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# Dynamics of nutrient availability in okra production with organic and inorganic fertilizers

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**Abstract**
The present study was carried out at the Research farm of Abhilashi University, Mandi (H.P) during the summer season of 2023. The experiment was laid out in a randomized block design with three replications comprising seven treatments consisting of different combinations of organic manures and inorganic fertilizers to assess the impact of integrated nutrient management on growth, yield, soil and economics of okra crop. The results revealed that treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] influenced all parameters like days to first flower appearance (36.40), plant height (98.03 cm), stem diameter (3.0 cm), number of leaves per plant (26.39), length of leaves (30.91 cm), average fruit weight (26.95 g), fruit length (24.07 cm), fruit diameter (3.27 cm), yield per plot (6.91 kg), yield per hectare (155.42 q), available nitrogen (301.32 kg/ha), available phosphorus (36.02 kg/ha), available potassium (249.08 kg/ha). The maximum water holding capacity (24.68%) and organic carbon (1.02%) were recorded in treatment $T_3$ [N: P: K (50%) + Farm Yard Manure (50%)] and $T_5$ [N: P: K (50%) + Vermicompost (50%)] respectively. The economics in terms of gross return (₹ 466258.5), net return (₹ 358,245) and B: C ratio (3.32) were also maximum in $T_7$.

**Keywords:** Okra, fertilizers, yield, economics, manures

## Introduction
Okra (*Abelmoschus esculentus* (L). Moench) is one of the most important vegetable crop belongs to the family Malvaceae. It is grown in tropical and subtropical region of the world and originated from Ethiopia and West Africa. Its basic chromosome number is 2n = 130 (amphidiploid). Okra is grown for its fruits or pods, the immature fruits, leaves and succulent shoots are picked and eaten as a vegetable, either fresh or dried to provide nutrients (Arapitsas, 2008) [2]. Okra is rich in nutrients, including protein, carbohydrates, phosphorus, calcium, magnesium, iron and trace amounts of vitamins B and C (Gopalan, 2007) [8]. The tender fruits have high levels of mucilage, protein, vitamin A and C, including riboflavin, and minerals like calcium, magnesium, iron and phosphorus (Ndaeyo *et al*., 2005) [22].
Okra is a nutritious vegetable crop grown for its immature pods, which can be used to salads, soups and stews or eaten as a vegetable when boiled or fried. The fruits also serve as soup thickeners. Okra seed can be dried or roasted and the dried seeds are rich in nutrition that can be used to prepare vegetable curds. Young fruits of okra may be eaten raw and they have oil content comparable to poultry eggs and soyabean (Adesida *et al*. 2019) [1].
In India it is grown in an area of 531 thousand ha with a production of 6.46 mMT (Anonymous, 2021). Gujarat is the leading state in okra production in the country with an area of 85.15 thousand ha having 1019.42 thousand MT production followed by West Bengal, Bihar and Madhya Pradesh respectively (Anonymous, 2021). In Himachal Pradesh, it is grown in an area of about 3.92 thousand ha with a production of 60.95 thousand MT (Anonymous, 2021).
Chemical fertilizers are most important to increase growth and yield of okra. Nitrogen builds proteins and chlorophyll, as well as promoting the growth of leaves. Phosphorous contributes to root, fruit and flower development (Chauhan *et al.*, 2023) [4]. Okra responds extremely well to fertilizer application and using fertilizer effectively is essential to increasing its growth and yield (Kumar, 2019) [13].

Organic manure can help to enhance the physical state of the soil and supply sufficient amounts of essential nutrients to support soil productivity (Qhureshi, 2007) [26]. Organic fertilizers are environmentally friendly; it promotes population of beneficial microorganisms and generally improves the soil health (Oyewole *et al*., 2012) [25]. Organic fertilizers have been reported to increase crop production similar to inorganic fertilizers (Tonfack *et al*., 2009) [30] because they contain both micro and macro nutrients in addition to some plant promoting factors and beneficial microorganisms (Sreenivasa *et al*., 2010) [28].

The full potential of a crop can only be judged when the nutrient supply system includes both organic sources and synthetic fertilizers. The nutrient sources opted for a crop's cultivation are likely to have an impact on the yield of the crop, the quality of the soil and the farmer's overall profits. Utilizing different inputs in crop production effectively helps to achieve maximum crop production and productivity, as well as profitability and sustainability for rural livelihoods (Chauhan *et al.,* 2023) [4]. We therefore hypothesised that in order to thoroughly evaluate various nutrient sources, its impact on the soil's health, crop economics and yield need to be critically quantified. Adopting best nutrient management practices can effectively address the current idea of "farming for health" the sustainability of the natural resources base, particularly soil and ultimately the way of life for the farming community.

## Materials and Methods

### Experimental site

The present investigation was conducted during the summer season of 2023 at the Research Farm, School of Agriculture, Abhilashi University, Mandi (H.P.). The experimental farm is situated at $31^0$ 33'34" N latitude and $77^0$ 00'40" E longitude with an elevation of 1,423 m above mean sea level.

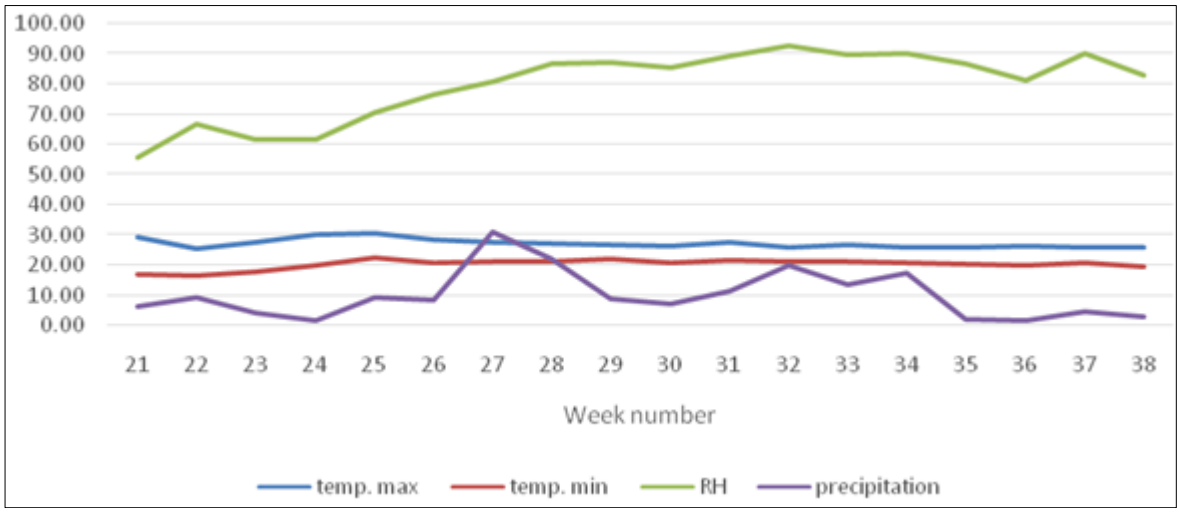


**Fig 1:** Meteorological data of experimental farm recorded during May to September, 2023

**Table 1:** Treatment details

| Treatment code | Treatments |
|---|---|
| $T_1$ | Absolute control |
| $T_2$ | N: P: K (100%) |
| $T_3$ | N: P: K (50%) + Farm Yard Manure (50%) |
| $T_4$ | N: P: K (50%) + Poultry Manure (50%) |
| $T_5$ | N: P: K (50%) + Vermicompost (50%) |
| $T_6$ | N: P: K (50%) + Farm Yard Manure (25%) + Poultry Manure (25%) |
| $T_7$ | N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%) |

**Note:** Recommended dose of fertilizers 150: 112: 75 kg/ha N, $P_2O_5$ and $K_2O$.

### Design of experiment

The experiment was laid out in Randomized Block Design with three replications comprising of seven treatment combinations of inorganic fertilizer with organic manures. The layout plan is provided below:

### Growth parameters

### Days to first flower appearance

The plants were observed daily after 30 days of sowing to record the appearance of first flower. Total number of days from sowing time to the date when first flower appeared were counted and subjected to statistical analysis.

### Plant height (cm)

Plant height from the base of the plant to the emerging leaf was measured from five tagged plants per replication per treatment at harvest and their average was worked out and expressed in cm.

### Diameter of stem (cm)

Stem diameter was measured from five tagged plants per replication per treatment at harvest and their mean was worked out.

### Number of leaves per plant

The number of leaves was counted from five randomly selected plants at harvest and averaged to get number of leaves per plant.

**Length of leaves per plant (cm):** The length of leaves was measured from five randomly selected plants at harvest and their mean was worked out and expressed in cm.

**Yield parameters**

**Weight of fruit (g)**

Fruit weight was calculated from five randomly selected and labelled plants from each treatment.

**Size of fruit (cm) (length, diameter)**

The length of five fruits from every treatment was measured from the base of the fruit to the apex, after every harvesting average was calculated and expressed in centimeters. The diameter of five fruits from every treatment was measured by using vernier calliper and their means were computed and expressed in centimeters.

**Yield per plot (kg)**

The total fruit yield per plot was recorded from each plot per replication per treatment and expressed in kilo grams. Fruit yield per plot was multiplied with the total number of plants per plot to obtain yield per plot.

**Yield per hectare (q)**

The total yield per hectare was recorded from each plot per replication per treatment and expressed in quintals. The yield per plot (kg) was transformed into yield per hectare (q) by multiplying the respective figures with a common factor of 10.

**Soil analysis**

After the experiment, soil samples from 0-15 cm depth were collected from all the plots separately. Those samples were air dried, crushed, passed through 2 mm sieve and stored in bags for chemical analysis.

**Available N (kg ha$^{-1}$)**

Available nitrogen in the soil (kg ha$^{-1}$) was determined through alkaline potassium permanganate method (Subbaiah and Asija, 1956) [29] by digestion, distillation and collection of $NH_3$ in 2% boric acid and titrating it against standard sulphuric acid.

**Available P (kg ha$^{-1}$)**

Available phosphorus content was determined by Olsen's method (1954) as described by Jackson (1973) [10].

**Available K (kg ha$^{-1}$)**

Available potassium in soil (kg ha$^{-1}$) was extracted by neutral 1 N ammonium acetate and determined by flame photometric method as described by Jackson (1973) [10].

**Soil pH**

Soil pH was determined in 1: 2.5 soil to water suspension after stirring the contents intermittently for half an hour. The pH value was recorded using glass electrode method (Jackson, 1973) [10].

**Water holding capacity**

The maximum water holding capacity of the soils was determined using Keen's box method.

**Organic carbon**

Organic carbon or easily oxidizable organic carbon of soil samples were determined by Walkley and Black's wet oxidation method.

**Results and Discussion**

**Growth parameters**

The result recorded for number of days taken to first flower appearance was significantly affected by different treatment combinations. The minimum days to first flower appearance (36.40) was recorded in treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] which was statistically at par with the treatment $T_6$ and the maximum days taken to first flower appearance (45.67) was found in $T_1$ (Absolute control). The similar results were observed by Mal *et al*. (2013) [16] and Narwariya *et al*. (2023) [21].

The plant height was also significantly influenced by application of organic manures with inorganic fertilizers. The maximum plant height (98.03 cm) was recorded in treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] which was statistically at par with the treatment $T_6$. However, the minimum plant height (67.34 cm) was measured in $T_1$ (Absolute control). It might be due to the presence of higher amount of nitrogen in vermicompost. The similar results were observed by Mal *et al*. (2013) [16], Sachan *et al*. 2017 [27], Dessai *et al*. (2023) [6] and Narwariya *et al*. (2023) [21].

The maximum stem diameter is might be due to the application of $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] which was statistically at par with the treatment $T_6$ and $T_5$. On the other hand the minimum diameter of stem (0.89 cm) was measured in $T_1$ (Absolute control). The increase in stem diameter is might be due to the application of FYM and vermicompost which increases the plant diameter by providing organic matter, nitrogen and other beneficial elements which were responsible for increased stem diameter. The addition of FYM increases nutrient uptake and water from maximum soil volume resulting in improved stem diameter. Similar results were also in concordance with the findings reported by Meena *et al*. (2019) [17].

Among all the treatments the maximum number of leaves (26.39) was recorded in treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] which was statistically at par with the treatment $T_6$ and $T_5$. On the other hand the minimum number of leaves (15.65) was found in $T_1$ (Absolute control). Similar results were found in Dessai *et al*. (2023) [6] and Narwariya *et al*. (2023) [21].

The length of leaves was relatively affected by different treatment combinations in the experiment. The maximum length of leaves (30.91 cm) was exhibited in treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] which was statistically at par with the treatment $T_6$ and $T_5$. However, the minimum length of leaves (21.74 cm) was recorded in $T_1$ (Absolute control). It might be due to the improved soil health and physicochemical properties of soil were enhanced leading to an increase in both microbial activity and macro and micro nutrients. Similar results were observed by Kumar *et al*. (2021) [12].

**Yield parameters**

The data on the average fruit weight was influenced by conjoint use of chemical fertilizers with organic manures. The maximum weight of fruit (26.95 g) was recorded in treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] which was statistically at par with the

treatment $T_6$. However, the minimum weight of fruit (17.95 g) was measured in $T_1$ (Absolute control). The maximum fruit weight was achieved by the application of FYM and vermicompost because of the increased nutrient uptake. Similar results were found by Mal *et al*. (2013) [16], Sachan *et al*. (2017) [27], Miah *et al*. (2020) [20] and Narwariya *et al*. (2023) [21].

The length and diameter of fruit were also influenced by application of organic manures with inorganic fertilizers. The maximum fruit length (24.07 cm) and diameter (3.27 cm) were observed in treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] which was statistically at par with the treatment $T_6$ and $T_5$. However, the minimum fruit length (14.45 cm) and diameter (0.63 cm) were measured in $T_1$ (Absolute control). Similar results of this present investigation were also in concordance with the findings reported by Mal *et al*. (2013) [16].

The yield per plot was relatively affected by different treatment combinations in the experiment. The treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] recorded highest yield per plot (6.91 kg) which was statistically at par with the treatment $T_6$ and the lowest yield per plot (3.03 kg) was measured in $T_1$ (Absolute control). Supplemented organic manures are known to play a positive impact in enhancing the physical, chemical and biological properties of soil, which helps plants to better absorb nutrients and produce more. Similar results for maximum yield per plot has been reported by Narwariya *et al*. (2023) [21].

The yield per hectare was relatively affected by different treatment combinations in the experiment. The maximum yield per hectare was observed with the application of $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)]. This might be due to the application of vermicompost with inorganic fertilizers lead to increased vegetative growth, increase fruit production per plant, improve nutrient availability during critical growth periods and increase the synthesis and translocation of carbohydrates. Similar results for yield per hectare were found by Mal *et al*. (2013) [16], Sachan *et al*. (2017) [27], Dessai *et al*. (2023) [6] and Narwariya *et al*. (2023) [21].

**Table 2:** Initial physico-chemical parameters of experimental plot

| Sr. No. | Parameters | Values obtained | Methods used |
|---|---|---|---|
| 1. | Water holding capacity (%) | 16.21 | Keen's box method (Keen and Raczkowaski, 1973) |
| 2. | Soil pH (1: 2.5 soil: water) | 5.8 | Glass electrode method (Jackson, 1973) [10] |
| 3. | Available Nitrogen (kg/ha) | 224.05 | Alkaline potassium permanganate method (Subbiah and Asija, 1956) [29] |
| 4. | Available Phosphorus (kg/ha) | 19.61 | Olsen's method of extraction with 0.5 1$NaHCO_3$ at pH 8.5 (Olsen *et al*. 1954) [24] |
| 5. | Available Potassium (kg/ha) | 190.33 | Neutral ammonium acetate method (Merwin and Peech, 1950) [19] |
| 6. | Organic carbon (%) | 0.68 | Rapid titration method (Walkley and Black, 1934) [31] |

**Table 3:** Effect of different treatments on days to first flower appearance, plant height (cm), stem diameter (cm), number of leaves and leaf length (cm).

| Treatments | Days to first flower appearance | Plant height (cm) | Stem diameter (cm) | Number of leaves | Leaf length (cm) |
|---|---|---|---|---|---|
| Absolute control | 45.67 | 67.34 | 0.89 | 15.65 | 21.74 |
| N: P: K (100%) | 44.30 | 70.98 | 1.05 | 17.52 | 23.78 |
| N: P: K (50%) + Farm Yard Manure (50%) | 42.68 | 74.68 | 1.73 | 19.66 | 25.35 |
| N: P: K (50%) + Poultry Manure (50%) | 40.65 | 85.98 | 2.04 | 21.69 | 27.47 |
| N: P: K (50%) + Vermicompost (50%) | 39.76 | 88.66 | 2.47 | 23.77 | 28.82 |
| N: P: K (50%) + Farm Yard Manure (25%) + Poultry Manure (25%) | 37.45 | 96.23 | 2.91 | 25.45 | 30.04 |
| N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%) | 36.40 | 98.03 | 3.01 | 26.39 | 30.91 |
| SE(m) (±) | 0.63 | 1.31 | 0.19 | 1.47 | 1.11 |
| $CD_{(0.05)}$ | 1.95 | 4.04 | 0.57 | 4.53 | 3.42 |

**Table 4:** Effect of different treatments on average fruit weight (g), length of fruit (cm), diameter of fruit (cm), yield per plot (kg) and yield per hectare (q)

| Treatments | Average fruit weight (g) | Length of fruit (cm) | Diameter of fruit (cm) | Yield per plot (kg) | Yield per hectare (q) |
|---|---|---|---|---|---|
| Absolute control | 17.95 | 14.45 | 0.63 | 3.03 | 68.27 |
| N: P: K (100%) | 19.93 | 16.90 | 0.97 | 3.55 | 79.90 |
| N: P: K (50%) + Farm Yard Manure (50%) | 20.95 | 18.53 | 1.05 | 4.12 | 92.73 |
| N: P: K (50%) + Poultry Manure (50%) | 22.89 | 19.11 | 1.41 | 4.79 | 107.88 |
| N: P: K (50%) + Vermicompost (50%) | 23.67 | 21.39 | 1.90 | 5.45 | 122.60 |
| N: P: K (50%) + Farm Yard Manure (25%) + Poultry Manure (25%) | 25.78 | 23.57 | 2.98 | 6.32 | 142.31 |
| N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%) | 26.95 | 24.07 | 3.27 | 6.91 | 155.42 |
| SE(m) (±) | 0.79 | 1.16 | 0.18 | 0.22 | 4.95 |
| $CD_{(0.05)}$ | 2.43 | 3.59 | 0.56 | 0.68 | 15.27 |

**Table 5:** Effect of different treatments on available N, P and K, soil pH, water holding capacity (%) and organic carbon (%)

| Treatments | Available N, P and K (kg/ha) | | | Soil pH | Water holding capacity (%) | Organic carbon (%) |
|---|---|---|---|---|---|---|
| | N | P | K | | | |
| Absolute control | 220.07 | 19.61 | 190.33 | 5.80 | 16.21 | 0.68 |
| N: P: K (100%) | 289.52 | 30.62 | 240.29 | 5.70 | 14.02 | 0.61 |
| N: P: K (50%) + Farm Yard Manure (50%) | 274.03 | 23.20 | 218.22 | 6.02 | 24.68 | 0.97 |
| N: P: K (50%) + Poultry Manure (50%) | 268.10 | 22.54 | 212.18 | 5.98 | 19.81 | 0.95 |
| N: P: K (50%) + Vermicompost (50%) | 295.33 | 32.42 | 240.29 | 5.94 | 22.81 | 1.02 |
| N: P: K (50%) + Farm Yard Manure (25%) + Poultry Manure (25%) | 282.79 | 26.04 | 236.64 | 6.05 | 21.51 | 0.82 |
| N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%) | 301.32 | 36.02 | 249.08 | 6.03 | 22.08 | 0.88 |
| SE(m) (±) | 3.18 | 0.42 | 2.18 | 0.11 | 0.56 | 0.01 |
| $CD_{(0.05)}$ | 9.79 | 1.30 | 6.73 | NS | 1.73 | 0.04 |

**Table 6:** Effect of different treatments on economics of okra

| Treatments | Cost of cultivation (₹/ha) | Gross return (₹/ha) | Net return (₹/ha) | B: C ratio |
|---|---|---|---|---|
| Absolute control | 86,753 | 204824.9 | 118,072 | 1: 1.36 |
| N: P: K (100%) | 90,323.80 | 239701.2 | 149,377 | 1: 1.65 |
| N: P: K (50%) + Farm Yard Manure (50%) | 107,388.40 | 278196.5 | 170,808 | 1: 1.59 |
| N: P: K (50%) + Poultry Manure (50%) | 94,638.40 | 323646.1 | 229,008 | 1: 2.42 |
| N: P: K (50%) + Vermicompost (50%) | 108,638.40 | 367789.9 | 259,151 | 1: 2.39 |
| N: P: K (50%) + Farm Yard Manure (25%) + Poultry Manure (25%) | 101,013.40 | 426926.8 | 325,913 | 1: 3.23 |
| N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%) | 108,013.40 | 466258.5 | 358,245 | 1: 3.32 |

**Soil analysis**

The maximum amount of available nitrogen (301.32 kg/ha) was exhibited in treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] which was statistically at par with the treatment $T_5$. The maximum amount of available phosphorus (36.02 kg/ha) and available potassium (249.08 kg/ha) was exhibited in treatment $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] followed by treatment $T_5$. However, the minimum amount of available nitrogen (220.07 kg/ha), available phosphorus (19.61 kg/ha) and available potassium (190.33 kg/ha) was measured in $T_1$ (Absolute control). It might be due to the application of organic manures, such as vermicompost in bulk quantities that increased the soil's ability to hold onto nutrients by releasing more nitrogenous molecules into the soil. In addition to the decrease in potassium fixation and its release as a result of organic matter interacting with clay particles, the positive effects of vermicompost and farm yard manure on accessible K may also be linked to the direct supply of potassium to the soil (Sharma *et al*., 2014) [21]. Similar results of this investigation were also in concordance with the findings reported by Paul *et al*. (2019) [3] and Gangadharappa *et al*. (2020) [7].

By the application of different treatment combinations there is an increase in pH (6.05) with the application of treatment $T_6$ [N: P: K (50%) + Farm Yard Manure (25%) + Poultry Manure (25%)]. Whereas minimum pH (5.70) was recorded in $T_2$ [N: P: K (100%)].

The water holding capacity has substantial effect of different organic manures and inorganic fertilizer treatment combinations. The highest water holding capacity (24.68%) in soil was observed in treatment $T_3$ [N: P: K (50%) + Farm Yard Manure (50%)] followed by treatment $T_5$. Although, lowest water holding capacity (14.02%) was measured in $T_2$ [N: P: K (100%)]. Similar results were observed by Ola *et al*. (2017) [23], Yadav *et al*. (2020) [32] and Merentoshi *et al*. (2022) [18].

The result recorded for organic carbon was significantly affected by different treatment combinations. The highest organic carbon (1.02%) in soil was observed in treatment $T_5$ [N: P: K (50%) + Vermicompost (50%)] followed by treatment $T_3$. Although, lowest organic carbon (0.61%) was measured in $T_2$ [N: P: K (100%)]. It might be due to the application of vermicompost which is totally organic and contain high amount of organic carbon. Similar results were also in concordance with the findings reported by Lakra *et al*. (2017) [15], Gupta *et al*. (2019) [19] and Choudhary *et al*. (2022) [5].

**Economics**

The conjoint use of organic manures and inorganic fertilizers have substantial effect on economics. The highest cost of cultivation ₹ 108,638.40 was found in treatment $T_5$ [N: P: K (50%) + Vermicompost (50%)] followed by $T_7$ i.e. ₹ 108,013.40 and $T_3$ i.e. ₹ 107,388.40 whereas least cost of cultivation was found in $T_1$ (Absolute control) i.e. ₹ 86,753. The economics in terms of gross return (₹ 466258.5), net return (₹ 358,245) and B: C ratio (3.32) were also maximum in $T_7$ [N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] and minimum was incurred in $T_1$ (Absolute control) i.e. ₹ 204824.9, ₹ 118,072 and 1.36 respectively.

**Conclusion**

The results of this experiment concluded that integrated use of organic and inorganic fertilizers has a beneficial effect on growth yield and soil. The treatment $T_7$ [(N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] came out to be best for growth, yield as well as gross and net returns followed by treatment $T_6$ [(N: P K (50%) + Farm Yard Manure (25%) + Poultry Manure (25%)]. Soil available N, P and K were also improved in this treatment. Therefore, it may be concluded that treatment $T_7$ [(N: P: K (50%) + Farm Yard Manure (25%) + Vermicompost (25%)] has been proved best for growing okra and maintaining soil health.

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