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Influence of enriched organic manure, biostimulants and bio-mulches on organic okra (*Abelmoschus esculentus*)

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ABSTRACT

Field experiments were conducted to identify the best source of nutrients and bio-mulch for fruit yield, quality and soil properties of organic okra (Abelmoschus esculentus) at U B K V, Pundibari, West Bengal, India during February-May 2017-18. The experiment was laid out in Factorial RBD comprising of two factors, viz. organic nutrient sources (N) and bio-mulches (M) having four levels each. The findings of the experiment suggested that basal application of *Azophos* biofertilizer enriched vermicompost (5 t/ha) along with foliar spray of seaweed extract (2 ml/l) at 30, 40 and 50 days of sowing (N_4) emerged as best treatment in terms of highest number of fruits (19.94/plant) and maximum yield (14.39 t/ha). Among the different bio-mulches, the vegetable legume plant residue mulch (M_4) recorded highest number of fruits (20.79/plant), total fruit yield (14.79 t/ha), maximum ascorbic acid content (18.47 mg/100 g) and increased total chlorophyll content (46.99 mg/100 g). The interaction of N_4M_4 recorded highest number of fruit (22.88/plant), fruit yield (348.08 gm/plant), total yield (16.68 t/ha) and the maximum total fruit chlorophyll content (51.60 mg/100 g). All the interaction of organic nutrient sources and bio-mulches showed increase in available N, P, K and organic carbon content in post harvest soil over the initial status. The study concluded that adoption of biofertilizer enriched vermicompost in combination with 3 times foliar spray of seaweed extract in standing crop with legume as mulch have significant positive impact on fruit yield, quality and soil properties of organic okra.

Key words: Bio-mulches, Enriched farmyard manure, Organic okra, Vermicompost

Okra (*Abelmoschus esculentus*) is one of the important warm-season fruit vegetables grown throughout the tropics and warmer parts of the temperate zone. It grows well in areas where day temperature remains 25-40°C and that of night are over 22°C. Tender pods of okra are used as delicious vegetable. Fresh pod contains around 88% water, 0.1% fat, 8% carbohydrate, 1.8% protein and 0.9% fibre (Agbo *et al*. 2008). The fruit is an excellent source of minerals like calcium, potassium and iodine which helps in control of goiter (Yawalkar 1965). Okra requires heavy manuring for its potential production (Naik and Shrinivas 1992). Indiscriminate use of chemical fertilizers affects the plant growth, yield and quality of fresh fruits. Organic nutrient sources help to maintain the fertility of the soil, avoids depletion of soil organic matter and plant nutrients besides suppression of some insect-pests and diseases (Gaur 2001). Therefore, the application of plant nutrients through organic sources like compost, farmyard manure and biofertilizers remain the alternative choice of the growers for maintaining its sustainable production (Dart 1986 and Gaur 1990).

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Sole use of traditional farmyard manure may not be sufficient for producing reasonable yield of organic okra. Therefore, use of enriched organic manure along with bio-stimulants like humic acid and seaweed extract may be considered as a strategy of modern production practices. Humic acid, the major constituent of humic substance enhances lateral root growth, induces abiotic stress tolerance and promote plant physiology and mechanism (Adani *et al.* 1998, Trevisan *et al.* 2010, Aydin *et al.* 2012). Seaweed extract is the fresh extract obtained from brown algae (*Ascophyllum nodosum*) which increases plant nutrient uptake capacity, disease resistance and plant hormonal activities (Crouch 1990, Khan *et al.* 2009, Zodape *et al*. 2011). Advantages of mulching are well known. In organic production an alternative to the use of plastic mulch is organic mulch. Organic mulch systems are recyclable in the soil, reduce production cost and benefit the environment, improve soil quality and stimulate soil microbial communities due to the addition of organic matter (Lalande *et al*. 1998, Oslen and Gounder 2001). Keeping in view, an attempt was made to evaluate the effect of different enriched organic manures with biostimulants and bio-mulches on yield, quality and soil properties of okra.

MATERIALS AND METHODS

Field experiments were conducted during February-May

of 2017 and 2018 at Instructional Farm of UBKV, Pundibari, Cooch Behar, West Bengal, India (26°19′ N latitude and 89°23′ E longitude at an elevation of 43 m amsl). Climatic conditions were ideal for cultivation of okra during summer months. The initial available N, available P, available K content and organic carbon content were 84 kg/ha, 19.82 kg/ha, 123.99 kg/ha and 0.73% respectively. There were four levels of nutrient sources (N) namely N_1–Farmyard manure (25 t/ha) + *Azophos* biofertiliser + Humic Acid; N_2 –Farmyard manure (25 t/ha) + *Azophos* biofertiliser + Seaweed extract; N_3–Vermicompost (5 t/ha) + *Azophos* biofertiliser + Humic acid; N_4 - Vermicompost (5 t/ha) + *Azophos* biofertiliser +Seaweed extract as well as four levels of bio-mulches (M) namely M_1 - Rice straw; M_2- Dry water hyacinth (*Eichhornia crassipes* Mart. Solms); M_3- Dry local weed (*Polygonum persicaria* L.); M_4- Dry vegetable legume plant residues. Thus 16 treatment combinations were laid out in factorial randomized block design and replicated thrice. Okra seeds (cv. Arka Anamika) were sown on 28th of February in both the year 2017 and 2018 at the seed rate of 20 kg/ha with spacing 45cm × 45 cm. To prepare enriched organic manure, the *Azophos* biofertiliser (*Azotobacter* + Phosphate Solubilizing Bacteria) was mixed with vermicompost and farmyard manure and kept for 15 days before field application. The biostiulants, humic acid and seaweed extract (*Ascophyllum nodosum* L.) were sprayed on standing crop at 30, 40 and 50 days after sowing at the rate of 2 ml/l (Kumari *et al*. 2011). Mulching (10 t/ha) was done just after thinning of seedlings. All the standard cultural practices were followed during the crop growth. Harvesting of the pods was done after 6 days of anthesis and was continued up to 7th picking depending upon marketable stage. Random samples were collected from each plot at the time of 3rd picking for quality estimation like ascorbic acid content and total chlorophyll content. Ascorbic acid content of fruit was determined by the procedure given by Ranganna (1986) and total chlorophyll content of fruit was determined by the procedure given by Witham *et al*. (1971). Yield/ plant, yield/plot and total yield were estimated with standard practices. Available nitrogen 'N' (kg/ha) was determined by Kjeldhal method developed by Subbiah and Asija (1956), for estimation of available phosphorus P (kg/ ha) spectrophotometric method by Bray and Kurtz (1945), for available potassium K (kg/ha) Flame photometric method by Jackson (1967) and for Available organic carbon (%) wet oxidation method by Walkley and Black (1934) were followed. The cost of cultivation was calculated as per the present market rates. Farmyard manure, vermicompost and biofertilisers were purchased from University farm centre at the rate of ₹ 1.00/ kg, ₹ 5.00/kg and ₹ 100.00/500g respectively. The cost of humic acid was ₹ 318.00/500 ml, seaweed extract was ₹ 107.00/100 ml. Collection and application cost of mulch materials were ₹10000.00/ha for rice straw and ₹ 5000.00/ha for dry local weed, water hyacinth and legume plant residue mulch. Two years data collected on various parameters were pooled and statistically analyzed using INDOSTAT statistical package (version 7.00, Hyderabad, India).

RESULTS AND DISCUSSION

Fruit yield: A perusal of pooled data on fruit yield parameters okra (Table 1) depicted that among the different organic nutrient sources, the maximum number of fruits/ plant (19.94) was observed in the treatment where *Azophos* biofertiliser enriched vermicompost (5 t/ha) was applied as basal along with three times of foliar spray of seaweed extract (N_4) in standing crop followed by the nutrient source N_3. The vegetable legume plant residue mulch (M_4) recorded the highest number of fruits per plant (20.79) whereas the lowest was observed by local weed mulch (M_3). The interaction effect of (N_4M_4) recorded the highest number of fruits (22.80 per plant), yield per plant (348.08 g) and subsequently recorded highest total yield (16.65 t/ ha). Lowest yield was obtained by N_3M_3. Earlier similar type of result was observed by Zodape *et al*. (2008) where number of fruit was increased with application of liquid seaweed extract.

The findings indicated that combined application of vermicompost with biofertiliser along with foliar spraying of seaweed extract have pronounced effect on yield per plant as well as total yield per ha. This might be resulted due to the organic matter present in the vermicompost which improved the soil physical, chemical and biological properties and when combined with the biofertiliser, it attributed the solubilization, mineralization of reserved nutrient in soil and made it available to plant for better growth and development. The foliar application seaweed extract might have act as a plant and soil conditioner by increasing the nutrient uptake capacity, inducing plant metabolism and plant physiological activities (Fan *et al.* 2013).

Quality of fruits: The pooled data (Table 1) indicated that among the different organic nutrient sources, *Azophos* biofertiliser enriched farmyard manure along with three times foliar application of seaweed extract (N_2) showed increased level of ascorbic acid content (19.03 mg/100 g) in fruit followed by the treatment N_4. Again among the different mulch materials, the vegetable legume plant residue (M_4) showed greater amount of ascorbic acid content and the minimum amount was recorded by M_3. The interaction of N_2M_4 resulted in higher ascorbic acid content (20.90 mg/100 g) compared to other treatments. The results clearly indicated that organic manure particularly farmyard manure have favorable effect on ascorbic acid content of okra pod compared to vermicompost as organic manure. Increase in ascorbic acid content might be possible due to addition of *Azophos* biofertiliser and also seaweed extract could be attributed to the stimulatory effect of easily available plant nutrient which might have enhanced the synthesis of its precursor.

The fruit chlorophyll content (45.82 mg/100 g) was found maximum when *Azophos* biofertiliser enriched vermicompost (5 t/ha) along with seaweed extract (N_4) was applied. Among the different type of organic mulches, the vegetable legume plant residue mulch (M_4) recorded

Table 1 Effect of enriched organic manures and bio-mulches on yield, quality and post harvest soil properties of okra

Treatment*	No. of fruits/ plant	Yield/ plant (g)	Total yield (t/ha)	Ascorbic acid content of fruit (mg/100g)	Total chlorophyll content of fruit (mg/100g)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)	Organic carbon (%)
Nutrient Sources (N)									
N_1	17.99	302.70	13.30	16.08	37.68	103.04	26.76	158.71	0.89
N_2	19.10	318.21	13.90	19.03	42.07	110.09	22.53	161.97	0.93
N_3	17.53	284.62	12.92	16.53	36.61	101.27	29.02	169.89	1.08
N_4	19.94	322.15	14.39	17.86	45.82	112.68	25.32	154.85	1.00
CD (P=0.05)	0.498	3.826	1.644	0.522	1.225	4.741	4.125	11.330	N.S
Bio-mulches (M)									
M_1	18.12	306.96	13.59	17.31	39.84	105.20	23.33	158.52	0.99
M_2	18.99	304.21	13.82	18.12	41.00	108.99	25.78	173.75	1.04
M_3	16.68	291.66	12.30	15.60	34.35	98.91	23.28	154.28	0.95
M_4	20.79	324.86	14.79	18.47	46.99	113.94	31.24	158.88	0.91
CD (P=0.05)	0.498	3.826	1.644	0.522	1.225	4.741	4.125	11.330	N.S
Interaction effect									
N_1M_1	16.73	302.76	13.35	16.19	36.40	102.10	24.95	150.72	0.86
N_1M_2	18.20	293.94	13.84	16.26	38.17	104.37	26.32	174.56	0.92
N_1M_3	17.22	295.20	12.17	14.95	31.53	96.42	22.55	153.26	0.87
N_1M_4	19.84	318.90	13.82	16.92	44.63	109.21	33.20	156.29	0.89
N_2M_1	18.91	315.44	13.76	18.63	42.32	108.10	21.31	143.90	0.85
N_2M_2	20.27	319.07	13.80	19.56	43.03	111.30	20.43	185.47	0.99
N_2M_3	16.55	305.80	12.18	17.05	35.71	103.28	21.54	155.94	0.97
N_2M_4	20.68	332.52	15.83	20.90	47.24	117.67	26.83	162.58	0.92
N_3M_1	17.80	286.10	13.27	15.76	35.88	101.40	25.09	194.99	1.29
N_3M_2	17.10	286.07	13.42	18.13	36.46	104.17	28.22	169.93	1.11
N_3M_3	15.48	266.39	12.11	15.42	29.58	93.19	26.49	159.20	0.94
N_3M_4	19.75	299.92	12.86	16.81	44.50	106.35	36.28	155.45	0.96
N_4M_1	19.04	323.55	13.95	18.67	44.78	109.30	21.95	144.46	0.97
N_4M_2	20.39	317.75	14.22	18.54	46.34	116.13	28.16	165.04	1.13
N_4M_3	17.48	299.23	12.73	14.98	40.59	102.76	22.54	148.71	1.03
N_4M_4	22.88	348.08	16.65	19.26	51.60	122.54	28.63	161.18	0.86
CD (P=0.05)	0.996	7.652	3.288	1.044	3.464	9.428	8.251	22.661	0.170

*Treatment details are in materials and methods.

maximum chlorophyll content of fruit (46.99 mg/100 g). The interaction of N_4M_4 exerted higher chlorophyll content (51.60 mg/100 g) compared to other treatments.

Post-harvest soil properties: The data containing post harvest soil properties for the second year has been presented in the Table 1. The nutrient source containing *Azophos* biofertiliser enriched vermicompost (5 t/ha) as basal along with three times of foliar spray of seaweed extract (N_4) had a significant effect on available soil nitrogen content and recorded the highest available soil nitrogen content (112.68 kg/ha) followed by the nutrient source N_2. Application of vegetable legume plant residue mulch (M_4) also had significant effect and showed maximum value on available nitrogen content. The interaction of N_4M_4 showed that highest amount of nitrogen in the rhizosphere soil which was followed by the treatment combination N_2M_4.

The phosphorous content of the soil was found maximum when *Azophos* biofertiliser enriched vermicompost (5 t/ha) along with three times foliar spray humic acid (N_3) was applied. Again vegetable legume plant residue mulch (M_4) significantly increased the phosphorous content in soil. The interaction of N_3M_4 further increased the phosphorous content of the soil followed by the treatment N_1M_4. The result further showed that the maximum available potassium content was recorded for the treatment N_3. Among the bio-mulches, application of dry water hyacinth (M_2) was found to be the effective mulching material for enriching the potassium status (168.39 kg/ha) of the soil. Application of biofertiliser enriched vermicompost along with foliar spray of humic acid combined with rice straw as mulch material

Table 2 Effect of different nutrient sources and biomulches on economics of okra cultivation

Treatment*	Fruit yield (t/ha)	Gross return (₹)	Treatment cost (₹)			Net return (₹)	Benefit: cost ratio
			Fixed cost	Variable cost	Total cost		
N_1M_1	13.35	173550	33170	37908	71078	102472	1.44
N_1M_2	13.84	179920	33170	32908	66078	113842	1.72
N_1M_3	12.17	158210	33170	32908	66078	92132	1.39
N_1M_4	13.82	179660	33170	32908	66078	113582	1.72
N_2M_1	13.76	178880	33170	39210	72380	106500	1.47
N_2M_2	13.80	179400	33170	34210	67380	112020	1.66
N_2M_3	12.18	158340	33170	34210	67380	90960	1.35
N_2M_4	15.83	205790	33170	34210	67380	138410	2.05
N_3M_1	13.27	172510	33170	37908	71078	101432	1.43
N_3M_2	13.42	174460	33170	32908	66078	108382	1.64
N_3M_3	12.11	157430	33170	32908	66078	91352	1.38
N_3M_4	12.86	167180	33170	32908	66078	101102	1.53
N_4M_1	13.95	181350	33170	39210	72380	108970	1.51
N_4M_2	14.22	184860	33170	34210	67380	117480	1.74
N_4M_3	12.73	165490	33170	34210	67380	98110	1.46
N_4M_4	16.65	216450	33170	34210	67380	149070	2.21

*Treatment details are in materials and methods, sale price of okra: ₹ 13.00.

(N_3M_1) interactively increased the potassium content of the soil compared to other treatment. The individual treatments showed no significant effect on the organic carbon content of the soil, but in all the cases the organic carbon percentage was increased than the initial value. The buildup in organic carbon content in soil than the initial content (0.79%) might be due to slow releasing nature of organic manures like farmyard manure and vermicompost. When biofertiliser was inoculated with this manure it enhanced the soil physiochemical properties by increasing microbial activity of soil. Again application of bio-mulches reduced the leaching loss of available nutrients and maintained the favorable soil environment. In long run decomposition of these substrates will further increase the organic carbon content of the soil.

Economics: Economics of okra production was estimated and has been presented in Table 2. The interaction of N_4M_4 exhibited highest net return of ₹ 149070.00 with B:C ratio 2.21. It was followed by N_2M_4 with net return of ₹ 138410.00. Lowest net return ₹ 91352.00 was obtained by the treatment combination N_3M_3.

Traditional organic okra cultivation suffers from slow release of nutrients and consequently resulted in low fruit yield. The findings of the present experiment showed that enriched organic manure with bioferiliser along with foliar application of biostimulants hold promising to enhance the productivity of organic okra. The study established that basal application of *Azophos* biofertiliser (*Azotobacter* + Phosphate Solubilizing Bacteria) enriched vermicompost (5 t/ha) along with three foliar spray (at 30 DAS, 40 DAS and 50 DAS) of seaweed extract (2 ml/l) in combination with vegetable legume plant residue as bio-mulch (10 t/ha) was the most productive nutrient combination with respect to fruit yield, quality and soil properties of organic okra.

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