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Influence of Organic Manure and Bioagents on Growth, Yield and Quality of Okra under Assam Condition

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Authors' contributions

This work was carried out in collaboration between both authors. Author MK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SG managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

A field trial was conducted to assess the effect of organic inputs and bioagents on growth, yield, and quality of okra. Thirteen treatments in the experiment were laid out in Randomized Block Design with three replications. The results revealed that the yield parameters were best in conjoint application of organic and inorganic fertilizer whereas the physical and quality parameters showed a maximum in integrated application of organic amendments and bioagents. On the basis of the findings it may be concluded that FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter resulted the highest B: C ratio (2.66) and can be recommended as substitute for the inorganic combination of FYM @ 10 t/ha + 50:50:50 kg NPK/ha for higher quality yield with remunerative return.

Keywords: Okra; organic amendments; yield; B: C ratio.

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1. INTRODUCTION

Okra [*Abelmoschus esculentus*(L.) Moench] is an important warm season vegetable crop grown commercially in the tropics and sub-tropics. In India, okra covers 509 thousand hectares area with a production of 6095 thousand metric ton [1]. India is the largest producer in the world and has tremendous scope for export because of its year-round availability in the country. It is a good source of antioxidants, fiber, carbohydrate, proteins, fats, minerals and vitamins thus plays a vital role in the human diet and health [2]. Okra plant needs to be fertilized with balanced nutrients for high-quality yield and profitability [3]. So it is necessary to add such nutrient inputs either in organic or inorganic form to the soils in order to have good sustainable crop production. Injudicious use of chemical fertilizers in agriculture gives rise to environmental pollution and depletion of soil, health hazards and reduced nutrient retention efficiency hence adversely affect crop growth and yield. Microorganisms meant for different purposes are now been widely used in organic agriculture which can substitute synthetic fertilizers or pesticides. The utilization of microorganisms in agriculture has the potential to provide nutrients and induce resistance against biotic and abiotic stress [4,5]. One key role of microorganisms is recycling of nutrients in the ecosystems by aiding in the fixation of atmospheric nitrogen as well as carbon fixation and oxygen production. The beneficial microorganisms used in agriculture *viz*., Azospirillum, Azotobacter, Trichoderma, Rhizobium, Enterobacter, Erwinia, Flavobacter, Beijerinckia and Bacillus are found in the rhizosphere of plants which helps in growth and development of the crops [6]. Organic farming by using organic amendments is a holistic approach and production management system that helps in improving the agro-ecosystem and human health [7,8]. Therefore supply of plant nutrients through organic sources like compost, FYM and bio-fertilizers, bio-inoculants remain the alternative choice of growers for maintaining sustainable production of the crop. It is a flexible approach to minimize the use of chemical fertilizers, and maximize the efficiency of organic inputs, so as to provide good soil health and enhanced profit to farmers. Keeping in view the above facts, the present investigation was undertaken to evaluate the effects of organic supplements on okra growth, yield and nutrient status of the soil.

2. MATERIALS AND METHODS

Organic inputs and bio-inoculants are eco-friendly and can be used as bio-pesticides which do not have any residual effect on crop harvest. Regular inoculation of organic manure and bio-agent improves soil quality, sustain yield and return. For vegetable crop production there is a need of immediate attention in natural and environment-friendly alternatives to chemical fertilizers. Therefore an attempt has been made to evaluate the benefits and effects of organic amendments at Horticulture Experimental Farm of Assam Agricultural University, Jorhat, during kharif season of 2018 and 2019. Okra variety Arka Anamika seeds were sown in plots of 4.0 m x 3.2 m size at 50 cm x 40 cm spacing. The soil was sandy loam with initial pH 5.57, organic carbon 0.54%, N 263.45 kg/ha, P_2O_5 24.38 kg/ha and K_2O 98.90 kg/ha. The seed was sown at a spacing of 60 cm x 45 cm after treating with microbial consortium @200g/kg of seed and soil application @ 5kg/ha fifteen days before sowing. Available N, P and K in soil were estimated using standard procedures [9]. Observations were recorded from twenty numbers of randomly selected plants from each plot. Two years data have been pooled and statistically analyzed at 5 per cent of significance by F test [10]. All the treatments as follow were arranged in Randomized Block Design with three replications.

Number	Treatment
T_1	FYM @ 20 t/ha
T_2	Vermicompost @ 5 t/ha
T_3	Neem cake @ 2 t/ha
T_4	FYM @ 10 t/ha + VC @ 2.5 t/ha
T_5	FYM @ 10 t/ha + NC @ 1 t/ha
T_6	FYM @ 10 t/ha + PM @ 2.5 t/ha
T_7	VC @ 2.5 t/ha + NC @ 1 t/ha
T_8	VC @ 5 t/ha + VAM + Pseudomonas+ Trichoderma + Azotobacter
T_9	NC @ 2 t/ha + VAM + Pseudomonas +Trichoderma + Azotobacter
T_{10}	FYM @ 20 t/ha + VAM + Pseudomonas+Trichoderma+Azotoba cter
T_{11}	Recommended NPK (50:50:50 kg NPK/ha)
T_{12}	Untreated control
T_{13}	FYM @ 10 t/ha + 50:50:50 kg NPK/ha

VC: Vermicompost NC: Neem cake PM: Poultry manure

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

The results (Table 1) revealed that maximum plant height was recorded (122.73cm) in T_2 (vermicompost @5t/ha), followed by 121.33 cm in **T_4** (FYM @ 10 t/ha + Vermicompost @ 2.5 t/ha) which were statistically at par with all other treatments except untreated control treatment (T_{12}) which recorded the minimum plant height (63.17 cm). Vermicompost enhances soil biodiversity by promoting various microbial populations with some additional substances such as humic acid (17-36%), fluvic acid (13-30%) that is not found in chemical fertilizers [11,12]. This predominance of microorganisms in organic sources increases the nutrient availability in soil, creates a favorable condition for proper vegetative growth which result increased in plant height.

3.2 Days to Harvest

Days to harvest (Table 1) was obtained minimum in (T_9) Neem cake @ 2 t/ha + VAM + Pseudomonas + Trichoderrma + Azotobacter (47.89) followed by 48.67cm in (**T_3**) Neem cake @ 2 t/ha. Neem cake is a totally natural product compatible with soil microbes and rhizosphere microflora which enhances fertility of the soil. Vesicular arbuscular fungi can effectively increase mobilization of phosphate uptake from deeper layer of soil to the plant thus enhances early flowering and fruiting [13]. The combined application of bio-inoculants and organic inputs might have resulted in pronounced nitrogen and phosphorus uptake which helped in the development of reproductive parts, stimulated early fruiting and harvesting.

3.3 Fruits per Plant

The highest number of pods per plant (22.38) was found in FYM @ 10 t/ha + 50:50:50 kg NPK/ha (T_{13}) and was statistically different from all other treatments except FYM @ 20 t/ha + VAM +Pseudomonas + Trichoderma + Azotobacter (T_{10}). While less number of pods per plant (13.56) was observed in the untreated control (T_{12}) due to its poor nutritional status (Table 1). The nutrient use efficiency of crops is better with a combined application of organic manure and inorganic fertilizers [14]. It can be also recommended that bio-inoculant applications like pseudomonas and trichoderma species can reinvigorate plant growth and improves yield in vegetable crops [15]. The increase in number of fruits per plant might be due to better availability and uptake of nutrients by plants with combination of organic and inorganic fertilizers which enhances nutrient uptake by the plants. The availability of nutrients helps the plant to bear more number of flowers and reduces the chances of flower drop as a consequence of increased fruit load per plant.

3.4 Fruit Weight (g)

FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter (T_{10}) recorded the maximum fruit weight (12.29 g) closely followed by 12.25g with FYM @ 10 t/ha + Vermicompost @ 2.5 t/ha (T_4), Vermicompost @ 5 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter (T_8), FYM @ 10 t/ha + Poultry manure @ 2.5 t/ha (T_6) as against the lowest of 11.06 g in untreated control (T_{12})(Table1). This finding might be due to the significant increase in the chlorophyll content in the leaves with the application of the organic amendments. The partitioning of photosynthates to the growing pods having more demand for assimilates lead to higher fruit weight. It has also been reported that the application of organic amendments enhances plant resistance to fight against insect pests and diseases besides higher concentration of available nutrients [16].

3.5 Fruit Length

The application of FYM @ 10 t/ha + 50:50:50 kg NPK/ha (T_{13}) resulted in (Table1) the maximum fruit length (11.08 cm), followed by FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter (T_{10}) which, however, was at par with all other treatments. The lowest fruit length (9.71cm) was recorded by Neem cake @ 2 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter (T_9). Dissolving of N present in inorganic fertilizer is very much faster than that in organic manure hence release is fast and easy to the crop compared to organic manures for growth and development. [17] reported that the adequate amount of nutrient supply leads to better physiological performances of the crop resulting increased in fruit length. In contrary, the lowest fruit length (9.01 cm) in control might be due to slow mineralization of the organic manures as was observed by [18,19].

Table 1. Growth, yield and quality parameters of organic farming in Okra

Treatment	**Plant height** (cm)	**Days to harvest**	**Fruits per plant**	**Fruit weight** (g)	**Fruit length** (cm)	**Fruit diameter** (cm)	**Shelf life of fruits** (days)	**Yield per plant** (g)	**Total yield** (q/ha)
T_1 FYM @ 20 t/ha	117.97	48.89	18.77	11.91	10.98	1.97	4.27	223.58	104.03
T_2 Vermicompost @ 5 t/ha	122.73	52.22	18.85	12.08	10.83	1.85	4.13	232.00	112.05
T_3 Neem cake @ 2 t/ha	103.53	48.67	17.15	11.13	9.74	1.72	4.27	191.80	87.85
T_4 FYM @ 10 t/ha + VC @ 2.5 t/ha	121.33	51.67	19.97	12.25	10.52	1.89	4.27	244.75	114.51
T_5 FYM @ 10 t/ha + NC @ 1 t/ha	112.13	51.44	18.27	11.96	10.43	1.95	4.33	219.03	101.9
T_6 FYM @ 10 t/ha + PM @ 2.5 t/ha	118.27	51.33	19.03	12.17	10.62	1.90	4.13	231.37	105.64
T_7 VC @ 2.5 t/ha + NC @ 1 t/ha	103.30	51.56	17.99	11.93	10.58	1.76	4.33	214.76	102.2
T_8 VC @ 5 t/ha + VAM + Pseudomonas+ Trichoderma + Azotobacter	111.47	51.11	19.16	12.22	10.95	1.90	4.27	234.28	109.77
T_9 NC @ 2 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter	114.10	47.89	17.23	11.92	9.71	1.68	4.07	206.21	94.59
T_{10} FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter	115.10	49.22	21.06	12.29	11.03	2.03	4.27	254.71	118.32
T_{11} Recommended NPK (50:50:50 kg NPK/ha)	110.03	51.22	18.03	11.92	9.72	1.80	3.20	214.82	96.23
T_{12} Untreated control	63.17	52.56	13.56	11.06	9.01	1.62	2.93	150.08	66.65
T_{13} FYM @ 10 t/ha + 50:50:50 kg NPK/ha	94.68	49.11	22.38	12.14	11.08	1.99	3.47	271.01	123.89
S.Ed.(±)	20.75	1.01	1.03	0.50	0.48	0.16	0.20	15.54	7.58
CD(5%)	40.87	2.00	2.04	0.98	0.94	0.31	0.41	30.61	14.93

VC: Vermicompost NC: Neem cake PM: Poultry manu

3.6 Fruit Diameter

The results (Table1) showed that maximum fruit diameter (2.03 cm) in FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter (T_{10}) was not significantly higher than other treatments except untreated control (T_{12}) and Neem cake @ 2 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter (T_9). Azotobacter, Pseudomonas and Trichoderma plays an important role in increasing uptake of macro and micronutrients in leaves due to the metabolization and assimilation through roots with the help of microorganisms [20]. Increased rate of photosynthesis and higher metabolic activities, mobilization of soluble nutrients and production of growth promoting substances that have positive effect on the physiological activity of the plants could be attributed to an increase in fruit diameter and fruit weight [21]. Similar findings were reported by Chaitra and Patil [22] in several other crops.

3.7 Fruit Yield

The highest yield per plant (271.01g) (Table1) recorded in FYM @ 10 t/ha + 50:50:50 kg NPK/ha (T_{13}) was not significantly higher than that with FYM @ 20 t/ha fortified with bio-agents (T_{10}) and combined application of FYM @ 10 t/ha + VC @ 2.5 t/ha (T_4). The conjoint application of FYM and NPK has special advantages of production of photosynthates during the growth stages and consequently partitioning and distribution of the dry matter at the developmental stages of okra. Quick mobilisation and availability of nutrients might have resulted in increased yield per plant. This is in conformity with the findings of [14,23] on integration of organic with inorganic fertilizer in okra. Consequently, the highest total fruit yield (123.89 q/ha) was obtained with FYM @ 10 t/ha + 50:50:50 kg NPK/ha (T_{13}), closely followed by FYM @ 20 t/ha + bio-agents (118.32 q/ha) and FYM @ 10 t/ha + VC @ 2.5 t/ha (114.51 q/ha). FYM decomposition increased dissolution of nutrients by forming humic complex which are easily imbibed by the plants [24]. The total fruit yield remained significantly low on addition of synthetic fertilizers without any organic supplements (96.23 q/ha).

3.8 Shelf Life of Fruits

The shelf life (Table 1) of green fruits was enhanced on application of organic treatments the maximum being with FYM @ 10 t/ha + Neem cake @ 1 t/ha (4.33 days) and Vermicompost @ 2.5 t/ha + Neem cake @ 1 t/ha (4.33 days) and the lowest was recorded in untreated control (2.93 days). Reduced physiological processes like respiration, transpiration and weight loss lowers the shrinkage level and ethylene synthesis is reduced resulting in extended fruit shelf life. Neem cake also has some impact on increasing the shelf life for its antifeedant properties that protects plant from pathogens probably due to its limonene content. This finding is in concordance with the results of Vanilarasu and Balakrishnamurthy [25] in banana.

3.9 Soil Parameters

Soil nutrient status (Table 2) in the experimental site before investigation was pH 5.57, organic carbon 0.54%, available N 263.45 kg/ha, available $P_2O_5$24.38 Kg/ha, available K_2O 98.90 Kg/ha that showed N in optimum side, P in the higher side and K in the lower side. After treating with the treatments the pH recorded in T4 (FYM @ 10 t/ha + Vermicompost @ 2.5 t/ha) was 5.12. This might be due to FYM application which maintains the soil pH and the vermicompost has potential to reduce Al toxicity [26]. The higher proportion of organic substances that coagulate when base extract is acidified resulted in the possibility of stable chalets with Al^{3+} [17]. In $\mathbf{T_{11}}$ Recommended NPK (50:50:50 kg NPK/ha) lowest pH 5.05 was obtained due to the use of inorganic fertilizer reduced mineralization and slowed down microbial activity lowering the crop yield [28]. Organic carbon was observed optimum in $\mathbf{T_{10}}$ FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter(0.50) and less in T_{11} NPK (50:50:50 kg NPK/ha) and T_{12} control(0.43, 0.45) respectively. The response of crop to organic application depends on soil organic matter decomposed by microorganisms and break down to simplest components that facilitates nutrients availability to the plants. The organic carbon found in the organic compound plays a crucial role in maintaining soil fertility, sustaining crop production and environmental quality due to their effect on soil physical, chemical and biological properties, such as soil water retention, nutrient recycling and root growth [29]. Available N 261.5 kg/ha was found optimum in Neem cake @ 2 t/ha (T_3) which did not vary significantly from other treatments. Though inorganic fertilizer increases plant growth, its continuous use degrades the soil fertility. Organic input in the form of neem cake reduces alkalinity in soil as it produces organic acids on decomposition. It improves the organic matter content of the soil, water holding capacity, ameliorates soil texture and keeps the soil aerated for better root development. In the inorganic fertilizer treated plots, the total N content decreased from 2.63 kg/ha before cropping to 2.59 kg/ha after cropping. This might be due to leaching and volatilization. This observation is in agreement with [30]. Due to decrease in P sorption available P was also observed highest (24.54 kg/ha) in the same treatment (Neem cake @ 2 t/ha) and significantly lower in plots treated with NPK 50:50:50 kg NPK/ha (T_{11}), followed by Untreated control, (23.00 kg/ha). High nitrogen and phosphorus in neem treated plot is due to high content of N and P nutrient in the neem-based natural fertilizer. K was found 99.56 in T_2 (Vermicompost @ 5 t/ha) same as before treating the treatment which was found non-significant to all other treatments.

3.10 Production Economics

It can be noted (Table 3, Fig. 1) that FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter (T_{10}) obtained more profitable with net return Rs.172115.00 leading to the highest B:C ratio (2.66), followed by FYM @ 10 t/ha + Poultry manure @ 2.5 t/ha (T_6) with ratio of 2.46 as against FYM @ 10 t/ha + 50:50:50 kg NPK/ha (T_{13}) which registered a low B:C ratio of 1.0. The productivity in inorganic fertilizer + organic manure treatments was comparatively more than that in organic treatments. However, organic amendment treatments proved profitable than that of inorganic due to higher prices of the organic produce.

Table 2. Soil nutrient status before and after harvest

Treatment	**Soil pH**	**Organic carbon** (%)	**N** (kg/ha)	**P** (kg/ha)	**K** (kg/ha)
Initial soil nutrient status	5.57	0.54	263.45	24.38	98.90
T_1 FYM @ 20 t/ha	5.08	0.49	259.4	23.61	98.23
T_2 Vermicompost @ 5 t/ha	5.10	0.46	261.2	24.00	99.56
T_3 Neem cake @ 2 t/ha	5.06	0.44	261.5	24.54	99.24
T_4 FYM @ 10 t/ha + VC @ 2.5 t/ha	5.12	0.48	258.9	23.24	98.05
T_5 FYM @ 10 t/ha + NC @ 1 t/ha	5.06	0.46	260.3	22.67	98.24
T_6 FYM @ 10 t/ha + PM @ 2.5 t/ha	5.08	0.47	261.3	23.47	98.26
T_7 VC @ 2.5 t/ha + NC @ 1 t/ha	5.06	0.45	259.4	23.57	98.01
T_8 VC @ 5 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter	5.08	0.47	260.3	22.64	98.27
T_9 NC @ 2 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter	5.07	0.44	259.4	23.67	99.52
T_{10} FYM @ 20 t/ha + VAM + Pseudomonas +Trichoderma + Azotobacter	5.09	0.50	259.4	22.58	98.02
T_{11} Recommended NPK (50:50:50 kg NPK/ha)	5.05	0.45	256.3	22.34	97.06
T_{12} Untreated control	5.07	0.43	260.4	23.00	97.07
T_{13} FYM @ 10 t/ha + 50:50:50 kg NPK/ha	5.08	0.47	261.1	23.34	98.37
S.Ed. (±)	0.02	0.01	23.31	0.43	0.95
CD (5%)	0.04	0.02	NS	0.85	NS

VC: Vermicompost NC: Neem cake PM: Poultry manure

Table 3. Production economics of organic farming in okra

Treatment	Total fruit yield (q/ha)	Gross Return (Rs)	Total Cost (Rs)	Net Return (Rs)	B:C ratio
T_1 FYM @ 20 t/ha	104.03	208060.00	63350.00	144710.00	2.28
T_2 Vermicompost @ 5 t/ha	112.05	224100.00	76500.00	147600.00	1.93
T_3 Neem cake @ 2 t/ha	87.85	17500.00	136500.00	39200.00	0.29
T_4 FYM @ 10 t/ha + VC @ 2.5 t/ha	114.51	229020.00	71050.00	157970.00	2.22
T_5 FYM @ 10 t/ha + NC @ 1 t/ha	101.90	203800.00	101050.00	102750.00	1.02
T_6 FYM @ 10 t/ha + PM @ 2.5 t/ha	105.64	211280.00	61050.00	150230.00	2.46
T_7 VC @ 2.5 t/ha + NC @ 1 t/ha	102.20	204400.00	106500.00	97900.00	0.92
T_8 VC @ 5 t/ha + VAM + Pseudomonas+Trichoderma + Azotobacter	109.77	219540.00	77425.00	142115.00	1.84
T_9 NC @ 2 t/ha + VAM + Pseudomonas+Trichoderma + Azotobacter	94.59	189180.00	137425.00	51755.00	0.38
T_{10} FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter	118.32	236640.00	64525.00	172115.00	2.66
T_{11} Recommended NPK (50:50:50 kg NPK/ha)	96.23	96230.01	43775.00	52455.00	1.20
T_{12} Untreated control	66.65	66650.00	35250.00	31400.00	0.90
T_{13} FYM @ 10 t/ha + 50:50:50 kg NPK/ha	123.89	123888.00	61825.00	62063.00	1.00

VC: Vermicompost NC: Neem cake PM: Poultry manure

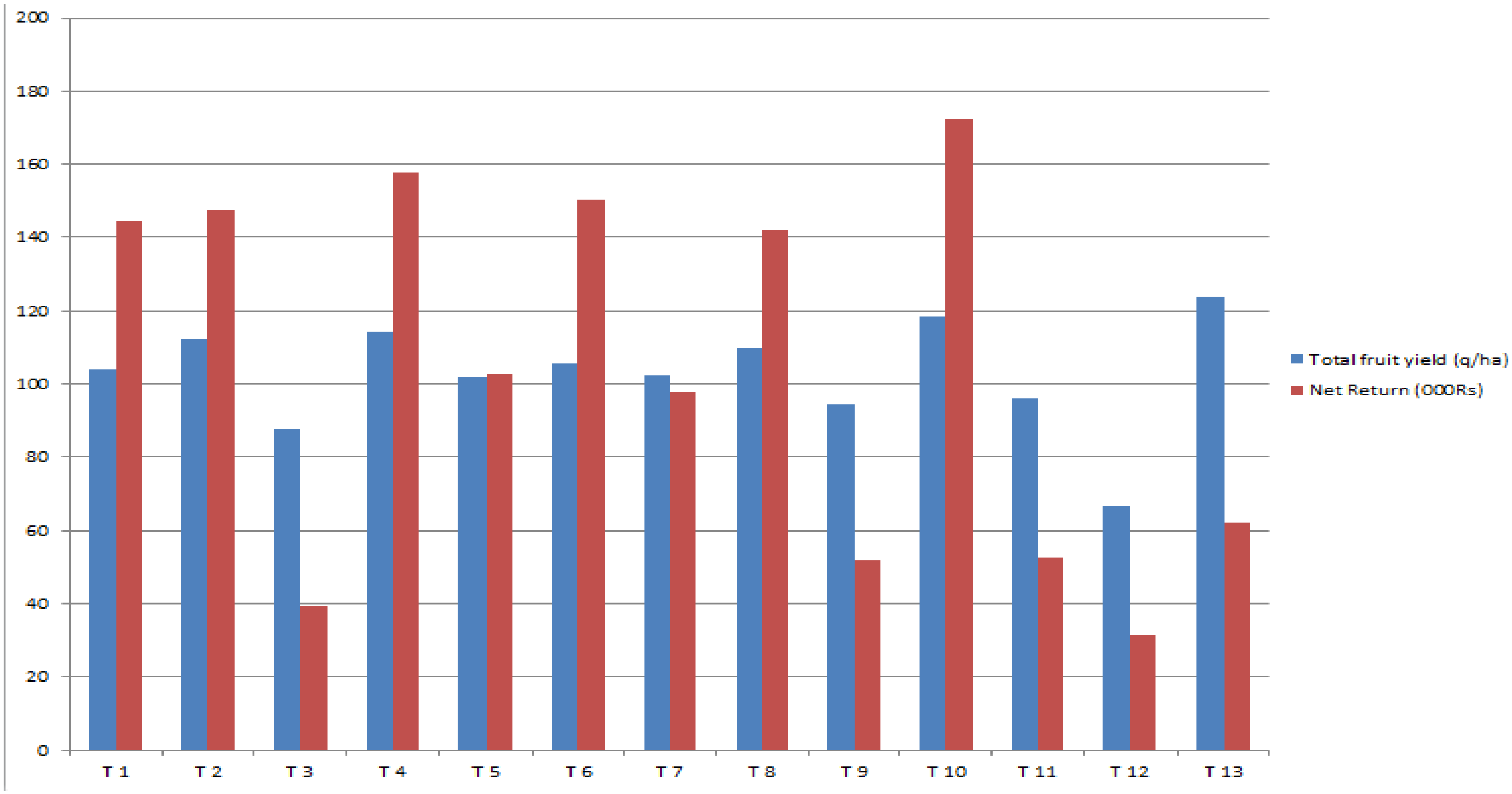

Fig. 1. Production economics of organic farming in okra

4. CONCLUSION

The inorganic fertilizers dissolves quickly and immediately available to the plants in large amount at the early stage of growth, while the organic residues create a conducive condition for plant to grow vigorously and also release nutrients slowly which can be used by plant at a later period of development. From the above findings, we can conclude that the application FYM @ 10 t/ha + 50:50:50 kg NPK/ha which resulted the highest fruit per plant, fruit length, yield per plant, yield per hectare among the treatments which was also equally comparable to FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter in terms of plant growth and yield with highest Benefit: Cost ratio of 2.66 followed by 2.46 in FYM @ 10 t/ha + Poultry manure @ 2.5 t/ha treatment. Therefore, it can be recommended that the okra crop supplied with FYM @ 20 t/ha + VAM + Pseudomonas + Trichoderma + Azotobacter which can be adopted by the farmers for better organic yield and higher monetary return.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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