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Effect of Integrated Nutrient Management on Growth and Yield Characteristics of Cauliflower (*Brassica oleracea* var. botrytis L.) cv. Snow Crown

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ABSTRACT: The modern cultivated cauliflower (*Brassica oleracea* L. *var. botrytis*) is one of the most important, vegetable and nutritious vegetable for the world. Increasing need for enhanced crop productivity due to ever increasing population necessitates adequate amount of plant nutrition. Integrated Nutrient Management involves judicious use of organic, inorganic and microbial sources in such a way that it sustains optimum yield, improves and maintains the soil physical, chemical and biological properties, which can bring about equilibrium between degenerative and restorative activates in the soil environment. A field experiment was carried out At the Department of Horticulture, Baba Farid Group of Institute of Management and Technology, Dehradun (U.K.)-248007 (India), during October 2020 to February 2021 to assess the growth and yield characteristics of cauliflower (*Brassica olearaceaceae* L.) botrytis cv. Snow crown. There were 8 treatments comparing control T1, T2 (recommended dose of NPK (150:100:80 kg/ha), T3 (half dose of NPK/ha+FYM@15 t/ha), T4, (half dose of NPK/ ha + Vermicompost @ 2.5 t/ha + FYM @ 15 t/ha), T5 (Half dose NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg/ha), T6 (Half dose NPK/ha + VAM @ 5 kg/ha), T7 (half dose NPK/ha + FYM @15 tons/ha + Azosprilliun @5 kg/ha), T8 (half dose NPK/ha + Azospirillium @ 5 kg/ha). result cm) plant spread (44.30 cm), curd diameter (19.96 cm), curd weight per plant (1002.63 g), curd yield per plot (9.31 kg) and curd weight per hectare (31.04 t/ha) were observed at half the dose. NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg revealed that the highest plant height (59.42 cm), number of leaves (16.28), leaf length (49.02 /ha (T5). half dose of NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg/ha to increase growth and yield of cauliflower.

Keywords: Azospirillium, FYM, Treatments VAM, Yield.

INTRODUCTION

Cauliflower (*Brassica oleracea* var. botrytis L.) is the most popular cruciferous vegetable among Cole crops derived from wild cabbage (*Brassica oleracea* var. sylvestris) and the island of Cyprus is believed to be its center of origin (Kohli *et al.*, 2008). It is a monogenomic species, whose genomic constitution is C and the number of chromosomes 2n=18, belongs to the Cruciferae family. The word cauliflower is derived from the Latin words “Caulis” meaning stem and “floris” meaning flower (Gocher *et al.*, 2017). Worldwide, 25,310,691 tons of cauliflower and broccoli are produced annually.

China is the largest producer of cauliflower in the world with 10,263,746 tons per year; China and India together produce more than 70% of the world's production. India is second with 9235,000 tons per year. In India, cultivation of cauliflower is done over an area of about 552.6 ha with a production of 8668.2 MT and their productivity is 19.2 MT/ Ha (NHB, 2018). In terms of sales, cauliflower, cabbage and tomatoes are the main and common commercial vegetables. It can be grown effectively in temperate to tropical conditions from the interior Terai to the high hills. It can be grown in normal season as well as off season with suitable technologies and varieties as per requirements (Pandey and Pokhrel 2000; Pandey, 2003). Cauliflower is a rich source of vitamins and minerals that can protect against heart disease, and when eaten regularly, it also helps maintain cholesterol levels (Keck, 2004). It is grown for its white tender curd which is used as a vegetable, soup and for pickling. Cauliflower has high quality proteins and peculiar in stability of vitamin C after cooking. It is rich in minerals. Cauliflower fresh curd is highly nutritive and contains moisture 90.8g, protein 2.6g, fat 0.4g, minerals 1.0g, fiber 1.2g, carbohydrates 4.0g, energy 30 kcal, calcium 33 mg, phosphorus 57 mg, Iron 1.5 mg, carotene 30 mg, thiamine 0.04 mg, riboflavin 0.10 mg, niacin 1.0 mg and vitamin-C 56.0 mg per 100 g of edible portion (Jood and Khetrapaul 2011).

The edible part of the curd is consumed as a cooking vegetable, curries, raw as a salad, pickled vegetables, and widely used in the preparation of fried snacks, burgers, and sandwiches in restaurants (Ashraf *et al.* 2017). Among the various agronomic practices affecting production, nutrition was found to have a major effect on the growth, yield, quality and economics of Cole crops. Cauliflower is a heavy feeder of mineral elements and removes a large amount of macronutrients from the soil. Imbalanced use and ever-increasing cost of chemical fertilizers are two disincentives to increase the productivity of these crops. Integrated nutrient management is the balanced use of inorganic fertilizers, organic fertilizers, crop residues and biofertilizers in combination to maintain desired crop production while maintaining soil health.

The basic concept of Integrated Nutrient Management (INM) is to improve soil health and maintain soil fertility status. The use of chemical fertilizers contributes greatly to meeting the nutritional requirements of crops, but the regular, excessive and unbalanced application of chemical fertilizers deteriorates the physico-chemical properties of the soil, the quality of the products and ultimately results in poor crop yields. On the other hand, the demand for micronutrients has increased due to the introduction of profitable varieties and intensive cultivation system for sustainability in crop production. It is essential to maintain the level of soil fertility using all available methods, i.e. chemical fertilizers, organic fertilizers and biological fertilizers. It is therefore necessary to apply all possible sources of nutrients based on economic considerations and to supplement the balance needed for the crop with chemical fertilizers.

The term biofertilizer refers to all nutrients of biological origin for plant growth and development. Biofertilizers are products containing agriculturally important beneficial viable microorganisms that have the ability to mobilize nutritionally important elements from unusable to usable form through a biological process. Beneficial soil microbes that are very important are biological nitrogen fixation, phosphate solubilizer and mycorrhizal fungi. Azospirillium and Azotobactor are bacteria known to fix nitrogen biologically. Using these microbial fertilizers to reduce nitrogen fertilizer quality with some improvement in crop yield. They are also reported to play an effective role in improving crop disease resistance by producing antibacterial and antifungal compounds as well as producing growth regulators. The bacteria cause plant roots to secrete a slime that creates a low-oxygen environment and helps fix atmospheric nitrogen. Azospirillium fixes nitrogen, where as Azotobactor it saves the addition of nitrogen fertilizers. Its inoculation helps the plants in better vegetable growth due to the production of growth hormones such as auxins, gibberellins and cytokinins. FYM supplies organic matter, improves the physical, chemical and biological properties of the soil. It functions as a nutrient reservoir, but its application itself suffers from the disadvantage of high demand and low nutrient status. In recent years, the concept of integrated nutrient supply, use or management includes efficient and judicious supply of all major components of plant nutrient resources. Chemical fertilizers in combination with animal sources, FYM, pest composting, biofertilizers, plant residues or recyclable waste and other locally available sources of nutrients to maintain soil fertility, health and productivity are gaining importance. Integrated supply and utilization of plant nutrients from chemical fertilizers and organic fertilizers has been shown to result in higher crop yields than when both are applied simultaneously. This increase in crop productivity results from their combined effect of a synergistic effect, improving the chemical, physical and biological properties of the soil. Using different sources of nutrients in an integrated manner helps to produce a sustainable yield with good quality. In the study, efforts were made to increase crop productivity using integrated fertilizers, FYM, compost for insect control and phosphorus solubilizing mycorrhizae.

MATERIALS AND METHODS

Experiments were arranged in a Randomized Block Design with three replications. There were eight different treatments, and each treatment was randomly assigned to each plot over the years of the study. In a field experiment, it was not possible to study all plants in detail because all plants used the same opportunities and facilities for their growth and development, that is, within the total population of plants in the plots; five plants were randomly selected from the observation plots. These plants were tagged to record various cauliflower data. A tape measure was used to measure plant height, leaf length, plant spread, and a caliper was used to measure leaf width and curd diameter. Curd weight and total biomass were determined using electronic scales. No. Leaves per plant were visually counted.

RESULT AND DISCUSSION

The observations of various parameters such as plant growth and yield attributes influenced by different sources of integrated nutrient management on cauliflower (*Brassica oleracea* var. botrytis L.) were recorded during 2020-21.

Height of plant (cm). The cauliflower height (cm) as affected by different sources of integrated nutrient management is shown in Table 1 and graphically represented in Fig. 1. Cauliflower height was gradually increased from 30 DAT to 90 DAT. The highest was recorded at (17.47 cm) at 30 days, (13.14) at 60 days and (16.28) at 90 days with T_5 treatment (half rate of NPK/ha + Vermicompost @ 2.5 tons/ha + Azospirillium @ 5 kg/ha) while the minimum plant height of cauliflower was recorded at (15.05 cm) at 30 days, (32.94 cm) at 60 days and (51.86 cm) at 90 days with T_1 (control). The increase in cauliflower height under different treatments can be attributed to the increase in plant growth. This is probably due to the fact that nitrogen may have contributed to an increase in the length of the node and internode, and ultimately to an increase in plant expansion. Similar findings were also reported by Nakaande (2013) in cabbage, Shree *et al.* (2014) in cauliflower, Kumar *et al.* (2015) in cabbage.

Table 1: Effect of integrated nutrient management options on height of plant (cm) of cauliflower at different DAT.

Treatments	30 DAT	60 DAT	90 DAT
T_1	15.05	32.94	51.86
T_2	15.77	34.27	53.68
T_3	15.78	36.56	54.00
T_4	17.15	40.77	57.86
T_5	17.47	44.88	59.42
T_6	17.00	38.70	57.24
T_7	16.97	38.56	55.90
T_8	16.25	37.45	55.25
Mean	16.43	38.02	55.65
SEM±	0.23	0.77	0.72
CD	0.68	2.35	2.20

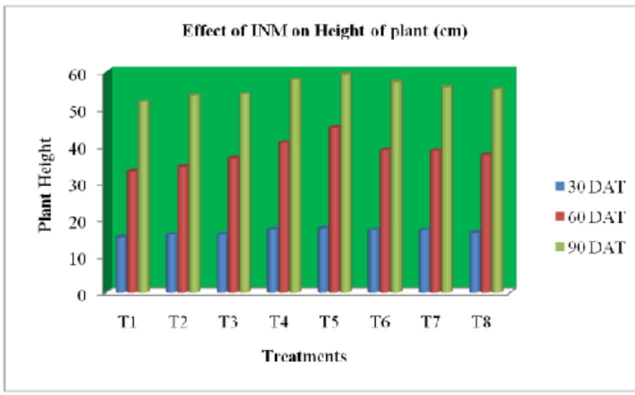

Fig. 1. Effect of integrated nutrient management options on height of plant (cm) of cauliflower at different DAT.

Number of leaves per plant. The number of leaves per plant (cm) of cauliflower as affected by different sources of integrated nutrient management is shown in Table 2 and graphically represented in Fig. 2. The number of cauliflower leaves gradually increased from 30 DAT to 90 DAT. The highest was recorded at (5.04) at 30 days, (13.14) at 60 days and (16.28) at 90 days with T_5 treatment (half dose of NPK/ha + Vermicompost @ 2.5 tons/ha + Azospirillium @ 5 kg/ha) while minimum number of leaves per cauliflower plant was recorded (4.03) at 30 days, (11.01) at 60 days and (13.56) at 90 days with T_1 (control). These findings are in close agreement with the results of Moniruzzamana *et al.* (2007); Salim *et al.* (2008) in cauliflower, Easmin *et al.* in Chinese cabbage Pawar *et al.* (2018) in cauliflower. The increase in the number of leaves could be due to the increased growth of the plant in terms of height and number of leaves that accumulated more photosynthesis and thus increased the number of leaves per plant.

Table 2: Effect of integrated nutrient management options on number of leaves per plant of cauliflower at different DAT.

Treatment	30 DAT	60 DAT	90 DAT
T_1	4.03	11.01	13.56
T_2	4.67	11.35	14.26
T_3	4.68	11.37	14.25
T_4	5.02	12.48	16.22
T_5	5.04	13.14	16.28
T_6	4.76	12.04	15.29
T_7	4.75	11.57	14.97
T_8	4.69	11.55	14.89
Mean	4.70	11.81	14.97
SEM±	0.08	0.24	0.21
CD	0.24	0.73	0.35

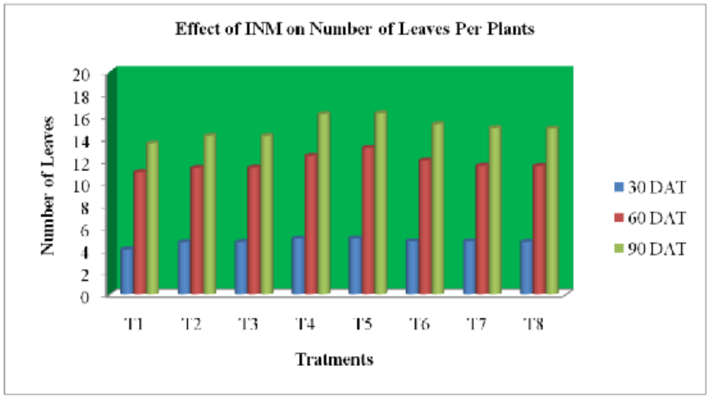

Fig. 2. Effect of integrated nutrient management options on number of leaves per plant of cauliflower at different DAT.

Length of leaf (cm). The cauliflower leaf length increased progressively from 30 DAT to 90 DAT. The highest was recorded at (18.58 cm) at 30 days, (33.88 cm) and (49.02 cm) at 90 days with T_5 treatment (half rate of NPK/ha + Vermicompost @ 2.5 tons/ha + Azospirillium @ 5 kg/ha); while the minimum leaf length of cauliflower plants was recorded as (16.68 cm) at 30 days, (29.86 cm) days and (38.98 cm) at 90 days with T_1 (control). The increase in individual leaf lengths due to the optimal supply of plant nutrients and growth hormones in the right amount throughout the harvest period caused more vegetative growth, ultimately more photosynthesis, and thus the elongation of cauliflower leaves. Cauliflower leaf length (cm) data as affected by different sources of integrated nutrient management are given in Table 3 and graphically represented in Fig. 3. These findings are in close agreement with the results of Moniruzzamana *et al.* (2007), Salim *et al.* (2008) in cauliflower, Easmin *et al.* in Chinese cabbage, Pawar *et al.* (2018) in cauliflower and Yesmin *et al.* (2021) in broccoli.

Table 3: Effect of integrated nutrient management options on length of leaf (cm) of cauliflower at different DAT.

Treatment	30 DAT	60 DAT	90 DAT
T_1	16.68	29.86	38.98
T_2	17.40	31.44	39.64
T_3	17.42	32.01	39.66
T_4	18.36	33.49	47.12
T_5	18.58	33.88	49.02
T_6	17.86	33.15	45.09
T_7	17.68	32.80	44.18
T_8	17.44	32.01	42.17
Mean	17.68	32.33	43.23
SEM±	0.25	0.14	0.13
CD	0.75	0.42	0.39

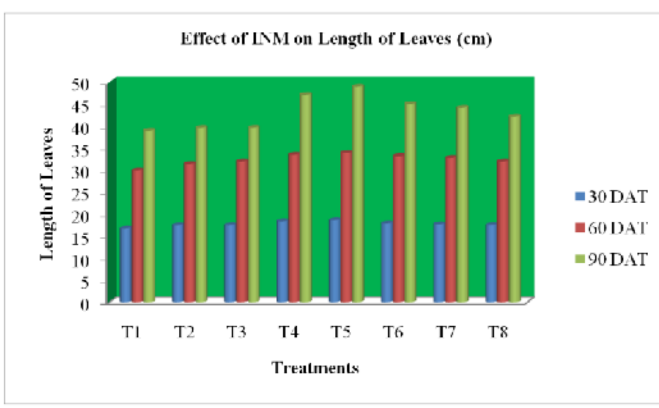

Fig. 3. Effect of integrated nutrient management options on length of leaf (cm) of cauliflower at different DAT.

Spread of plant (cm). Cauliflower spread (cm) data as affected by different sources of integrated nutrient management are presented in Table 4 and graphically represented in Fig. 4. Cauliflower expansion gradually increased from 30 DAT to 90 DAT. The highest was recorded at (19.06 cm) at 30 days, (33.73 cm) at 60 days and (44.30 cm) at 90 days with T_5 treatment (half rate of NPK/ha + Vermicompost @ 2.5 tonnes/ha + Azospirillium @ 5 kg/ha); while minimum spread of cauliflower plants was recorded (15.82 cm) after 30 days, (30.52 cm) after 60 days and (39.93 cm) after 90 days with T_1 treatment (control). Nitrogen Phosphorus and potassium are components of amino acids, nucleotides, nucleic acids, a number of coenzymes, auxins, cytokinins and alkaloids, they induce cell elongation, cell enlargement and cell division. The results of the present investigation in terms of plant height are consistent with the findings previously reported by Salim *et al.* (2008) in cauliflower, Kachari and Korla (2009) in cauliflower, Shree *et al.* (2014); Pawar and Barkule (2017).

Table 4: Effect of integrated nutrient management options on spread of Plant (cm) of cauliflower at different DAT.

Treatment	30 DAT	60 DAT	90 DAT
T_1	15.82	30.52	39.93
T_2	16.94	31.45	40.98
T_3	16.96	31.95	41.01
T_4	18.08	32.97	44.18
T_5	19.06	33.73	44.30
T_6	17.43	32.36	42.25
T_7	17.40	32.35	42.11
T_8	17.15	32.34	41.88
Mean	17.35	32.21	42.08
SEM±	0.13	0.24	0.06
CD	0.40	0.73	0.17

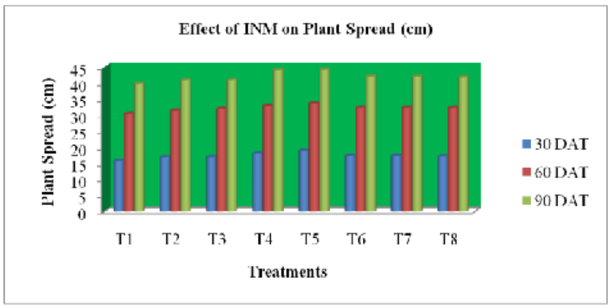

Fig. 4. Effect of integrated nutrient management options on spread of Plant (cm) of cauliflower at different DAT.

Diameter of curd (cm). The effect of various sources of integrated nutrient management is shown in Table 5 and graphically represented in Fig. 5. The diameter of the cauliflower curd increased progressively at harvest time. The highest was recorded (19.96 cm) in T5 treatment (Half dose of NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg/ha) plants (15.07 cm) in T_1 treatment (control). It was closely followed by (17.95 cm), (17.22 cm) with treatments T_4 (Half dose of NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg/ha) and T_6 (Half dose of NPK/ha + VAM @5 kg/ha); while minimum cauliflower curd diameter was recorded (15.07 cm) in T_1 treatment (control). The obtained result was consistent with the findings of Devi *et al.* (2018) in cauliflower and Mohanata *et al.* (2018) in sprouting broccoli. This may be due to an increase in the photosynthetic activity of the plant with overall growth and an increase in chlorophyll content. Increased chlorophyll content produced more photosynthesis that was diverted for curd growth and resulted in better curd nutrition, leading to an increase in curd diameter.

Table 5: Effect of integrated nutrient management options on diameter of curd (cm) of cauliflower.

Treatment	CD 90 DAT
T_1	15.07
T_2	16.08
T_3	16.13
T_4	17.95
T_5	19.96
T_6	17.22
T_7	17.09
T_8	16.64
Mean	17.02
SEM	0.05
CD	0.16

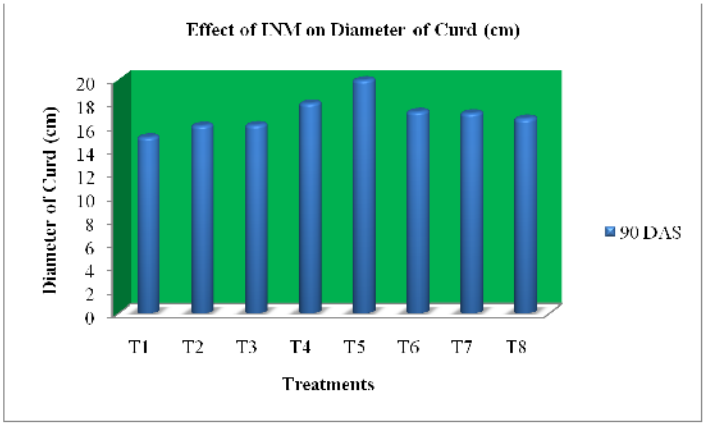

Fig. 5. Effect of integrated nutrient management options on diameter of curd (cm) of cauliflower.

Weight of curd per plant (g). The weight of curd per plant increased progressively due to integrated nutrient management is shown in Table 6 and graphically shown in Fig. 6. The highest was recorded (1002.63) at harvest time with T_5 treatment (Half dose NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg/ha) closely followed by (999.08 g), (973.57 g).) with treatment T_4 (half dose of NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg/ha) and (T_6 half dose of NPK/ha + VAM @ 5 kg/ha); whereas minimum curd weight of cauliflower plants was recorded (713.64) with T_1 treatment (control). Application of organic manure in combination with biofertilizer improves soil structure and soil biological activity. This would reduce nitrogen losses by increasing the cation and anion exchange capacity of the soil, thereby increasing the marketable weight of cauliflower curd. Further improvement of soil structure with greater aggregation, water holding capacity and air permeability were increased. The increase in curd market weight (g $plant^{-1}$) can be attributed to the increase in plant height, leaf number and curd diameter, which may have increased the photosynthetic surface area and led to greater synthesis and translocation of photosynthetase towards curd formation. A similar result was in agreement with Sable and Bhamare (2007); Upadhyay *et al.* (2012) in cauliflower Ujjwal *et al.* (2020) in broccoli.

Table 6: Effect of integrated nutrient management options on weight of curd (g) of cauliflower at harvest (90 DAT).

Treatment	CD 90 DAT
T_1	713.64
T_2	770.59
T_3	772.30
T_4	999.08
T_5	1002.63
T_6	973.57
T_7	954.01
T_8	834.35
Mean	877.52
SEM	6.08
CD	18.43

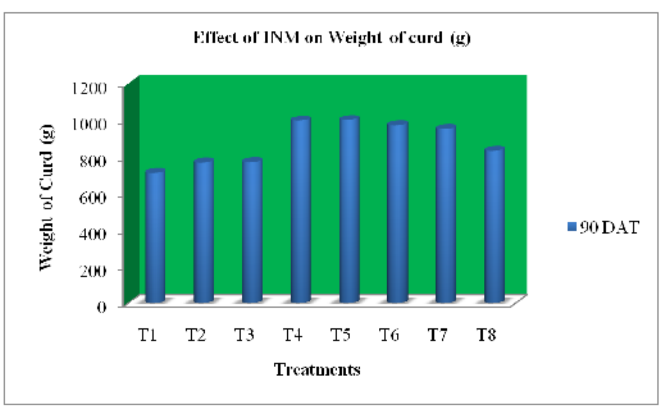

Fig. 6. Effect of integrated nutrient management options on weight of curd (g) of cauliflower at harvest (90 DAT).

Yield per plot (kg). Observations were recorded for yield per plot affected by different sources of integrated nutrient management, which are presented in Table 7 and graphically illustrated in Fig. 7. The maximum yield per plot (9.31 kg/plot) was recorded when applying half rate (NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg/ha (T_5), closely followed by (9.02 cm)), (8.99 cm) with treatment T_4 (Half dose of NPK/ha + Vermicompost @ 2.5 tons/ha + Azospirillium @ 5 kg/ha) and T_6 (Half dose of NPK/ha + VAM @5 kg/ha); while minimum yield per plot of cauliflower was recorded (6.41) in T_1 treatment (control) The similar result was conformity with Bashyal (2011) in cauliflower, Gupta *et al.*, (2010) in knol-khol cv. King and Sarangthem *et al.* (2011) in cabbage.

Table 7: Effect of integrated nutrient management options on yield per plot (kg) of cauliflower at harvest (90 DAT).

Treatment	90 DAT
T_1	6.41
T_2	6.94
T_3	7.41
T_4	9.02
T_5	9.31
T_6	8.99
T_7	8.97
T_8	7.75
Mean	8.10
SEM	0.08
CD	0.23

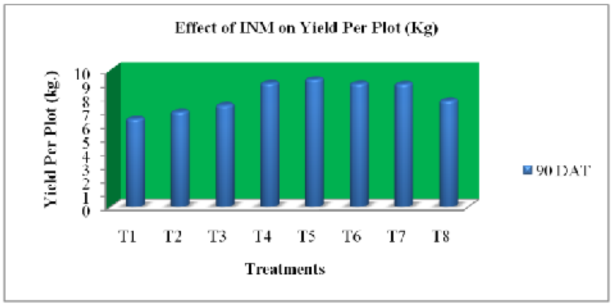

Fig. 7. Effect of integrated nutrient management options on yield per plot (kg) of cauliflower at harvest (90 DAT).

Yield per hectare (tonnes/hectare). The data regarding the hectare yield of cauliflower (tons) affected by different sources of integrated nutrient management at harvest (90 DAT) are presented in Table 8. Data survey revealed that significantly higher yield of cauliflower curd (31.04 t/hectare) achieved by application of T5 (half dose of NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg/ha) resp. for further treatment. It was closely followed by (30.06 cm), (29.97 cm) with treatment T4 (Half dose of NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillium @ 5 kg/ha) and T6 (Half dose of NPK/ha + VAM @5 kg/ha); while minimum hectare yield of cauliflower was recorded (21.38) in T_1 treatment (control). It is interesting to point out that the application of different organic sources + half dose of NPK showed a highly significant response compared to the recommended dose of NPK alone in terms of increase in curd yield (tons/hectare) of cauliflower The similar result was conformity with Chaterjee *et al.*, (2012) in cabbage, Choudhary *et al.* (2012) in sprouting broccoli, Upadhyay *et al.* (2012) in cabbage and Islam *et al.* (2014) in cauliflower.

Table 8: Effect of integrated nutrient management options on yield per hectare (tons/hactare) of cauliflower at harvest (90 DAT).

Treatment	90 DAT
T_1	21.38
T_2	23.13
T_3	24.69
T_4	30.06
T_5	31.04
T_6	29.97
T_7	29.91
T_8	25.84
Mean	27.00
SEM	0.25
CD	0.77

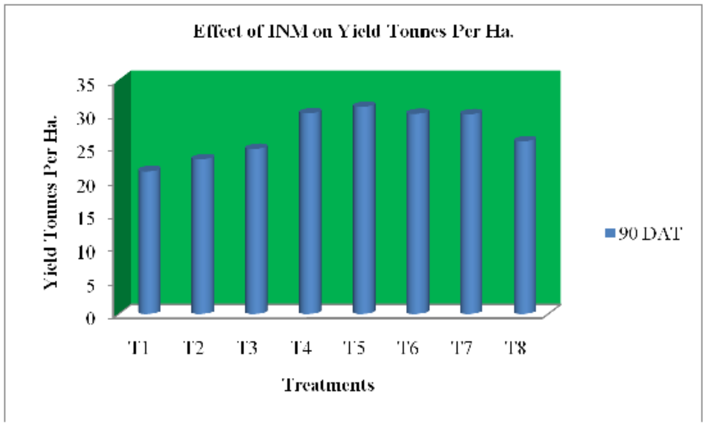

Fig. 8. Effect of integrated nutrient management options on yield per hectare (tons/hactare) of cauliflower at harvest (90 DAT).

CONCLUSION

Based on the results, of this study it can be realized that among the treatments on cauliflower application half dose of NPK/ha + Vermicompost @ 2.5 tonnes/ha + *Azospirillium* @ 5 kg/ha (T_5) was found to be best for growth and yield of the cauliflower. Application half dose of NPK/ha + Vermicompost @ 2.5 tonnes/ha + *Azospirillium* @ 5 kg/ha (T_5) was found effective in improving plant height, number of leaves per plant, spread of plant, curd diameter, curd weight, yield per plot and yield per hectare. The application half dose of NPK/ha + Vermicompost @ 2.5 tonnes/ha + *Azospirillium* @ 5 kg/ha (T_5) for growth and yield of cauliflower. It was found to be most remunerative for farmers. From this study it can be recommend that the application of INM at half dose of NPK/ha + Vermicompost @ 2.5 tonnes/ha + *Azospirillium* @ 5 kg/ha can be applied to obtain maximum yield of Cauliflower variety Snow crown.

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Conflicts of Interest. None.

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