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Effect of Integrated Nutrient Management on Growth, Yield Attributes, Yield and Economics of Off-season Cauliflower (*Brassica oleracea* var. *Botrytis* L.) Grown under North Eastern Ghat Zone of Odisha

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ABSTRACT

The experiment was conducted during 2019 (July–October) at farmer's field in Kandhamal district of Odisha under Krishi Vigyan Kendra, Kandhamal, Zone-V, Kolkata, OUAT, Bhubaneswar, Odisha, India to study the effect of integrated nutrient management on growth, yield attributes, yield and economics of off-season cauliflower (*Brassica oleracea* var. *Botrytis* L.). The experiment was laid out in Randomized Block Design (RBD) consisted of four treatments with seven replications. The treatments comprised of T_1: Farmer's practice (FYM @ 1 t ha^{-1} and fertilizer @ 60-40-30 kg N-$P_2O_5K_2O$ ha^{-1}), T_2: 100% RDF @120:60:60 kg N-P_2O_5-K_2O ha^{-1}, T_3: Soil test based NPK+FYM @ 5 t ha^{-1} and T_4: Soil test based NPK+FYM @ 5 t ha^{-1}+Boron. From the experiment it was found that integrated application of chemical fertilizers as per soil test results, organic manures (FYM @ 5 t ha^{-1}) and micronutrient (boron) was the best option for achieving better yield. The highest plant height (57.3 cm), number of leaves plant^{-1} (22.7), leaf length (35.6 cm), curd yield (188.4 q ha^{-1}), marketable curd weight (635.4 g), net return (₹ 1,48,260 ha^{-1}) and B C ratio (1:3.2) were recorded with the treatment T_4 followed by and T_2. Whereas, the lowest values of growth parameters like plant height (40.7 cm), number of leaves plant^{-1} (16.2), leaf length (26.1 cm), curd yield (140.2 q ha^{-1}), marketable curd weight (466.8 g), net return (₹ 1,01,130 ha^{-1}) and B C ratio (1:2.7) were recorded with the treatment T_1.

KEYWORDS: Boron, economics, integrated nutrient management, RDF, yield

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Cauliflower (*Brassica oleraceae* var. *Botrytis* L.) is one of the most important vegetables among the cole crops grown round the year. The crop is a native of Southern Europe in the Mediterranean region and was introduced to India from England in 1822 (Bairwa et al., 2023). The pre-floral white fleshy apical meristem known as curd is the edible part of cauliflower constitutes roughly 45% of the entire plant (Thakur et al., 2019). Cauliflower curd is usually consumed as salad, vegetables, curries and pickles and is also used in the preparation of fried snacks, burgers and sandwiches in resturants (Ashraf et al., 2017). 100 g of curd has high value protein (2.6 g), moisture (90.8 g), fat (0.4 g), carbohydrates (4.0 g), fibre (1.2 g), calcium (33.0 mg), phosphorus (57.0 mg), iron (1.5 mg), vitamin A (51 mg), vitamin C (56.0 mg) and energy (30 kcal) (Chaudhary et al., 2024). Besides, cauliflower contains a higher amount of folic acid, water and ascorbic acid (Eimon et al., 2019). It also contains several phytochemicals that might be beneficial to human health (Kaur et al., 2020 and Madumathi et al., 2017).

In India, cauliflower is grown mainly in the states like Bihar, Uttar Pradesh, Odisha, West Bengal, Assam, Maharashtra, Haryana and Himachal Pradesh in an area of 4,58,000 hectare with a production of 88,40,000 mt and productivity of 19.13 t ha^{-1} (Sharma et al., 2022). However, the cauliflower is grown in an area of around 4000 hectares with an average productivity of 13.09 t ha^{-1} in Kandhamal district of Odisha.

Most of the farmers of Kandhamal district are tribal and they grow cauliflower mostly adopting the traditional practices. The farmers usually get low yield and net return from this vegetable cultivation. Among the many factors responsible for low productivity, inadequate and imbalanced nutrition occupy the top position.

Farmyard manure improves soil qualities, lowering the need for chemical fertilizers, increases soil moisture content in the soil. (Koodi et al., 2022).

Micronutrients are very important for growth and production of cauliflower. Micronutrients, although required in trace amounts, however, they act as a catalyst in the uptake and use of macronutrients (Swetha et al., 2020). Among the essential plant micronutrients, boron is necessary for cell division, germination of pollen, movement of sugars through protoplasmic membranes, development of phloem and transport of certain hormones (Dogra et al., 2019). Boron has emerged as the most deficient nutrient in Indian soils accounting for 23.2% deficiency level among the micro and secondary nutrients (Shukla and Behera, 2017). Boron deficiency causes abnormal development of reproductive organs and reduces plant yield (Dogra et al., 2019).

Among the various agronomic practices affecting crop production, nutrition was found to have a major effect on the growth, yield, quality and economics of cole crops. (Thapa et al., 2022). Systematic approach to nutrient management by tapping all possible sources of organic as well as inorganic in a judicious manner to maintain soil fertility and crop productivity is the essence of integrated nutrient management (Meena et al., 2022 and Pawar and Barkule, 2017).

Several studies have been conducted on INM in cauliflower in India but there is very limited information available in Odisha. Moreover, no research work has been reported on the effects of INM including boron in cauliflower in Kandhamal district of Odisha. Therefore, in order to boost the yield of cauliflower and give farmers a high income, the present study was undertaken during 2019–20.

2. MATERIALS AND METHODS

A field experiment was conducted at farmer's field in Kandhamal district of Odisha under Krishi Vigyan Kendra, Kandhamal, ICAR-Agricultural Technology Application Research Institute, Zone -V, Kolkata, OUAT, Bhubaneswar, India during *kharif* (July to October), 2019. The district lies between 19°34' to 20°36' N latitude and 83°34' to 84°34' E longitude. This trial was conducted in different villages of G. Udayagiri and Tikabali blocks of the district which comes under North Eastern Ghat Zone of Odisha.

The initial soil samples before conducting the trial were collected and analyzed. The pH was determined by electric pH meter and available nitrogen was determined by alkaline permanganate method as reported by Piper (2019) and available phosphorus and potash by Bray's No. 1 method and flame photometer method, respectively. The Electrical Conductivity (EC) was determined by Conductivity Bridge as described by Jackson (1967). The soils of the experimental site were acidic in reaction and the pH varied between 5.01 and 5.43, sandy clay loam in texture and the content of available nitrogen, phosphorus, potassium and boron were varied between 241.3 and 272.8 kg ha^{-1}, 11.8 and 16.9 kg ha^{-1}, 184.7 and 292.8 kg ha^{-1} and 0.31 and 0.44 mg kg^{-1}, respectively. The organic carbon content at initiation of the experiment was in a range of 3.18 to 5.34 g kg^{-1} soil.

The experiment was laid out in Randomized Block Design (RBD) consisted of four treatments with seven replications. The treatments comprised of T_1: Farmer's practice (FYM @ 1 t ha^{-1} and fertilizer @ 60-40-30 kg N-P_2O_5-K_2O ha^{-1}), T_2: RDF @ 120:60:60 kg N-P_2O_5-K_2O ha^{-1}, T_3: Soil test based NPK+FYM @ 5 t ha^{-1} and T_4: Soil test based NPK+FYM @ 5 t ha^{-1}+Boron. Raised beds of 3.0×1.0×0.15 m^3 (L×B×H) size was prepared. The upper 5 cm layer of the bed was

mixed with equal quantity of well rotten FYM and soil. Seeds of cauliflower var. Minakshi Gold were sown in rows of 10 cm apart on 5th July, 2019. Watering was done regularly by rose can and the beds were kept clean by weeding from time to time. The seedlings were kept healthy by taking two sprays of pesticides as per the requirements. Twenty-one days old healthy seedlings were used for transplanting in the main field at a spacing of 45×30 cm^2. Light irrigation was given immediately after transplanting of seedling.

The recommended dose of fertilizer (RDF) @ 120-60-60 kg N-P_2O_5-K_2O ha^{-1} was applied in T_2 treatment, whereas the NPK as per soil test recommendations and FYM @ 5 t ha^{-1} was applied in T_3 and T_4 treatments. The fertilizer @ 60-40-30 Kg N -P_2O_5-K_2O ha^{-1} and FYM @ 1 t ha^{-1} were applied in T_1 treatment (Farmer's practice). In the present investigation, the micronutrient boron was applied in the form of borax in both soil and foliar feed in the treatment T_4 only. The borax @ 0.5 kg ha^{-1} applied in the soil at the time of planting and two foliar sprays of borax @ 0.25% was done at 15 days interval from 25 days after transplanting. Commercially available borax (10.5% B) was used as a source of boron. At the time of transplanting full dose of P and K, half dose of N along with FYM and boron as per the treatments were applied in the soil. Remaining half dose of N was applied at 25 days after transplanting as top dressing. The source for N, P, K and B were urea, single supper phosphate, muriate of potash and borax, respectively. Irrigation and other intercultural operations were followed as per the recommended package of practices. Ten plants were randomly selected excluding the boundary area to record observations for various growth and yield contributing characters of cauliflower. The crop was harvested by cutting the entire plant at ground level. Growth parameters like plant height, leaf number, leaf length and yield parameters like marketable curd weight, curd depth, curd diameter and curd yield were recorded following the standard methods. Further, the days to curd maturity was recorded by observing the field regularly. Five plant samples at the time of harvest were also randomly collected from each plot and mixed separately to determine concentrations of N, P and K. Well ground samples of known weight of plant (leaf, curd and root) were digested in di-acid mixture observing all relevant precautions as laid down by Piper (1966) for estimation of P and K content. Separate digestion was carried out for N content estimation as suggested by Jackson (1973).

To determine the most economic treatment, the economics of each treatment were calculated based on the current market price of the produce and inputs used. Benefit cost ratios (B:C) for each treatment were determined after calculating the gross and net return. Gross return (₹ ha^{-1}) was calculated by multiplying total produce (yield) by the relevant market prices at the time. The economic parameters were calculated by using the following formulae.

The data obtained during the trial were analyzed by following the standard statistical procedure given for RBD by Panse and Sukhatme (1985). To evaluate whether there was a significant difference between the treatments, the Critical Difference (CD) at the 5% level was utilized.

3. RESULTS AND DISCUSSION

3.1. Growth parameters

It was found from the present study that INM practices significantly increased the growth parameters of cauliflower like plant height (cm), number of leaves $plant^{-1}$, leaf length (cm) and days to maturity. The highest plant height (57.3 cm), number of leaves $plant^{-1}$ (22.7) and leaf length (35.6 cm) were recorded (Table 1) with the treatment T_4 (Soil test based NPK+FYM @ 5 t ha^{-1}+Boron) followed by T_3 (Soil test based NPK+FYM @ 5 t ha^{-1}) and T_2 (100% RDF). Whereas, the lowest values of growth parameters like plant height (40.7 cm), number of leaves $plant^{-1}$ (16.2) and leaf length (26.1 cm) were recorded with the treatment T_1 (Farmer's Practice).

The increased in growth parameters in T_4 was because of combined application of optimum level of inorganic and organic fertilizers along with micronutrient (boron) improved the physico-chemical and biological properties of the growth medium (Sharma et al., 2022). The inorganic fertilizers might have supplied nutrients at the start of the growth period, whereas FYM provided the nutrients throughout the crop growth period in keeping with the need of the plants. Singh et al. (2015) also noted maximum plant height and leaves $plant^{-1}$ with the application of integrated use of N, P, K, organic manures and boron in broccoli. This might be due to the synthesis of proteins from nitrogen which formed the carbohydrates in crop plants and which in turn favoured increased in plant growth parameters. Meena et al. (2023) also reported that combined application of inorganic, organic fertilizers along with micronutrient (boron) enhanced the growth parameters like plant height, leaf area and number of leaves $plant^{-1}$ of cauliflower, this might be because the root zone provided a better nutritional environment for plant growth and development. These findings closely matched with Kumhar (2004), Maniruzzaman et al. (2007), Pawar and Barkule (2017) and Simarmata et al. (2016). The minimum growth parameters during the study were observed in the treatment T_1 which might be due to boron deficiency and imbalanced nutrition. Boron played vital role for enhancement of growth parameters of cauliflower. The increased in growth parameters of cauliflower might be due to availability of more micronutrient to the plants, which increases the foliage of plant and there by enhances photosynthesis (Tarafder

Table 1: Effect of integrated nutrient management practices on growth parameters, yield attributes and nutrient uptake by cauliflower

Treatments	Plant height (cm)	No. of leaves plant^{-1}	Leaf length (cm)	Days to maturity	Marketable curd weight (g)	Curd diameter (cm)	Curd depth (cm)	Curd yield (q ha^{-1})	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
T_1	40.7	16.2	26.1	92.4	466.8	7.9	6.1	140.2	42.8	6.9	32.4
T_2	48.6	20.5	30.7	85.8	502.3	8.5	6.8	159.5	55.6	8.1	42.3
T_3	54.9	21.9	33.4	83.6	597.5	9.2	7.2	172.8	59.1	8.9	46.4
T_4	57.3	22.7	35.6	79.3	635.4	10.4	7.7	188.4	63.2	9.7	50.8
CD (p=0.05)	1.78	0.74	0.74	1.22	13.91	0.38	0.23	3.42	1.25	0.42	0.92
SEm±	0.60	0.24	0.25	0.41	4.68	0.12	0.07	1.15	0.42	0.14	0.31

T_1: Farmer's practice; T_2: 100% RDF; T_3: Soil test based NPK+FYM @ 5 t ha^{-1}; T_4: Soil test based NPK+FYM @ 5 t ha^{-1}+Boron; * Farmer's Practice: FYM @ 1 t ha^{-1}, 60-40-30 kg N-P_2O_5-K_2O ha^{-1}

and Roy, 2023). Kumar and Khare (2015) reported that, the increase in plant height might be attributed due to balanced supply of nutrients through chemical fertilizers resulting in higher plant canopy which in turn increased photosynthetic processes during development. These findings were strongly supported by Chatopadhyay and Mukhapadhyay (2003), Hossain et al. (2000) and Meena et al. (2022).

Harvesting of horticultural produce at the appropriate maturity stage is crucial for optimum yield and to maintain its quality for maximum earning. Cauliflower is harvested as soon as the curd attains desirable size, shape and colour (Sharma et al., 2022). Harvesting too early or too late reduces productivity and quality of cauliflower. In the present study it was observed that cauliflower under T_4 took minimum days (79.3 days) to attain marketable curd maturity. Integrated nutrient management practices might have a significant impact as they enhanced the soil fertility status, resulted in a faster rate of crop growth and development, which led to early head formation (Chaubey et al., 2006).

3.2. Yield and yield attributes

Yield and productivity along with good quality of cauliflower largely depended on weight and size of the curd. Yield and yield attributes were also significantly affected by INM practices. Maximum marketable curd weight (635.4 g), curd diameter (10.4 cm), curd depth (7.7 cm) and curd yield (188.4 q ha^{-1}) were recorded (Table 1) with the treatment T_4 (Soil test based NPK+FYM @ 5 t ha^{-1}+Boron) followed by T_3 (Soil test based NPK+FYM @ 5 t ha^{-1}) and T_2 (100% RDF). Whereas, the lowest of these values were recorded in T_1 (Farmer's practice). These highest values of yield and yield attributes in T_4 might be due to prolonged availability of nutrients through organic, inorganic and micronutrient combinations. Thakur et al. (2019) reported that the increase in yield attributing characters of cauliflower were recorded due to application of boron along with recommended dose of NPK and FYM, this might be due to increased cell division and cell elongation increased tissue formation. Bairwa et al. (2023) in his study revealed that the combined application of micronutrients along with RDF improved the yield and quality of cauliflower. This increase might be due to large uptake and effective utilization of nutrients for increased synthesis of carbohydrates, more vegetative growth and subsequently better partitioning and remobilization of accumulated assimilates towards developing curds. The favorable effect of boron might be attributed to its involvement in cell division and cell expansion. Boron also plays an essential role in development of growth of new cells in the plant meristem. Therefore, increased cell division and cell elongation led to better crop yield. These results were coincided with the findings reported by Singh et al. (2018), Neupane et al. (2020), Sharma et al. (2022), Sagar et al. (2023) and Tarafder and Roy (2023). Thakur et al. (2019) reported that highest curd weight and minimum time for maturity were achieved due to foliar application of micronutrient boron and molybdenum.

3.3. Nutrient uptake

A glance of data given in Table 1 depicted that the N,P and K uptake by cauliflower were highest 63.2 kg ha^{-1}, 9.7 kg ha^{-1} and 50.8 kg ha^{-1}, respectively due to application of Soil test based NPK+FYM @ 5 t ha^{-1}+Boron.

The lower values of N uptake (42.8 kg ha^{-1}), P uptake (6.9 kg ha^{-1}) and K uptake (32.4 kg ha^{-1}) were recorded in the treatment T_1 (Farmer's practice). Combined application of organic, inorganic and micronutrient modified the soil environment, improved crop growth and increased yield that resulted in higher uptake of NPK by cauliflower (Saha and Wani, 2017).

3.4. Economics

The cost of cultivation was directly associated with different inputs viz. Chemical fertilizers, FYM and boron. Gross income was found directly related with the yield of curd under different treatments. The maximum gross income and net return of ₹ 2,16,660 ha^{-1} and ₹ 1,48,260 ha^{-1} (Table 2) were calculated with the treatment T_4 (Soil test based NPK+FYM @ 5 t ha^{-1}+Boron), respectively. The highest cost benefit ratio of 1:3.2 was also tabulated with the treatment T_4.

However, the lowest return of ₹ 1,01,130 ha^{-1} and cost benefit ratio of 1:2.7 were observed with treatment T_1 (Farmer's Practice). Similar result was observed by Singh et al. (2023).

Table 2: Effect of integrated nutrient management practices on economics of cauliflower

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
T_1: Farmer's practice*	60100	161230	101130	2.7
T_2: 100% RDF	63400	183425	120025	2.9
T_3: Soil test based NPK+FYM @ 5 t ha^{-1}	65200	198720	133520	3.0
T_4- Soil test based NPK+FYM @5 t ha^{-1}+Boron	68400	216660	148260	3.2

*Farmer's Practice: FYM @ 1 t ha^{-1}, 60-40-30 kg N-P_2O_5-K_2O ha^{-1}; 1US$=INR 71.02 (Average value for October'2019)

4. CONCLUSION

The integrated application of chemical fertilizers, organic manures (FYM @ 5 t ha^{-1}) and micronutrient (boron) enhanced the growth, yield, nutrient uptake and yield attributes of cauliflower which ultimately resulted in maximum net return and B:C ratio.

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