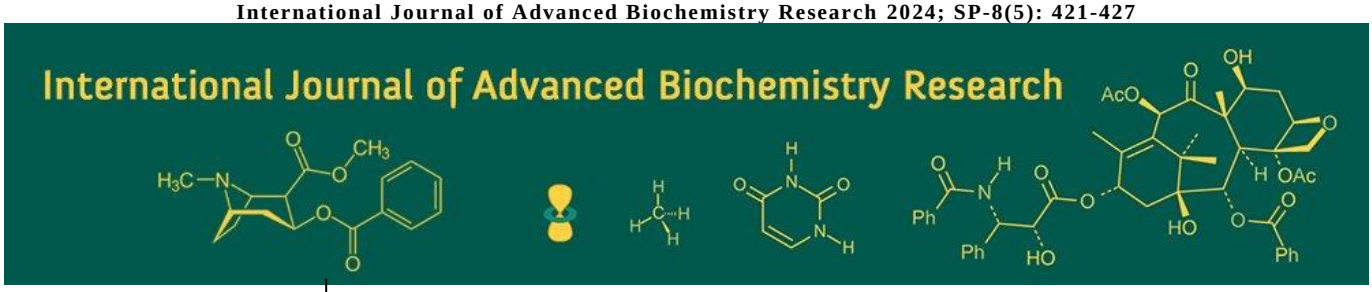

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Soil fertility, growth and yield of broccoli (*Brassica oleracea* L. var. *italica*) as influenced by integrated nutrient management practices

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Abstract
The present investigation entitled was carried out at the Research farm of the School of Agriculture, Abhilashi University, Mandi (H.P) during *rabi* season 2023-24. The research was laid out in a randomized block design with three replications and seven treatments. The result revealed that the maximum plant height (59.07cm), number of leaf (21.49) and length of leaf (31.14cm), were recorded under treatment T_6 [Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)] but, head initiation day after transplanting (50.31), head diameter(12.41 cm), weight of head (510.52 g), yield per plot(4.59 kg) and yield per ha (170 q) was recorded under treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)].The higher soil pH (6.20) was recorded in treatment T_6 [Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)], the higher organic carbon (1.64) is recorded in treatment T_3 [Vermicompost (100%)], higher water holding capacity were observed in treatment T_2 [Farm Yard Manure (100%)]. The higher available N (247.83 kg/ha), P (35.41kg/ha) and K (274.68 kg/ha) were recorded under treatment T_1 [N: P: K (100%)]. The highest gross return (₹ 5, 95, 537), net returns (₹ 4, 78, 616) were observed in treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)]. Among all the treatments the highest B: C ratio (4.15:1) was observed in treatment T_1 [N: P: K (100%)] as compare to treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)] (4.09:1).

Keywords: Broccoli, organic, manure, fertilizers, economics

Introduction
Broccoli (*Brassica oleracea* L. var. *italica*) is one of the most important members of cole crops and has originated in the Mediterranean region. It belongs to the family Brassicaceae and is mainly grown as cool season vegetable crop. Its basic chromosome number is 2n = 2x = 18. Broccoli is also known as Hari Gobhi. Cole crops originated from the word 'caulis' (Latin) meaning stalk or solid upright stem of plant, while the word broccoli derived its name from the Latin word 'Brachium' meaning an arm or branch. Broccoli is of two types, sprouting and heading. Heading broccoli forms curd like cauliflower, while sprouting broccoli contains a group of green immature buds and thick fleshy flower stalk forming a head (Jindal *et al.*, 2017) [8].

It contains more nutrients than other cole crops and is rich in vitamins, minerals and antioxidants. It holds 130 times more Vitamin A than cauliflower and 22 times than that of cabbage. It is also the rich source of 'Sulphoraphane' which is having the anti-cancerous property. It also contains thiamin, riboflavin, niacin, vitamin C and minerals like Ca, P, K and Fe (Mitr *et al.*, 2022) [18]. Broccoli contains indole-3-carbinol which helps to fight cancer. It is used in curries, soups, and pickles and also eaten as a salad and cooked as a single or mixed vegetable with potato. Broccoli buds are rich source of minerals especially K, S, P, Mg and micro-elements (Zhao *et al.*, 2007) [28, 29]. It is one of the most significant vegetable crops grown in the mid and high hills of Himachal Pradesh. In the north Indian plains, the harvest is sold as an off-season vegetable, and farmers who sell their produce at fair prices profit handsomely (Shukla *et al.*, 2023) [22].

A balanced dose of nitrogen, phosphate, and potassium is necessary to improve crop growth while minimizing environmental impact. Applying nitrogenous, phosphate, and potassium fertilizers can significantly reduce nitrate accumulation in crops (Zhou *et al.*, 2000) [29].

Organic manure plays a direct role in improving the plant growth as a source of all necessary macro and micronutrients during mineralization and also improves the physical and chemical properties of soil (Chaterjee *et al*., 2005) [3]. With the use of mineral fertilizer (N, P, and K) broccoli vegetative growth, yield and quality is increased. Organic matter plays an important role in the chemical behavior of several metals in soils throughout its active which have the ability to retain the metals in complex and chelate forms (Bahadur *et al*., 2006) [1]. Integrated nutrient management improves and maintains soil fertility for long-term crop productivity. Optimize organic, inorganic, and biotic resources for each cropping system and farming condition, taking into account the ecological, social, and economic impacts. (Mohanta *et al*., 2017) [16].

Materials and Methods

Experimental site

The present study was carried out at the Experimental Research Farm, School of Agriculture, Abhilashi University, Mandi, (H.P.) during the winter season of 2023-24. The experimental site is located at 31º33'30" N latitude and 77º00'46"E longitude with the elevation of 1426 m above mean sea level. The details of experimental material used and methodology followed during the course of the investigation have been described below:

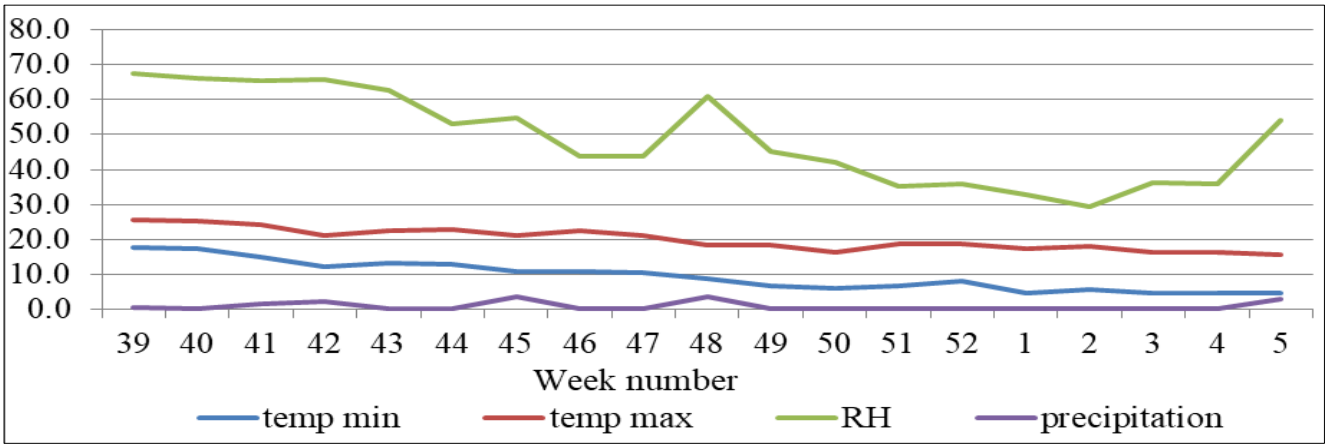

Fig 1: Metrological Data

Table 1: Treatment details

Notations	Treatments
T_1	N: P: K (100%)
T_2	Farm Yard Manure (100%)
T_3	Vermicompost (100%)
T_4	Poultry Manure (100%)
T_5	N: P: K (50%) + Farm Yard Manure (50%)
T_6	Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)
T_7	Vermicompost (50%) + Poultry Manure (50%)

Design of Experiment

The experiment was laid out in randomized block design (RBD) with seven treatments and three replications. Every replication has seven treatments. In every replication, every treatment was randomized in isolation.

Design	: Randomized Complete Block Design (RCBD)
Replication (s)	: 3
No of treatments	: 7
Number of experimental plots	: 21
Variety	: Matsuri (F_1 Hybrid)
Plot size	: 1.3 m ×1.8 m
Spacing	: 45 cm × 60 cm

Growth parameters

Plant height (cm)

Plant height was measured at the time of harvesting from the soil level to the highest tip of the plant with the help of a measuring scale. The height of five randomly selected plants was measured and the average value was expressed in centimetre.

Number of leaves

Numbers of leaves per plant was recorded under each treatment at the time of harvesting. All the fully grown leaves were counted except those which were attached to the heads. The number of leaves were counted from five randomly selected plants and averaged to get number of leaves per plant.

Leaf length (cm)

Five leaves was selected from lower, middle and top part of the selected plants per plot and then length of the leaves was measured from the tip of the entire leaf down to the base of the lowest leaflets where they meet the leaf stem using ruler and average was worked out as mean length of leaves.

Head initiation

Every day, the plants were monitored to track the development of the center head. Days were counted from the transplant date when the head was started, and the average number of days for the plant was determined.

Yield parameters

Head weight (g)

After harvesting of head from selected 5 plants, individual weight of fruit using the digital balance was recorded and the average weight was calculated and expressed as fruit weight in grams.

Head diameter (cm)

Mature green head were used for measuring diameter of individual fruit. Diameter was measured using ruler. The mean diameter of fruit was calculated and expressed in centimetre.

Yield per plot (kg)
The total yield of primary head of the individual plot was recorded by weighing with a single pan balance and the average mean was calculated and values were expressed in kilogram.

Yield per hectare (q/ha)
Each net plot's individual yield from each of the several treatments was recorded and converted to hectares. Yield per plot was then converted into yield per plant and ultimately to yield per hectare by multiplying with a suitable factor. It determined how much head was produced per hectare, and their quantities were expressed in quintals.

Soil analysis
Soil samples from 0-15 cm depth were collected from all the plots separately and were air dried, crushed, passed through 2 mm sieve and then soil testing was done for water holding capacity, soil pH, available NPK and organic carbon concentration.

Table 2: Initial soil parameters of the experimental soil

Sr. No.	Parameters	Values obtained	Methods used
1.	Water holding capacity	16.30	Keen's box method (keen and Raczkowski, 1973
2.	Soil pH (1:2.5 soil: water)	5.82	Glass electrode method (Jackson, 1973)
3.	Available Nitrogen (kg/ha)	235.42	Alkaline potassium permanganate (Subbiah and Asija, 1956)
4.	Available Phosphorous (kg/ha)	18.62	Olsen's method of extraction with 0.5 1NaHCO3 at pH 8.5 (Olsen et al. 1954)
5.	Available Potassium (kg/ha)	192.32	Neutral ammoniumacetate extraction method (Merwin and Peech 1950)
6.	Organic carbon (%)	0.60	Rapid titration method (Walkley and Black 1934)

Economics
The cost of cultivation of each treatment was calculated per hectare on the basis of prevailing rates of labour, organic manures, irrigation and other expenditure. The total income per hectare was calculated as per the average wholesale price of broccoli in the market. The net profit per hectare was obtained by deducting the cost from treatment.

Cost of cultivation (₹/ha)
By presuming the item-wise input cost based on the local market rate, the cost of cultivation per hectare of land was worked out and were computed treatment-wise also

Gross returns (₹/ha)
From the total yield of each treatment plot, the gross monetary return was worked out based on the average selling price of the product and it was recorded accordingly in ₹/ha.

Gross return (₹/ha) = Market price × Yield/ha

Net returns (₹/ha)
The most crucial factor to consider before recommending any remedies to farmers for widespread use is their economic viability. The average treatment yield and current market rates for inputs and output were utilized to determine the therapy's economics. The cost of cultivation for each treatment was deducted from the gross return from the economic yield to determine the net return. Net returns (₹/ha) are calculated as follows:

Net return (₹/ha) = Gross returns (₹/ha) - Cost of cultivation (₹/ha)

Benefit cost ratio (B: C ratio)
Benefit cost ratio were worked out for each nutrient treatment by adopting the following formula:

$$\text{Benefit: Cost ratio} = \frac{\text{Net return (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

Results and Discussion
Growth parameters
The plant height is one of the key factors in predicting crop productivity. Among all the treatments the maximum plant height (59.07 cm) was recorded in treatment T_6 [Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)] which was stastically at par with the treatment T_5 [(N: P: K (50%) + Farm Yard Manure (50%)], while the minimum plant height (45.17 cm) was found in treatment T_2 (Farm Yard Manure (100%). Taller plants are regarded as more desirable because they produce more leaf/branches for photosynthesis and accumulate more carbohydrates, which increase productivity and yield. The results of present study are similar with Faysal *et al*., (2006) [7], Singh *et al*., (2021) [23] and Biswas *et al*., (2021) [2].
The higher number of leaves (21.49) were recorded in treatment T_6 [Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)] which was statically at par with the treatment T_5 [(N: P: K (50%) + Farm Yard Manure (50%)] (18.21), while the minimum number of leaves (13.50) were found in treatment T_2 (Farm Yard Manure (100%). This might be the result of applying organic manures to make sure adequate air circulation and soil water-holding capacity, which would promote soil health. The results of present study are similar with Singh *et al*., (2021) [23], Biswas *et al*., (2021) [2] and Faysal *et al*., (2006) [7].
Among all the treatments the maximum length of leaves (31.14 cm) were recorded in treatment T_6 [Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)] which was statically at par with the treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)] (31.02), while the minimum number of leaves (25.99 cm) were found in treatment T_2 (Farm Yard Manure (100%). The use of organic waste like poultry manure and vermicompost probably enhanced soil fertility and productivity, resulting to increased plant nutrient uptake and longer leaf lengths. The result of present study is similar with Mal *et al*. (2014) [13] and Sharma *et al*., (2018) [21].
The earliest days to head initiation (50.31) were recorded in treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)] which was statistically at par with the treatment T_1 [N: P: K

(100%)] (53.22), while the maximum days (67.14) for head initiation was found in treatment T_2 (Farm Yard Manure (100%). A potential reason for early head maturity is the intake of carbohydrates, which were created during the nitrogen-induced protein synthesis. Furthermore, phosphorus is a key component of phospholipids, and nucleic acid. It also plays a significant role in the early stages of development since it supplies the necessary nutrients and ensures the development of strong roots. The results of present study are similar with Maurya *et al*., (2008) [14] and Kumar *et al*., (2013) [9].

Yield parameters

A review of the data showed that the weight of the central head is significantly affected by the treatments. Maximum head weight (510.42 g) was recorded in treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)] which was followed by the treatment T_1 [N: P: K (100%)], while the minimum head weight (305.39 g) were found in treatment T_2 (Farm Yard Manure (100%). The broccoli's improved head size may have resulted from the application of FYM, which imposed the plant's head weight by providing enough nutrients, moisture, and other vital elements for healthy growth and development. Similar result is close refers with the finding of Ouda *et al*., (2008) [19], Devi *et al*., (2018) [6], Shankar *et al*., (2019) [20] and Singh *et al*., (2021) [23].

Head size is an important attribute that correlates broccoli yield. Bigger head size equals greater yields and higher returns. A perusal of data revealed that treatments have significant effect on diameter of central head. In the present study the maximum head diameter (12.41 cm) was recorded in treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)] which was statistically at par with treatment T_1 [N: P: K (100%)] (12.04), while the minimum head diameter (7.83 cm) were found in treatment T_2 (Farm Yard Manure (100%). The reason behind the huge head could be attributed to the rapid division and growth of cells. When farm yard manure and synthetic fertilizers were applied together, there was a rise in the apical and lateral diameters, which led to an increase in head size. The results of present study are similar with Choudhary *et al*., (2018) [5], Varsha *et al*., (2022) [25], Kumar *et al.*, (2023) [12] and Shankar *et al*., (2019) [20].

In the present study the maximum head yield per plot (4.59 kg), yield per hectare (170.15 q) was recorded in treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)], while the minimum head yield (2.75 kg), yield per hectare (101.80 q) was found in treatment T_2 [Farm Yard Manure (100%)]. The application of inorganic fertilizers improving the rate of photosynthetic energy and their ability to absorb proteins, carbohydrates and other nutrients broccoli yield increased when organic and inorganic fertilizers were used together because the uptake of nutrients was improved. In addition, farm yard manure improves the chemical, biological and physical characteristics of the soil, which facilitates optimal nutrient uptake by the plants and an increase in output. The results of present study are similar with Mohanta *et al*., (2018) [17], Devi *et al*., (2018) [6] and Shankar *et al*., (2019) [20].

Table 3: Effect of different treatments on growth parameters (plant height (cm), number of leaf, leaf length (cm) and head initiation)

Treatments	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Head initiation
N: P: K (100%)	54.35	17.52	29.48	53.22
Farm Yard Manure (100%)	45.17	13.50	25.99	67.14
Vermicompost (100%)	48.82	16.05	26.08	63.74
Poultry Manure (100%)	51.40	16.81	26.14	62.81
N: P: K (50%) + Farm Yard Manure (50%)	57.28	18.21	31.02	50.31
Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)	59.07	21.49	31.14	59.51
Vermicompost (50%) + Poultry Manure (50%)	52.74	16.20	28.62	58.41
S.Em±	1.20	1.09	1.20	1.21
$CD_{(0.05)}$	3.71	3.36	3.68	3.72

Table 4: Effect of different treatments on yield parameters (head diameter (cm), head weight (g), yield per plot (kg), yield per hectare (q)

Treatments	Head diameter (cm)	Head weight (g)	Yield per plot (kg)	Yield per hectare (q)
N: P: K (100%)	12.04	465.66	4.19	155.23
Farm Yard Manure (100%)	7.83	305.39	2.75	101.80
Vermicompost (100%)	9.91	365.42	3.29	121.82
Poultry Manure (100%)	10.44	382.84	3.45	127.62
N: P: K (50%) + Farm Yard Manure (50%)	12.41	510.42	4.59	170.15
Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)	11.30	400.51	3.60	133.51
Vermicompost (50%) + Poultry Manure (50%)	11.35	440.29	3.96	146.78
S.Em ±	0.78	5.91	0.20	1.97
$CD_{(0.05)}$	2.40	18.20	0.61	6.07

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

Treatments	Water holding capacity (%)	Soil pH	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
N: P: K (100%)	15.22	5.74	0.52	305.32	35.41	274.68
Farm Yard Manure (100%)	26.43	6.18	0.69	247.83	22.18	198.11
Vermicompost (100%)	23.45	5.98	0.92	268.52	20.88	212.61
Poultry Manure (100%)	20.09	6.12	0.65	258.18	24.13	204.81
N: P: K (50%) + Farm Yard Manure (50%)	17.31	5.92	0.59	289.29	29.11	235.45
Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)	24.82	6.20	0.71	282.18	27.41	230.48
Vermicompost (50%) + Poultry Manure (50%)	22.18	6.12	0.87	274.78	25.61	223.15
S.Em±	0.23	0.10	0.01	3.08	0.41	4.19
$CD_{(0.05)}$	0.71	NS	0.03	9.52	1.29	12.32

Table 6: Economical analysis of organic manures and inorganic fertilizers (cost of cultivation (₹/ha), gross return (₹/ha), net return (₹/ha) and benefit cost ratio)

Treatments	Yield/ ha	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net returns (₹/ha)	Benefit: Cost Ratio
N: P: K (100%)	155.23	1,05,598	5,43,313.46	4,37,715.46	4.15:1
Farm Yard Manure (100%)	101.80	1,28,405	3,56,316.84	2,27,911.84	1.77:1
Vermicompost (100%)	121.82	1,22,245	4,26,357.44	3,04,112.44	2.49:1
Poultry Manure (100%)	127.62	1,06,245	4,46,682.4	3,40,437.40	3.20:1
N: P: K (50%) + Farm Yard Manure (50%)	170.15	1,16,921	5,95,537.64	4,78,616.64	4.09:1
Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)	133.51	1,21,245	4,67,299.05	3,46,054.05	2.85:1
Vermicompost (50%) + Poultry Manure (50%)	146.78	1,14,245	5,13,712.76	3,99,467.76	3.50:1

Soil parameters

Data revealed that higher water holding capacity (26.43) in soil was observed in treatment T_2 [Farm Yard Manure (100%)] followed by treatment T_6 [Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)]. Although, lower water holding capacity (15.22) was measured in T_1 [N: P: K (100%)]. The water holding capacity in soil is influenced by many factor especially soil texture, organic matter and structure of the soil. The similar result is in accordance with the finding of Kumar *et al*., (2018) [11], Yadav *et al*., (2020) [27] and Merentoshi *et al*., (2022) [15].

A review of the data showed that higher soil pH (6.20) was recorded in treatment T_6 [Farm Yard Manure (50%) + Poultry Manure (25%) + Vermicompost (25%)] which were statistically followed by the treatment T_2 [Farm Yard Manure (100%)], while the lower pH (5.74) was found in treatment T_1 (N: P: K (100%). The majority of soils are moderately acidic to slightly acidic in reaction.

A review of the data showed that highest organic carbon (0.93) was recorded in treatment T_3 [Vermicompost (100%)] which were followed by the treatment T_7 [Vermicompost (50%) + Poultry Manure (50%)], while the lowest organic carbon (0.52) was observed in treatment T_1 [N: P: K (100%)]. The application of organic manure like vermicompost, which promote the growth and activity of microorganisms, may be the cause of the increased organic carbon content. The result of present study is similar with Walling *et al*., (2022) [26] and Choudhary *et al*., (2022) [4].

The data pertaining to availability of N, P and K in post-harvest soil revealed that the higher content of available nitrogen (305.32 kg/ha), Phosphorus (35.41kg/ha) and Potassium (274.68 kg/ha) was recorded in treatment T_1 [N: P: K (50%)] which was followed by the treatment T_5 [NPK (50%) + Farm yard manure (50%)]. However, the lower content of available nitrogen (247.83 kg/ha), available phosphorus (22.18 kg/ha) and available potassium (204.81 kg/ha) was measured in T_2 [Farm yard manure (100%)]. The use of inorganic fertilizers increased the amount of N, P and K that accumulated in the soil. Increased soil nitrogen accessibility results from the addition of nitrogenous fertilizers. One potential explanation for the improvement in soil potassium status is a drop in K fixation and release brought about by the interaction of clay and organic matter. The result of present study is similar with Kumar *et al*., (2017) [10] and Walling *et al*., (2022) [26].

Economics

The combine use of organic manures and inorganic fertilizers has substantial effect on economics. The highest cost of cultivation ₹ 1, 28, 405 was incurred in treatment T_2 [Farm Yard Manure] followed by T_3 [Vermicompost (100%)] i.e. ₹ 1, 22, 245. The economics in terms of gross return (₹5, 95, 537.64), net return (₹4, 78, 616.64) were maximum in T_5 [N: P: K (50%) + Farm Yard Manure (50%)] and higher B: C ratio (4.15:1) was found in T_1 (N: P: K (100%). The minimum gross return (₹ 3, 56, 316.84), net return (₹ 2, 27, 911.84) and B: C ratio was found in treatment T_2 [Farm Yard Manure (100%)].

Conclusion

The combination of organic and inorganic sources of nutrients in the current study revealed significant variations for growth and yield of broccoli. On the basis of present investigation, it can be concluded that treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)] recorded best for growth and yield contributing traits. This treatment also had highest net return and gross returns. The combine application of organic and inorganic fertilizer treatment T_5 [N: P: K (50%) + Farm Yard Manure (50%)] show best result for growth and yield as compare to other treatments.

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