E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(6): 632-637
Received: 14-03-2024
Accepted: 18-04-2024

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Performance of cauliflower in north western Himalayas: Comparative assessment to integrated nutrient management practices

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i6i.940

Abstract
The present study was carried out at the Research farm of Abhilashi University, Mandi (H.P) during the *rabi* season of 2023 - 24. The experiment was laid out in a randomized block design with three replications comprising seven treatments consisting of different sources of organic manures and inorganic fertilizers to assess the impact of integrated nutrient management on the growth, yield, soil and economics of cauliflower. The results revealed that treatment consisting of N: P: K (50%) + Biochar (25%) + Poultry Manure (25%) influenced all parameters like plant height (53.16 cm), number of leaves per plant (15.56), leaf length (47.07 cm), curd weight (656.04 g), curd diameter (13.16 cm), yield per plot (5.90 kg) and yield per hectare (218.70 q/ha). The higher soil pH (6.0) was recorded in treatment T_2 [N: P: K (100%)], the higher organic carbon (0.98%) was recorded in treatment T_5 [Biochar (50%) + Poultry Manure (50%)], higher water holding capacity was observed in treatment T_4 [Farm Yard Manure (100%)]. The higher available N (303.82 kg/ha), P (38.09 kg/ha) and K (274.01 kg/ha) were recorded under treatment T_2 [N: P: K (100%)]. The maximum net return (₹ 3, 20, 107) and B: C ratio (2.7:1) were also increased by N: P: K (50%) + Biochar (25%) + Poultry Manure (25%). Hence, application of NPK (50%) + Biochar (25%) + Poultry Manure (25%) can be recommended for its commercial use after verifications of results by way of conducting on farm trials across the cauliflower growing areas of Himanchal Pradesh.

Keywords: Cauliflower, biochar, organic, inorganic, growth, yield, economics

Introduction
Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most popular winter vegetable belongs to the Brassicaceae family. It is an herbaceous annual for growing vegetables and a biennial for growing seeds. Cauliflower was derived from two Latin words "caulis" (Meaning stem) and "floris" (Meaning flower). In India it is grown over an area of 473 thousand ha with a production of 9.22 million MT (Anonymous 2021a) [1]. Being an important off-season vegetable crop of mid and high hills of Himachal Pradesh, it is grown in an area of about 5.64 thousand ha with a production of 135.11 thousand MT (Anonymous 2021b) [2]. After the green revolution, excessive use of chemical fertilizers has increased vegetable production and quality but also caused soil degradation, ecological hazards, and depletion of non-renewable energy sources (Chauhan *et al*. 2023) [7]. The rising cost of chemical fertilizers along with their negative impact on soil health, environment and human health, forced farmers to adopt alternative nutrient sources as a substitute for vegetable production. People shifted from conventional methods to integrated nutrient management systems because people became more aware of the decline in soil health and excessive application of chemical fertilizers in modern farming (Kumar and Srivastava 2006 [12]; (Chauhan *et al*. 2022) [6]
The increasing prices of inorganic fertilizers and their harmful impact on soil climate and human health also forced farmers to acquire alternate sources of nutrients for improving vegetable production. The integrated nutrient management (INM) is the best solution to overcome these problems which involve the combined use of organic and inorganic fertilizers to maintain crop production as well as sustain soil health.

Nutrient management is one of the most important factors influencing cauliflower growth, development and yield. Inorganic fertilizer (NPK) is used to provide nutrients for plants quickly (Shanta *et al*. 2015) [19]. It can increase the quality, yield and vegetative growth of cauliflower. But the long-term use of inorganic fertilizer can reduce the physical, chemical and biological qualities of soil and also pollute the environment and human health (Shambhavi and Sharma 2008) [18]. On the other hand, organic manures are cheap and affordable sources of nutrients that help to balance the soil ecosystem and also increase the soil nutrient availability, improve structure, increase water retention, maintain the proper carbon-to-nitrogen ratio, minimize soil pollution and promote the growth of beneficial microorganisms in the soil. Thus, we need to use an integrated approach to nutrient management (Jaswal *et al*. 2023) [10].

Material and Methods

Experimental site

The present investigation was conducted during the *rabi* season 2023-24 at the Research Farm School of Agriculture, Abhilashi University, Mandi (H.P). The experimental farm is situated at 31º33'29''N latitude and 77º00'48''E longitudes with an elevation of 1,410 m above mean sea level**.**

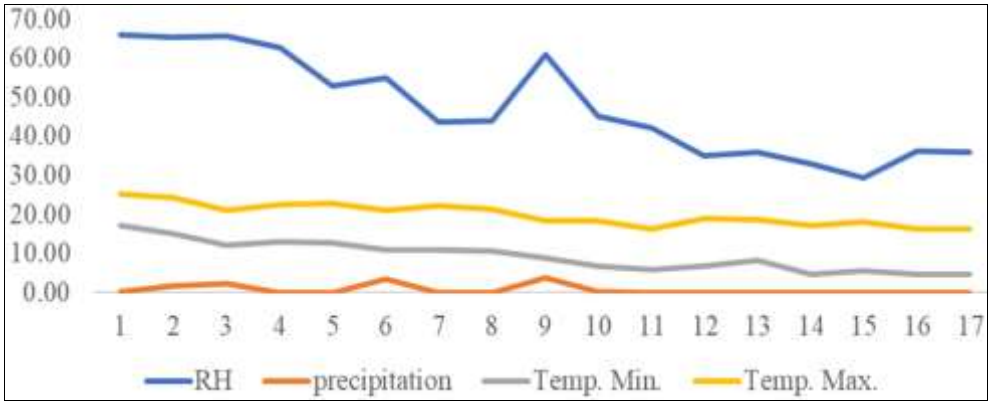

Fig 1: Meteorological data of the Experimental farm recorded during October 2023 to February 2024.

Table 1: Treatment details

Treatment code	Treatment details
T_1	Control
T_2	N: P: K (100%)
T_3	Biochar (100%)
T_4	Farm Yard Manure (100%)
T_5	Biochar (50%) + Poultry Manure (50%)
T_6	N: P: K (50%) + Biochar (25%) + Poultry Manure (25%)
T_7	N: P: K (50%) + Poultry Manure (50%)

Design of experiment

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

Variety	Girija (Cauliflower)
Design	Randomized Complete Block Design (RCBD)
Replication (s)	3
Treatments	7
Plot size	1.3m ×1.8m
Spacing	45 cm × 60 cm
Date of sowing	2 October 2023
Date of transplanting	30 October 2024

Growth parameters

Plant height (cm)

The height of five randomly chosen plants was measured at the harvesting stage from the ground level to the tip of each leaf and after that their average height per plant was calculated.

Number of leaves per plant

The number of leaves of five-tagged plant in each experimental plot was counted and their average was calculated.

Leaf length (cm)

The length of leaves of five-tagged plants was measured and the mean was calculated for each treatment.

Yield parameters

Curd weight (g)

To calculate the curd weight, the curds of five randomly selected plants in each plot, whole were weighed on electronic balance after cutting the leaves and stalk. Finally, the average weight of curd in each plot was calculated in grams.

Curd diameter (cm)

The maximum width of the curd of the five randomly selected and labelled plants are measured and the average is taken as the diameter of curd.

Yield per plot (kg)

All curds of tagged five plants from each treatment were weighed and the average was worked out and recorded as curd yield per plant. Curd yield per plot was obtained by multiplying plant yield with total number of plants per plot.

Yield per hectare (q)

Curd yield per plot was converted into yield per hectare by multiplying with a suitable factor taking into consideration 90% of net planting area which was expressed as q ha^{-1}.

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 chemical parameters like soil pH, available NPK and organic carbon concentration.

Table 2: Initial chemical parameters of the experimental soil

S No.	Parameters	Values obtained	Methods used
1	Water holding capacity (%)	16.5	Keen's box method (Keen and Raczkowski, 1973
2	Soil pH (1:2.5 soil:water)	5.8	Glass electrode method (Jackson, 1973) [24]
3	Available Nitrogen (kg/ha)	226.6	Alkaline potassium permanganate (Subbiah and Asija, 1956)
4	Available Phosphorous (kg/ha)	18.7	Olsen's method of extraction with 0.5 1NaHCO3 at pH 8.5 (Olsen *et al.* 1954) [25]
5	Available Potassium (kg/ha)	192.2	Neutral ammonium acetate extraction method (Merwin and Peech 1950) [26]
6	Organic carbon (%)	0.62	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 labor, organic manures, irrigation and other expenditure. The total income per hectare was calculated as per the average wholesale price of cauliflower 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 utilised 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 (Rs/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

Plant height is an important character in cauliflower for increased productivity. Plant height is a genetically controlled character is also influenced by the environment to a great extent. Among all the treatments, maximum plant height (53.16 cm) was recorded in treatment T_6 (N: P: K (50%) + Biochar (25%) + Poultry Manure (25%) which was followed by the treatment T_7 (N: P: K (50%) + Poultry Manure (50%) i.e (49.76 cm) while the minimum plant height (38.16 cm) was observed under the treatment T_1 (Control). This may be due to addition of biochar along with organic and inorganic amendment in addition to biochar, improves the soil nutrient status. Biochar additionally acts as a slow-release fertilizer for the crop, promoting good plant growth. The beneficial effects of biochar addition on crop production can be attributed to changes in soil characteristics and nutrient availability. (Chan *et al*. 2007 and Sohi *et al*. 2010) [5, 20].

The number of leaves in a plant is an important characteristic that is directly related to leaf area and ultimately, yield. More leaves per plant means more photosynthetic area, yield and as a result, higher returns. The maximum number of leaves per plant (15.56) was obtained under the treatment T_6 (N: P: K (50%) + Biochar (25%) + Poultry Manure (25%) which was followed by the treatment T_7 (N: P: K (50%) + Poultry Manure (50%) i.e (14.21). The minimum number of leaves per plant (9.47) was observed under the treatment T_1 (Control). The effects were caused by the increased nutritional supply that was encouraged by the addition of biochar with organic and inorganic fertilizer. This increased nutrient availability increased the amount of nitrogenous compounds that the plant could use from organic and inorganic sources, which increasing the plant foliage and photosynthesis (Sohi *et al*. 2010) [20].

Leaf length plays a significant role in determining overall plant height and ultimately yield of plant. Leaf length plays a crucial role in determining a plant photosynthesis potential, water retention capacity and overall ecological function within its ecosystem. Analysis of data shows that the maximum leaf length (47.07 cm) was observed in treatment T_6 (N: P: K (50%) + Biochar (25%) + Poultry Manure (25%) which was followed by the treatment T_7 (N: P: K (50%) + Poultry Manure (50%) i.e (43.76 cm). While the minimum leaf length (31.66 cm) was observed under the treatment T_1 (Control). Increase in leaf length might by due to application of organic and inorganic fertilizer along with biochar which increase nutrient quantity in soil and enhance the availability of more nitrogenous and other nutrient in the soil that can increase the foliage of plant and also increase the photosynthesis in plant. There result it can also increase in leaf length, plant height and number of leaves per plant (Sohi *et al*. 2009 and Gupta 2005) [21, 9].

Yield parameters

The weight of the curd determines yield and productivity, as well as the quality of the cauliflower. Gross plant weight is an important characteristic which has a direct and positive correlation with yield in cauliflower. Treatment T_6 (N: P: K (50%) + Biochar (25%) + Poultry Manure (25%) recorded the maximum average curd weight (656.04 g) which was followed by the treatment T_7 (N: P: K (50%) + Poultry Manure (50%) i.e. (616.08 g). While the minimum curd weight (371.23) was observed under the treatment T_1 (Control). The increased curd weight of cauliflower might be due to the use of various nutrient sources. In addition, biochar with organic and inorganic fertilizers can improve the availability of nutrients in soil which ultimately improves plant growth and also increases the curd weight of cauliflower (Baral *et al*. 2020) [4].

The curd diameter of cauliflower refers to the size of the central edible portion of the cauliflower head. Analysis of data shows that as compared to other treatments the maximum curd diameter (13.16 cm) was found in the treatment T_6 (N: P: K (50%) + Biochar (25%) + Poultry Manure (25%) which was

statistically at par with the treatment T_7 (N: P: K (50%) + Poultry Manure (50%) i.e (12.96 cm). The lowest curd diameter was found under the treatment T_1 (Control). This could be because the addition of biochar and organic and inorganic fertilizer favors an increase in the quantity of nutrients available to the plant, which in turn increases the diameter of the curd. The highest nutrient uptake and increase in microbial activity in soil caused due to the application of biochar and organic and inorganic fertilizer (Glaser *et al*. 2002 and Lehmann *et al*. 2003) [8, 14].

The main objective of cultivation is to have maximum yield for greater profits. The maximum yield per plot (5.90 kg) was recorded under the treatment T_6 (N: P: K (50%) + Biochar (25%) + Poultry Manure (25%) which was followed by the treatment T_7 (N: P: K (50%) + Poultry Manure (50%) i.e (5.54 kg) and minimum yield per plot (3.07 kg) was reported in treatment T_1 (Control). The combined application of organic and inorganic fertilizer with the addition of biochar increases the nutrient content in soil and also improves the soil fertility and provides nutrients for good growth of the plant that led to an increase in the yield of cauliflower (Baral *et al*. 2020) [4].

The main objective of cultivation is to maximize production in order to increase profitability. Treatment T_6 (N: P: K (50%) + Biochar (25%) + Poultry Manure (25%) recorded the maximum average curd yield of (218.70 q/ha) which was followed by the treatment T_7 (N: P: K (50%) + Poultry Manure (50%) i.e (205.38 q/ha). The minimum (113.74 q/ha) was recorded in treatment T_1 (Control). This is due to biochar and organic and inorganic amendments, alone or in combination, increased the nutrient status of the soil and improving the physical condition of the soil, facilitating plant growth and increasing cauliflower yield (Nooker 2014, Manolikaki and Diamadopoulos 2019 and Arif *et al*. 2012) [17, 16, 3].

Soil analysis

The higher content of N, P and K (N-303.82 kg/ha, P-38.09 kg/ha and K-247.10 kg/ha) was recorded in treatment T_2 [N: P: K (100%)] which was statistically at par with the treatments T_5 [(Biochar (50%) + Poultry Manure (50%)], T_6 [(N: P: K (50%) + Biochar (25%) + Poultry Manure (25%)] and T_7 [(N: P: K (50%) + Poultry Manure (50%)]. while the lower content of N, P and K was recorded in T_1 (control). It might be due to the application of N, P and K fertilizers directly increasing the nitrogen, phosphorus, and potassium content in the soil and preventing certain deficiencies in plants (Kumar *et al*., (2017) [11] and Walling *et al*., (2022) [22].

By the application of different treatment combinations there is an increase in pH (6.0) with the application of treatment T_2 [N: P: K (100%)] and T_6 [N: P: K (50%) + Biochar (25%) + Poultry Manure (25%)] whereas minimum pH (5.8) was recorded in T_1 [Control].

The higher content of water holding capacity (26.79%) in soil was observed in treatment T_4 (Farm Yard Manure (100%) followed by treatment T_5 (Biochar (50%) + Poultry Manure (50%). However, a lower content of water holding capacity (16.58%) was measured in T_2 (Control). This may be due to the organic manure increasing soil water holding capacity by enhancing organic matter content, improving soil structure and porosity, and promoting microbial activity that leads to the formation of water-retentive humus (Yadav *et al*. 2020) [23].

The higher content of organic carbon (0.98%) in soil was observed in treatment T_5 (Biochar (50%) + Poultry Manure (50%) followed by treatment T_3 (Biochar (100%) i.e (0.94%). Whereas, lower content of organic carbon (0.53%) was observed in T_1 (control) i.e (0.59%). Increasing in organic carbon in treatment T_5 might be due to biochar is a mixture of two carbon components one which degrades readily (labile fraction) and the second is a more recalcitrant fraction and the highest values of organic carbon at biochar treated soils indicate the recalcitrance of organic carbon in the biochar. The overall status shows that the soil were measured with high organic carbon (Lehmann 2007 and Liang *et al*. 2006) [14, 15].

Economics

The highest net return (₹ 3, 20, 107) was obtained from the treatment T_6 (N: P: K (50%) + Biochar (25%) + Poultry Manure (25%). Treatment T_1 (Control) recorded the lowest net return (₹ 1, 19, 535).

The overall maximum B: C ratio (2.7:1) was incurred under the treatment T_6 (N: P: K (50%) + Biochar (25%) + Poultry Manure (25%). While the minimum B: C ratio (1.1:1) was recorded in the treatment T_1 (Control).

Table 3: Effect of organic and inorganic sources of nutrients on physico-chemical properties of soil.

Treatment	Soil pH	Water holding capacity (%)	Organic carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available potassium (kg/ha)
Control	5.8	16.58	0.53	222.57	18.74	192.3
N: P: K (100%)	6.0	18.81	0.64	303.82	38.09	247.01
Biochar (100%)	5.9	21.63	0.94	270.06	19.87	212.19
Farm Yard Manure (100%)	5.9	26.79	0.74	276.53	20.86	220.21
Biochar (50%) + Poultry Manure (50%)	5.9	24.64	0.98	285.21	27.09	235.61
N:P:K (50%) + Biochar (25%) + Poultry Manure (25%)	6.0	23.25	0.89	297.83	34.39	242.28
N: P: K (50%) + Poultry Manure (50%)	5.9	20.04	0.82	292.02	31.06	238.03
SE(m) (±)	0.07	0.37	0.01	4.57	0.33	4.05
CD (0.05)	NS	1.15	0.06	14.09	1.03	12.47

Table 4: Effect of organic and inorganic sources of nutrients on plant height, number of leaves per plant and leaf length.

Treatment	Plant height (cm)	Number of leaves per plant	Leaf length (cm)
Control	38.16	9.47	31.66
N: P: K (100%)	46.86	13.81	40.96
Biochar (100%)	40.86	10.92	34.06
Farm Yard Manure (100%)	43.06	12.36	37.02
Biochar (50%) + Poultry Manure (50%)	44.66	13.12	38.66
N: P: K (50%) + Biochar (25%) + Poultry Manure (25%)	53.16	15.56	47.07
N: P: K (50%) + Poultry Manure (50%)	49.76	14.21	43.76
SE (m) (±)	0.54	0.15	0.47
CD $_{(0.05)}$	1.69	0.47	1.47

Table 5: Effect of organic and inorganic sources of nutrients on curd weight, curd diameter, yield per plot and yield per hectare.

Treatment	Curd weight (g)	Curd diameter (cm)	Yield per plot (kg)	Yield per hectare (q)
Control	371.23	9.86	3.10	114.82
N: P: K (100%)	584.65	12.29	5.43	201.13
Biochar (100%)	424.76	10.47	3.68	136.31
Farm Yard Manure (100%)	475.04	11.06	4.12	152.60
Biochar (50%) + Poultry Manure (50%)	534.52	11.64	4.79	177.42
N: P: K (50%) + Biochar (25%) + Poultry Manure (25%)	656.04	13.16	6.09	225.57
N: P: K (50%) + Poultry Manure (50%)	616.08	12.96	5.73	212.24
SE(m) (±)	8.72	0.14	0.05	2.11
CD $_{(0.05)}$	27.19	0.45	0.17	6.60

Table 6: Effect of organic and inorganic sources of nutrients on total cost of cultivation, gross returns, net returns and benefit: cost ratio.

Treatment	Total cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B: C Ratio
Control	1,07,970	2,27,505	1,19,535	1.1:1
N: P: K (100%)	1,15,794	3,77,130	2,61,336	2.3:1
Biochar (100%)	1,13,595	2,83,196	1,69,601	1.5:1
Farm Yard Manure (100%)	1,37,970	3,16,719	1,78,749	1.3:1
Biochar (50%) + Poultry Manure (50%)	1,18,782	3,56,375	2,37,593	2.0:1
N: P: K (50%) + Biochar (25%) + Poultry Manure (25%)	1,17,288	4,37,395	3,20,107	2.7:1
N: P: K (50%) + Poultry Manure (50%)	1,19,882	4,10,753	2,90,871	2.4:1

Conclusion

The present investigation pertaining to the effect of organic and inorganic sources of nutrients should have significant effects for all growth, yield and soil parameters. Results showed that application of N: P: K: (50%) + Biochar (25%) + Poultry manure (25%) proved best for growth, yield and soil. Studies also revealed that N: P: K: (50%) + Biochar (25%) + Poultry manure (25%) yielded maximum and also recorded maximum values of gross returns, net returns and B: C ratio. Therefore, it can be concluded that the treatment T_6 [N: P: K: (50%) + Biochar (25%) + Poultry manure (25%)] may be recommended for its commercialization after verification of results by way of conducting on farm trial across the cauliflower growing areas of Himachal Pradesh, India

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