter (4.41 cm). On the contrary, maximum pod diameter (4.25 cm) was observed at F_1 while the minimum (3.99 cm) was observed at F_0 treatment (Table 3). In interaction effect, both organic and inorganic treatments bear significant effect on pod diameter of okra. Interaction effect of organic and inorganic fertilizers resulted that at M_3F_2 combination the highest pod diameter (4.57 cm) was observed while at M_2F_0 treatment combination lowest pod diameter (3.78 cm) was found (Fig. 1a).

Pod length (cm): Organic manures highly affect the pod length of okra. In this experiment, maximum pod length (14.34 cm) was observed with the application of vermicompost. Whereas, the minimum pod length (12.59 cm) was observed with the application of cow dung (Table 3). Pod length of okra was also influenced by different doses of inorganic fertilizers. The highest pod length was observed at the F_1 treatment, which is 13.64 cm (Table 3). Organic manures along with inorganic fertilizers showed a significant role in increasing the pod length of the okra (Fig. 1b). The

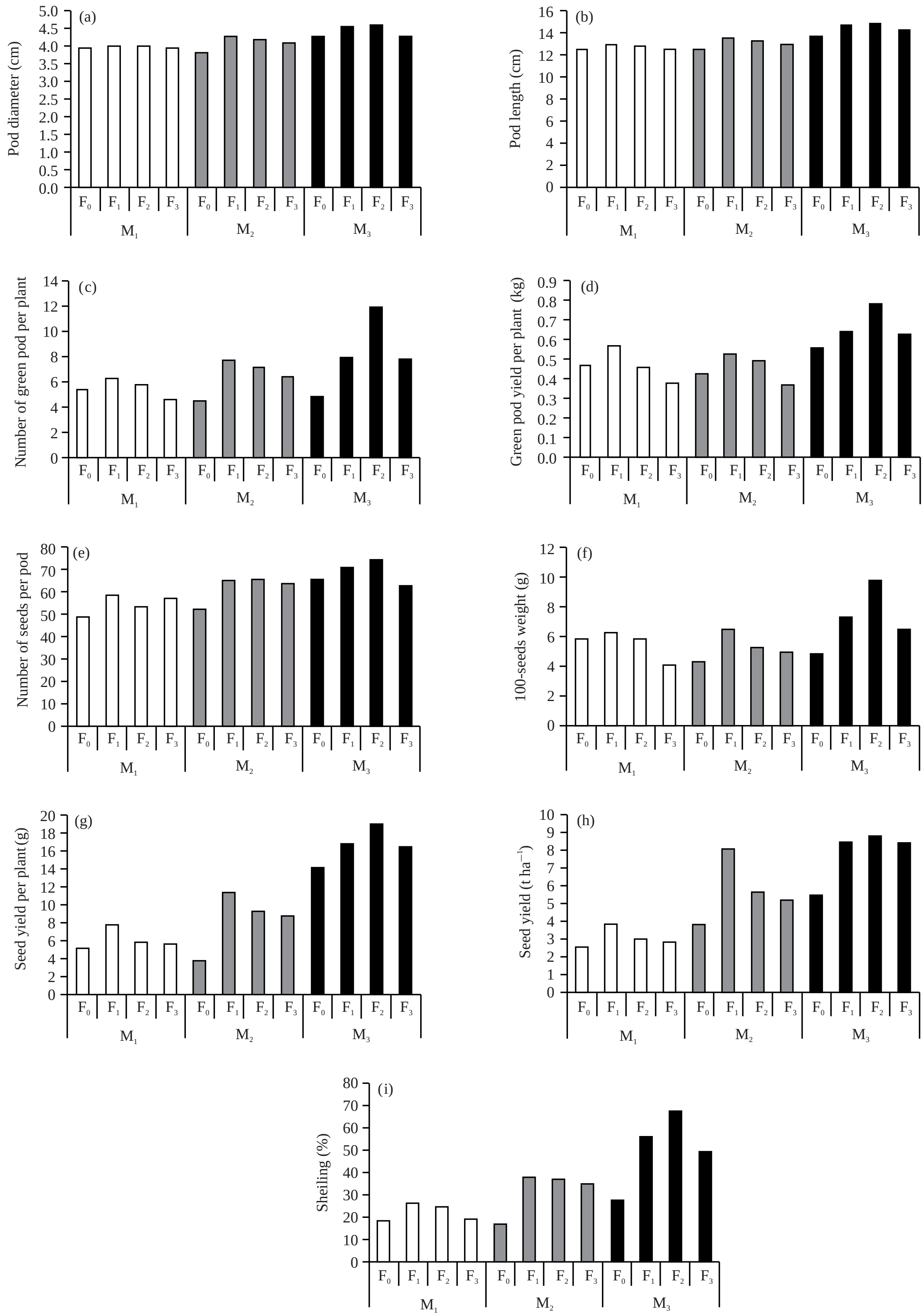

Fig. 1(a-i): Interaction effect of organic manures and inorganic fertilizer on yield contributing characters of okra (a-i)
Mean±SD was calculated from three replications for each treatment applying Fisher's LSD test at $p \leq 0.05$ level of significance, M_1, Cowdung, M_2: ACI compost, M_3: Vermicompost, F_0: No fertilizers (control), F_1: Recommended dose of fertilizer (RDF), F_2: 25% less of RDF, F_3: 50% less

highest pod length (14.88 cm) was found at vermicompost in combination with 25% fertilizers less than the recommended doses.

Number of green pod per plant: Organic sources had a significant effect on the green pod number in the plant. Cowdung, ACI compost and vermicompost variedly affect the green pod number of okra/plant. However, the highest number of green pod/plant (8.00) was observed with the application of vermicompost. Whereas the lowest number of green pod/plant (5.45) was observed with cow dung treatment. Furthermore, the number of green pods/plant was observed to be increased significantly with the application of inorganic fertilizers. There observed the highest green pod (8.16) due to the application of fertilizers at 25% less of RDF (Table 3). In combination of both the organic sources of nutrients and inorganic fertilizers showed significant role in increasing the green pod number of okra/plant (Fig. 1c). The highest green pod (11.75) was found at the M_3F_2 combination while the lowest was observed (4.41) at M_2F_0.

Green pod yield/plant (kg): Green pod yield/plant was influenced significantly by the application of different organic manures. The highest yield (0.64 kg) was recorded with the application of vermicompost whereas the lowest result (0.45 kg) was found with applying ACI compost. However, the application of cow dung and ACI compost showed a statistically similar result. Application of inorganic fertilizers at different levels significantly increased the green pod yield/plant. Here F_1 and F_2 resulted in significantly higher green pod yield (0.57 kg)/plant, which is 24% higher than the control (Table 3). The interactive effect between different organic manures and inorganic fertilizers was found to be significant in respect to green pod yield/plant. The application of vermicompost×25% less of RDF (M_3F_2) recorded the maximum pod yield (0.77 kg)/plant (Fig. 1d).

Number of seeds/pod: Seeds/pod are significantly influenced by the application of different types of organic manures. Among cow dung, ACI compost and vermicompost, the application of vermicompost showed the best performances in terms of seed pod^{-1} (67.90). On the contrary, the maximum seeds pod^{-1} (64.32) was observed at RDF while the minimum (55.07) was observed at F_0 (Table 3). The combination of both organic and inorganic fertilizer treatments bears a significant effect on seeds pod^{-1} of okra. Interaction effect of organic and inorganic fertilizers resulted that at M_3F_2 combination gave the highest seed pod^{-1} (74.01) while at M_1F_0 treatment combination lowest seed pod^{-1} (48.13) was found (Fig. 1e).

100-seed weight (g): Hundred seed weight exerted a significant effect due to the application of different types of organic materials. In the experiment, among cow dung, ACI compost and vermicompost, the application of vermicompost showed the best performances in terms of 100 seed weight (6.98 g). Although the 100 seed weight was increased with the application of inorganic fertilizers, there were no significant differences between the treatments at RDF (F_1) and 25% less of RDF (F_2). The maximum 100 seed weight (6.86 g) was observed at 25% less of RDF while the minimum (4.92 g) was observed at control (Table 3). Interaction effect of organic and inorganic fertilizers bears significant effect on 100 seed weight of okra plant which has been presented in Fig. 1f. Moreover, Results revealed that vermicompost interaction with 25% less RDF produced the highest 100 seed weight. Therefore, the M_3F_2 combination showed the highest 100 seed weight (9.59 g) whereas at M_1F_3 treatment combination gave the lowest 100 seed weight (4.06 g, Fig. 1f).

Seed yield/plant (g): Organic manures exerted a significant effect on the seed yield of okra. Different organic manure affects the seed yield by influencing the nutrient uptake ability. Among the three different organic manure, in our findings, vermicompost showed the best performance over the cow dung and ACI compost. The highest result (16.46 g) was observed while vermicompost was used where the minimum result was observed due to cow dung (5.98 g) application. Moreover, inorganic fertilizers at different levels showed significant seed yield variation in okra. The highest was found at F_1 (11.86 g) which is 57% higher than the control (Table 3). The interaction effect of organic manure and chemical fertilizer's effect has been presented in Fig. 1g. The figure indicates that the combination of M_3F_2 (vermicompost× 25% less of RDF) resulted in the best seed yield/plant (18.87 g). On the contrary, the minimum seed yield (3.72 g) was found at the M_2F_0 treatment combination.

Seed yield (t ha^{-1}): Seed yield was influenced by different organic manures. Here, vermicompost showed the best performance over the cow dung and ACI compost. The highest result (7.76 t ha^{-1}) was observed while vermicompost was used. However, Inorganic fertilizers at different levels showed significant yield variation in okra. The highest seed yield (6.75 t ha^{-1}) was found at RDF where the lowest

Table 4: Seed qualities of okra as influenced by different organic manures and levels of inorganic fertilizers

Treatments	Germination (%)	Root-shoot ratio	FW of seedling (g)	DW of seedling (g)
Organic manures				
M_1	85	0.71	0.16	0.03
M_2	86	0.78	0.18	0.03
M_3	85	0.90	0.25	0.04
LSD (0.05)	0.01	0.02	0.01	NS
CV (%)	0.02	0.04	0.02	NS
Fertilizer levels				
F_0	83	0.70	0.15	0.02
F_1	89	0.87	0.21	0.03
F_2	87	0.87	0.24	0.04
F_3	81	0.75	0.18	0.03
LSD (0.05)	0.01	0.02	0.01	NS
CV (%)	0.02	0.04	0.02	NS

Mean±SD was calculated from three replications for each treatment applying Fisher's LSD test at $p \leq 0.05$ level of significance, M_1: Cowdung, M_2: ACI compost, M_3: Vermicompost, F_0: No fertilizers (control), F_1: Recommended dose of fertilizer (RDF), F_2: 25% less of RDF, F_3: 50% less

Table 5: Interaction effect of organic and inorganic fertilizers on seed quality parameters of okra

Treatment combinations	Germination (%)	Root-shoot ratio	Fresh weight of seedlings^{-1} (g)	Dry weight of seedlings^{-1} (g)
M_1F_0	84	0.59	0.13	0.02
M_1F_1	92	0.84	0.16	0.03
M_1F_2	85	0.74	0.20	0.03
M_1F_3	78	0.69	0.16	0.03
M_2F_0	85	0.65	0.13	0.02
M_2F_1	91	0.87	0.20	0.04
M_2F_2	85	0.85	0.23	0.03
M_2F_3	84	0.75	0.16	0.03
M_3F_0	81	0.85	0.20	0.03
M_3F_1	85	0.90	0.27	0.04
M_3F_2	91	1.02	0.30	0.05
M_3F_3	81	0.82	0.23	0.04
LSD (0.05)	0.02	0.03	0.02	NS
CV (%)	0.03	0.08	0.04	NS

Mean±SD was calculated from three replications for each treatment applying Fisher's LSD test at $p \leq 0.05$ level of significance, M_1: Cowdung, M_2: ACI compost, M_3: Vermicompost, F_0: No fertilizers (control), F_1: Recommended dose of fertilizer (RDF), F_2: 25% less of RDF, F_3: 50% less

(3.87 t ha^{-1}) was observed when no fertilizer was used (Table 3). The interaction effect of organic manure and different level of inorganic fertilizer signifies that vermicompost×25% less of RDF resulted in the highest seed yield (8.82 t ha^{-1}). On the contrary, the minimum seed yield (2.50 t ha^{-1}) was found at the M_1F_0 treatment combination (Fig. 1h).

Shelling (%): Shelling % was highly influenced by the application of different types of organic materials. In the experiment, among three organic manures, vermicompost showed the best performances in terms of shelling % (49.87%). The shelling % of okra is influenced by different doses of inorganic fertilizers. Different doses of chemical fertilizer helped to increase the shelling % of okra. The highest shelling % was observed with 25% less RDF, which is 42.74% (Table 3). In combination of both organic manures and inorganic fertilizers showed a significant role in increasing the shelling % of okra (Fig. 1i). The highest shelling % (67.23%) was found at vermicompost in combination with 25% fertilizers less than the recommended doses.

Seed germination (%): Application of different organic manure exerted non-significant variation on seed germination (Table 4). The highest (86%) germination was resulted due to the application of ACI compost whereas the lowest (85%) was due to both cowdung and vermicompost. Different doses of inorganic fertilizers affect the germination percentage of okra. The highest germination (89%) was found at RDF and the lowest (81%) was at F_3 treatment (Table 4). The interaction effect of organic manure and inorganic fertilizers showed statistically similar results in all the combinations. However, the higher germination resulted from the combination of M_1F_1, followed by M_2F_1 and M_3F_2 which was 92, 91 and 91%, accordingly. The lowest germination (78%) in the treatment combination was at M_1F_3 (Table 5).

Root-shoot ratio: Cowdung, ACI compost and vermicompost had a significant effect on the root-shoot ration of the seedlings of okra. Due to vermicompost application, the highest root-shoot ratio was (0.90) found whereas the lowest (0.71) was found while cow dung was applied. Inorganic fertilizers similarly affect the root-shoot ratio of the okra seedlings. The highest ratio (0.87) was found at F_1 and F_2 and the lowest at F_0 (0.70, Table 4). In combination, a significant difference was observed in the root-shoot ratio of okra. The interaction effect showed that the best (1.02) performance was found at the M_3F_2 treatment combination (Table 5).

FW and DW of seedlings^{-1} (g): Plant biomass both dry weight and fresh weight were highly influenced due to the application of organic and inorganic fertilizers. Organic manures effect on fresh weight content of okra. Results showed that maximum FW was in vermicompost (0.25 g) and the minimum (0.16 g) at cow dung application. On the other hand, there was no significant difference among the treatments mean of dry weight content in okra due to the application of different organic manures (Table 4). Inorganic fertilizers at different doses showed a significant variation in plant dry and fresh weight content. The maximum fresh and dry weight was found at 0.24 g and 0.04 g both at F_2 treatment (Table 4). The interaction effects showed that the highest FW and DW content (0.30, 0.05 g) were recorded at the M_3F_2 treatment combination, respectively (Table 5).

DISCUSSION

For sustainable agriculture, the use of organic manure will be an unavoidable practice in the future because organic manures generally improve soil physical, chemical and biological qualities[15]. Soil physical properties largely depend on the status of soil organic matter which is the complex interaction between the number of mineral fertilizers and manures applied to soil[16]. Organic manures play a diverse role in soil amendments. Many of the physicochemical and biological properties of soil are influenced by organic supplementation, among which reduced soil bulk density, cation exchange capacity (CEC) and increased water infiltration rate, improved micronutrient absorption and enhanced biological activities are of great importance[17]. Moreover, the organic manure slowly releases nutrients thus acting as a reservoir for plant macronutrients. Organic materials with a high C:N ratio and lignin content would normally promote nutrient immobilization, organic matter accumulation and humus formation[18].

In this study, increased growth parameters of okra in terms of plant height and branch number due to application of organic manure, more emphasis on M_3, can be attributed to the nutrient composition of the organic manure used. The maximum increase of plant height (19.14, 82.28 and 105.97 cm) by vermicompost application was observed in all three intervals of plant heights viz. 20, 40 and 60 DAS, respectively. Essential nutrient contents are rich in vermicompost which can be released gradually and slowly for plant absorption and utilization. Coulibaly *et al.*[19] reported that the application of vermicompost resulted in the tallest okra plant along with the highest leaves per plant in two cultivars of okra. Haque *et al.*[20] also found increased plant height and leaves number due to the application of organic manures due to their capability to release a higher amount of organic nitrogen, phosphorus and potassium. These are the essential nutrient for the initial plant growth which are readily available to soil due to organic-microbial interactions. The highest branches number (4.34) in our study was observed with vermicompost application which could be associated with the increased leaf numbers too. The number of leaves and leaves were also increased in *Amaranthus cruentus* due to the application of organic soil amendments, earlier reported by Shiyam and Binang[21]. Pod length, pod diameter and green pod number were significantly increased due to the application of organic matter in this study which can be ascribed by the proper supply of nutrients from organic sources and thus resulted in the higher development of plant culminating in good yield. Upon good decomposition, organic matters reserve nutrient for a long period which releases throughout the plant life cycle and thus plant get proper nourishment during its' developmental stage that leads to higher yield[17].

Seed yield contributing parameters of okra were highly influenced by the application of organic manures shown in Table 3. Seeds pod^{-1}, 100-seed weight and seed yield result showed that among cow dung, compost and vermicompost, vermicompost application was superior over the rest of other organic manures. This result corroborates the earlier findings of Gupta *et al.*[22] in okra and Sarker and Kashem[23] in cabbage.

Seed germination is a vital regulatory part of plant establishment and a crucial event in the life of a seed. The successful emergence of seed embryos with essential structures is the prerequisite for the normal and healthy plant establishment[19]. In this study seed germination and other seed quality parameters were studied under organic and inorganic fertilization practice (Table 4). Results revealed that due to the application of organic manure there were no significant differences except 2% higher germination due to the application of vermicompost. This higher germination due to vermicompost application might be attributed due to higher water retention during germination. Seed viability and its maintenance are highly regulated by water during germination. The moist and humid condition created due to the application of organic manure vermicompost favours in breaking seed dormancy thus water enter inside the seed by osmosis process and triggers germination process. A similar increase rate of germination was observed by Alam *et al.*[24] while the soil was treated with trichocompost and vermicompost compared to control.

Moreover, the application of mineral fertilizers alone or in combination improved all agronomic traits in this experiment. Tables 2, 5 and Fig. 1 represent all the combination effects where vermicompost along with 25% lest of RDF showed the maximum results. This could have happened due to a significantly higher amount of NPK availability in the soil where organic manure vermicompost tremendously helped in the mineralization process through association with soil microbial activities. When equivalent amounts of vermicompost and farmyard manure were treated in conjunction with chemical fertilizers, the concentrations of N, P and K in okra were much greater in the case of vermicompost[22,25]. Higher yield in terms of pod and seed were also previously explored by other researchers in okra with vermicompost and chemical fertilizers combination[26,27]. The okra yield was higher due to the effect of inorganic fertilizers that can rapidly mobilize nutrients to soil solution and vermicompost retained soil properties for plant growth for a long time[19]. Earlier findings showed that yield and seed quality of okra were higher while vermicompost+25% less RDF was used compared to NPK fertilizers used alone by Srinivas and Swaroop[28]. This yield difference can be coupled with the variation in nutrients in the soil medium.

CONCLUSION

Integrated use of organic manures viz., cow dung, compost and vermicompost along with chemical fertilizers significantly increased the yield and growth parameters of okra over the sole use of chemical fertilizers. However, substantial improvement was recorded in the case of the plots receiving either vermicompost in combination with chemical fertilizers than the plots which had received chemical fertilizers alone. It can be concluded from the study that vermicompost @ 10 t ha^{-1} in combination with 25% less RDF is the best suitable option for getting maximum production of okra and maintaining better seed quality in this subtropical climatic and soil condition.

SIGNIFICANCE STATEMENT

This study discovers the essential aspect of organic amendments among which vermicompost showed the ameliorative results in enhancing yield and seed quality of okra. The combined effect of organic and inorganic amendments can significantly reduce the inorganic fertilizers pressure on cropland. In addition, the use of organic matter could be a great way of minimizing the cost of production for the farmer. In addition, this study will help the researchers to further investigate the mechanism underlying the crop-plant and crop-microbial nutrient metabolism assisted through organic supplements. Thus a potential array will be established in future crop production which will simultaneously ensure eco-sustainability.

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