International Journal of Economic Plants

https://ojs.pphouse.org/index.php/IJEP

Crossref

IJEP November 2024, 11(4): 394-399

Article IJEP5703c

Full Research

Doi: HTTPS://DOI.ORG/10.23910/2/2024.5703c

Effect of Integrated Nutrient Management on Growth and Yield Characteristics of Cauliflower (*Brassica oleracea* var. *botrytis* L.) cv. Pant Shubhra under Subtropical Conditions of Uttar Pradesh

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Article History

Received on 15th August, 2024
Received in revised form on 20th October, 2024
Accepted in final form on 06th November, 2024

Abstract

A field experiment was conducted during *rabi* season (September to January) of 2021 and 2022 at the experimental farm of Integral Institute of Agricultural Science and Technology, Integral University, Lucknow, Uttar Pradesh, India. The objective of the experiment is to find out the most efficient combination of different organic and inorganic sources of nutrients to increase the growth, yield characteristics of cauliflower. Total nine numbers of treatments along with the control treatment were assessed in Randomized Block Design with three numbers of replications. In view of, effect of different organic and inorganic sources of nutrients has observed significant variation. The result revealed that the growth parameters like plant height (5.57, 12.47, 19.77 cm), number of leaves (7.97, 9.53, 13.7), length of leaves (17.30, 24.73, 31.73 cm), width of leaves (7.17, 10.20, 15.10 cm), plant spread (285.50, 806.93, 1212.83 cm) at 20, 40 and 60 days respectively, yield parameters like weight of curd (893.73 g), yield of curd plot^{-1} (13.40 kg), yield of curd ha^{-1} (25.30 t) were observed higher in 75% N through RDF+25% N through FYM+Azotobacter @ 5 kg ha^{-1} (T_4). INM treatments showed lesser result on growth and yield of cauliflower in T_1 (control). The treatment T_4 were the most beneficial treatment which may be followed for commercial cauliflower cultivation on large scale. Thus, farmers are suggested to apply 75% N through RDF+25% N through FYM+Azotobacter @ 5 kg ha^{-1} to increase growth and yield of cauliflower.

Keywords: Azotobacter, azospirillum, cauliflower, FYM, vermicompost

1. Introduction

In tropical and temperate regions of the world, cauliflower (*Brassica oleracea* var. *botrytis* L.) is the most widely grown Cole crop belonging to the Brassicaceae family (Sharma et al., 2022). The purpose of growing cauliflower is for its curd, which makes up 20–30% of the plant overall. According to Shams (2019) the curds are high in phenolic compounds, minerals, vitamins C and A, and glucosinolates, which can reduce the risk of cancer. The curd is made up of fleshy, closely packed, truncated floral components (Sagar et al., 2023).

Due to its high nutrient requirements, cauliflower needs a steady supply of both water and substantial amounts of nutrients to support its vigorous growth. While using chemical fertilizers more frequently can increase cauliflower production, doing so indiscriminately increases soil acidity, decreases soil physical condition, reduces organic matter, starts micronutrient deficiencies, increases plant susceptibility to pests and diseases, decreases soil life, and increases soil, water, and air pollution through agricultural runoff and straining. As a result of the rising cost of chemical fertilizers, farmers are overburdened with additional expenses, which reduces the crop's benefit-to-cost ratio (Basnet et al., 2017).

The integrated nutrient management approach adopts the joint application of both organic and inorganic plant nutrient sources and has the potential to secure higher crop productivity which also enhances both human health as well as soil health (Chahal et al., 2019). Applying organic manures after harvesting has been associated with enhanced physical, chemical, and biological aspects of the soil as well as improved soil health, especially in marginal soils that already have low productivity, low native nutrient content, and little organic matter (Rahmann et al., 2017; Selim and Al Jawhara, 2017; Selim, 2018).

Organic components from green plants or animals that have either undergone more decomposition or are already decomposing are used to make organic manure (Simarmata et al., 2016). The long-term sustainability of crop production has been seriously challenged by the difference between the amount of nutrients removed by the crop and the amount of nutrients available in the soil (Mukherjee et al., 2017).

It has also been shown that vermicompost enhances the physical characteristics of soil, including aggregates, drainage, porosity, and aeration. Macronutrients (N, P_2O_5, K_2O), secondary nutrients (Ca, Mg), and the essential micronutrients (Fe, B, Zn, and Mo) are all abundant in vermicompost (Biswasi et al., 2020). Vermicompost has lower production costs and can stimulate growth by 50–100% more than regular compost and 30–40% more than chemical fertilizers (Verma et al., 2015).

Furthermore, applying biofertilizers, which can mobilize micronutrients like Zn and Mo and enrich the soil with healthy microbes, is vital for growth (Dash and Mishra, 2014). Utilizing bio-fertilizers enhances the soil with advantageous microorganisms and facilitates the biological conversion of non-useful components into useable ones. Vegetable yield and quality are enhanced when biofertilizers are used in conjunction with chemical fertilizers and organic manures (Saxena et al., 2021; Pawar, 2017). An annual contribution of 15 Kg N ha^{-1} has been recorded for *Azotobacter*. Even with sustained soil health, the yield of this heavy nutrient feeder crop cannot be increased by using organic manures and biological fertilizers alone. Therefore, an experiment was conducted with sustainable and economical approach to nutrient management by wisely utilizing all available organic and inorganic sources to achieve high production and preserve good soil health.

2. Materials and Methods

The experiment was conducted during the *Rabi* season (September to January) of 2021 and 2022 at Instructional Farm (26° 57′ 22.5396′′ N, 81° 0′ 13.4244′′ E and 8.24 m above mean sea level) of Integral Institute of Agricultural Science and Technology, Integral University, Lucknow, Uttar Pradesh, India, under subtropical climate. The experiment was laid down in a randomized block design (RBD) with 3 replications, comprising 9 nutrient management practices i.e. T_1: Control; T_2: 75% N through RDF; T_3: 75% N through RDF+25% N through FYM; T_4: 75% N through RDF+25% N through FYM+Azotobacter @ 5 kg ha^{-1}; T_5: 75% N through RDF+25% N through FYM+Azospirillum @ 5 kg ha^{-1}; T_6: 75% N through RDF+25% N through Vermicompost @ 2.5 t ha^{-1}; T_7: 75% N through RDF+25% N through Vermicompost @ 2.5 t ha^{-1}+Azotobacter @ 5 kg ha^{-1}; T_8: 75% N through RDF+25% N through Vermicompost @ 2.5 t ha^{-1}+Azospirillum @ 5 kg ha^{-1}; T_9: 100% N through RDF (120:80:40 kg ha^{-1}).

The seeds of cauliflower variety ‘Pant Shubhra’ were sown 60 cm apart from one row to another row while maintaining 45 cm plant-to-plant distance in the plots of 3.0×1.5 m^2 area. Growth parameters, viz. plant height, no. of leaves, length of leaves, width of leaves and spread of plant were recorded periodically at 20, 40, 60 DAS and at harvesting, yield attributes, viz. weight of curd, yield of curd plot^{-1}, yield of curd ha^{-1} were recorded.

A 2 mm sieve was used to filter the first soil samples, which were taken from various locations throughout the field and allowed to air dry before being completely combined and ground. The textural triangle technique was used to identify the soil textural class (Lyon et al., 1952). A hydrometer was used to measure the mechanical composition of the soil (percentage of sand, silt, and clay) (Bouyoucos, 1962). An µ-processor based pH-EC-Ion meter was used to monitor the pH and EC of the soil (in a 1:2.5 soil: water ratio) (Jackson, 1967). The amount of nitrogen that was accessible was calculated using Alkaline potassium permanganate methods (Subbiah, 1956). The available phosphorus (P) was determined by Olsen et al. (1954). The fraction of potassium that was available was determined by Warncke (1988).

The data were analysed according to the procedure outlined by Panse, (1967). At the 0.05 probability level, the sources of variance were found to differ significantly. To compare the difference between the mean values, the tables included the standard error of the mean (SEm±) and the CD value.

3. Results and Discussion

3.1. Growth attributes

All growth parameters of cauliflower, including plant height, number of leaves, length of leaves, width of leaves, and spread of plant, were recorded at 20, 40, and 60 DAS. These parameters were significantly influenced by the use of different organic management practices (Table 1). The application of 75% N through RDF+25% N through FYM+Azotobacter @5 kg ha^{-1} (T_4) produced significantly taller plants (5.57, 12.47, 19.77 cm) compared to the control (4.27, 8.53, 12.37 cm) at DAS. This result was similar to the treatments T_5 (75% N through RDF+25% N through FYM+Azospirillum @ 5 kg ha^{-1}) and T_8 (75% N through RDF+25% N through Vermicompost @ 2.5 t ha^{-1}+Azospirillum @ 5 kg ha^{-1}). The ability of microbial inoculation to produce growth-promoting chemicals may have contributed to the highest increase in plant height in treatment T_4, leading to improved cell division and cell elongation. Thus, sufficient nutrient availability is required for better plant growth, which in turn leads to an increase in plant height. Similar results were also reported by Ali et al. (2018) and Islam et al. (2021), who reported that plant height increased with the application of Azotobacter and FYM together. The application of 75% N through RDF+25% N through FYM+Azotobacter @ 5 kg ha^{-1} recorded a significantly higher number of leaves per plant (7.97, 9.53, 13.7), while the minimum number of leaves (4.97, 6.17. 9.7) was recorded in treatment T_1. The fact that treatment T_4 had the most leaves possible may have been

Table 1: Effect of different INM treatments on different growth parameters of cauliflower

Treatment Details	Plant height (cm)			Number of leaves			Length of leaves (cm)		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Control (T_1)	4.27	8.53	12.37	4.97	6.17	9.7	12.13	15.77	22.67
75% N through RDF (T_2)	4.60	10.27	14.97	5.90	6.63	11.8	14.20	17.53	26.00
75% N through RDF+25% N through FYM (T_3)	4.30	9.17	15.30	5.50	6.53	10.8	14.67	19.17	28.57
75% N through RDF+25% N through FYM+Azotobacter @ 5 kg ha^{-1} (T_4)	5.57	12.47	19.77	7.97	9.53	13.7	17.30	24.73	31.73
75% N through RDF+25% N through FYM+Azospirillum @ 5 kg ha^{-1} (T_5)	4.87	10.17	17.77	6.50	7.20	11.4	13.73	22.63	29.50
75% N through RDF+25% N through vermicompost @ 2.5 t ha^{-1} (T_6)	4.77	10.97	16.97	6.40	6.60	10.6	14.50	21.23	29.03
75% N through RDF+25% N through vermicompost @ 2.5 t ha^{-1}+Azotobacter @ 5 kg ha^{-1} (T_7)	5.23	10.43	16.43	5.73	7.47	12.3	16.03	23.43	30.67
75% N through RDF+25% N through vermicompost @ 2.5 t ha^{-1}+Azospirillum @5 kg ha^{-1} (T_8)	5.47	11.27	17.27	6.77	7.77	12.5	14.57	20.47	25.20
100 % N through RDF (120:80:40 Kg ha^{-1}) (T_9)	5.33	10.67	15.73	6.37	6.87	11.9	13.60	22.03	27.07
SEm±	0.291	0.678	0.969	0.419	0.456	0.693	0.73	0.98	1.67
CD (p=0.05)	0.873	2.034	2.906	1.259	1.367	2.08	2.20	2.96	5.03

caused by the timely delivery of nutrients, especially nitrogen, which was necessary for the plant's vegetative growth. The development of the physical characteristics of soil, such as porosity, aeration, and water-holding capacity, might aided by the FYM as a source of organic manure. The bio-fertilizers applied to the soil may contributed to increased availability of phosphorus and biological nitrogen fixation, both of which were necessary for robust vegetative development and the generation of additional leaves (Tekasangla et al., 2015). The maximum length of leaves (17.30, 24.73, 31.73 cm) and width of leaves (7.17, 10.20, 15.10 cm) were recorded in treatment T_4 and minimum in T_1 (12.13, 15.77, 22.67 cm), (4.53, 6.10, 8.20 cm) while the treatments T_7 (75% N through RDF+25% N through Vermicompost @ 2.5 t ha^{-1}+Azotobacter @ 5 kg ha^{-1}), T_5 (75% N through RDF+25% N through FYM+Azospirillum @5 kg ha^{-1}), were statistically at par (Table 2). Applying N, P, and K in addition to organic materials might boosted the amount of nitrogenous compounds available to the plant from both organic and inorganic sources, leading to an increased foliage and enhanced photosynthesis. A sufficient supply of the three primary nutrients–N, P, and K–was anticipated to favourably regulate the physiological processes and morphological responses of plants. The results of Meena et al. (2017) closely matched these findings. The maximum plant spread was recorded in treatment T_8- 75% N through RDF+25% N through Vermicompost @ 2.5 t ha^{-1}+Azospirillum @ 5 kg ha^{-1} spread of plant (285.50, 806.93, 1212.83 cm) and it was at par with treatment T_4 (277.60, 796.60, 1179.93 cm). When inorganic fertilizers were applied in conjunction with biofertilizers, which converted inaccessible forms of nutrients into available forms at crucial points in plant growth, the plant grew luxuriantly. Because they enhanced photosynthetic capability and secreted growth-promoting chemicals including riboflavin, thiamine, GA, IAA, and kinetin, improved plant growth may have been achieved with the integration of organic manures or bio-inoculants (Islam et al., 2021). These findings were in line with Tekasangla et al. (2015) in cauliflower who found maximum plant spread with inoculation of combination of bio inoculants and inorganic fertilizers.

3.2. Yield attributes

Significant differences were observed in the curd yield plot^{-1} and yield ha^{-1} in response to the amounts of inorganic fertilizers applied with organic manure and biofertilizers. The treatment of 75% N through RDF+25% N through FYM+Azotobacter @ 5 kg ha^{-1} (T_4) reported the maximum yield in terms of yield ha^{-1} and yield plot^{-1}. (13.40 kg plot^{-1}, 29.73 t ha^{-1}) and it was followed by the treatments T_7 (11.56 kg plot^{-1}, 25.69 t ha^{-1}). In treatment control (T_1), the lowest yield ha^{-1} and per plot were recorded i.e., 4.64 kg plot^{-1}, 10.32 t ha^{-1}. Similar positive effects on cauliflower had been noted by Chaudhary et al. (2023) and Kannaujiya et al. (2023) with biofertilizers and organic fertilizers, where they found maximum yield per plot and yield of curd per hectare. A balanced C:N ratio and improved availability of vital plant nutrients, along with higher rates and more efficient metabolic activities that led to increased protein and carbohydrate absorption, were responsible for the yield increase resulting from 75% RDF with FYM and bio-

Table 2: Effect of different INM treatments on width of leaves and spread of cauliflower plant

Treatment Details	Width of leaves (cm)			Spread of plant (cm)		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Control (T_1)	4.53	6.10	8.20	188.52	425.22	718.03
75% N through RDF (T_2)	5.70	6.77	11.60	206.60	622.53	1136.33
75% N through RDF+25% N through FYM (T_3)	6.37	7.37	12.80	239.40	722.03	1154.57
75% N through RDF+25% N through FYM+Azotobacter @ 5 kg ha^{-1} (T_4)	7.17	10.20	15.10	277.60	796.60	1179.93
75% N through RDF+25% N through FYM+Azospirillum @ 5 kg ha^{-1} (T_5)	6.10	8.67	13.33	235.43	673.0	1172.87
75% N through RDF+25% N through vermicompost @ 2.5 t ha^{-1} (T_6)	5.87	8.73	12.10	221.18	727.63	1094.43
75% N through RDF+25% N through vermicompost @ 2.5 t ha^{-1}+Azotobacter @ 5 kg ha^{-1} (T_7)	6.47	8.53	13.47	207.33	748.33	1151.30
75% N through RDF+25% N through vermicompost @ 2.5 t ha^{-1} +Azospirillum @ 5 kg ha^{-1} (T_8)	5.53	7.77	11.23	285.50	806.93	1212.83
100 % N through RDF (120:80:40 kg ha^{-1}) (T_9)	5.90	7.20	12.77	210.63	699.17	1127.53
SEm±	0.439	0.484	0.724	17.793	47.07	64.62
CD (p=0.05)	1.318	1.451	2.171	53.344	141.11	193.73

fertilizers. More FYM and biofertilizers were known to have a positive impact on the physical, chemical, and biological characteristics of the soil, which improved plant uptake of nutrients and increased output. The prolonged availability of nutrients during the growing season might also be responsible for an increase in production. The effectiveness of inorganic fertilizers was strengthened when they were mixed with organic manure and biofertilizers (Table 3).

Table 3: Effect of different INM treatments on yield attributes of cauliflower

Treatment details	Weight of curd (g)	Yield of curd $plot^{-1}$ (t)	Yield of curd ha^{-1} (t)
Control (T_1)	310.07	4.64	10.32
75% N through RDF (T_2)	480.80	7.21	16.01
75% N through RDF+25% N through FYM (T_3)	567.83	8.51	18.91
75% N through RDF+25% N through FYM+Azotobacter @ 5 kg ha^{-1} (T_4)	893.73	13.40	29.73
75% N through RDF+25% N through FYM+Azospirillum @ 5 kg ha^{-1} (T_5)	759.20	11.39	25.30
75% N through RDF+25% N through vermicompost @ 2.5 t ha^{-1} (T_6)	597.63	8.96	19.89
75% N through RDF+25% N through vermicompost @ 2.5 t ha^{-1}+Azotobacter @ 5 kg ha^{-1} (T_7)	771.17	11.56	25.69
75% N through RDF+25% N through vermicompost @ 2.5 t ha^{-1}+Azospirillum @ 5 kg ha^{-1} (T_8)	712.97	10.69	23.73
100 % N through RDF (120:80:40 kg ha^{-1}) (T_9)	589.40	8.83	19.60
SEm±	40.641	0.609	1.355
CD (p=0.05)	121.84	1.827	4.063

4. Conclusion

The application of T_4 (75% N through RDF+25% N through FYM+Azotobacter @ 5 kg ha^{-1}) treatment appeared to be the best for achieving the better growth and higher yield of cauliflower which shows that the productivity and growth parameters in cauliflower can be improved by the application of organic and inorganic sources of nutrients.

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