SYNERGISTIC EFFECT OF NITROGEN SUBSTITUTION THROUGH VERMICOMPOST ON PRODUCTIVITY AND QUALITY OF CAULIFLOWER IN LOW HILLS OF HIMACHAL PRADESH

ABSTRACT

Aims: To evaluate impact of substituting inorganic nitrogen source with vermicompost, alone and in association with *Azotobacter*, on the growth, yield and quality of cauliflower (*Brassica oleracea* var. botrytis L.).

Study design: Randomized Block Design (RBD).

Place and Duration of Study: Experimental farm of Department of Soil Science and Water Management, College of Horticulture and Forestry, Neri, Hamirpur, Himachal Pradesh during the *Rabi* season.

Methodology: The layout of the experiment was Randomized Block Design (RBD) comprising 11 treatments replicated thrice [T_1 (Absolute Control), T_2 (100% RDF), T_3 (75% RDF+ 25 % RDN through vermicompost), T_4 (50% RDF+50 % RDN through vermicompost, T_5 (25% RDF+ 75 % RDN through vermicompost), T_6 (100% RDN through vermicompost), T_7 (100 % RDF+ *Azotobacter*), T_8 (75% RDF+25 % RDN through vermicompost+ *Azotobacter*, T_9 (50% RDF+ 50% RDN through vermicompost + *Azotobacter*, T_{10} (25% RDF+75% RDN through vermicompost + *Azotobacter*) and T_{11} (100% RDN through vermicompost + *Azotobacter*)].

Results: The treatment involving 100% replacement of the recommended dose of nitrogen (RDN) through vermicompost combined with *Azotobacter* recorded the highest plant height (51.36 cm), leaf count (23.68), curd diameter (15.13 cm), curd weight (906.23 g) and curd yield (268.37 q ha^{-1}). This subsitutional approach significantly improved curd quality with higher crude protein (24.17%), TSS (7.21°B) and enhanced total macro and micronutrient content. Vermicompost enriched soil properties and nutrient availability, while *Azotobacter* enhanced nitrogen fixation and nutrient uptake.

Conclusion: The results concluded that the complete substitution of RDN with vermicompost in addition to *Azotobacter* sustains yield and quality and promotes soil health, offering a viable alternative to chemical fertilizers in cauliflower cultivation.

Keywords: **(**Cauliflower, Vermicompost, *Azotobacter*, Nitrogen substitution, Curd quality and Soil health**)**

1. INTRODUCTION

Cauliflower (*Brassica oleracea* var. botrytis L.), an eminent member of the family Brassicaceae, is one of the well-liked cole crops among temperate vegetables. It is grown worldwide throughout the year because of its wide adaptability under different ecological conditions and high nutritive and economic value. Cauliflower's edible part curd constitutes about one-fourth of the total above-ground biomass (Batabyal *et al.* 2016)[1].

West Bengal, Madhya Pradesh, Bihar, Gujarat, Haryana, Orissa, Assam, Uttar Pradesh and Maharashtra are highly contributing states of cauliflower, making India the second largest producer in the world with the production of 9661.72 thousand MT over an area of 500.83 thousand hectares (AGRICOOP, 2024)[2]. In Himachal Pradesh, it is cultivated over an area of about 5.55 thousand ha yielding a total production of 123.07 thousand MT (AGRICOOP, 2024)[2].

It serves as a commercial crop that brings profitable returns to marginalized and small-scale hill farmers of Himachal Pradesh, but due to its exhaustive nature, it removes large quantities of nutrients from the soil, resulting in quick nutrition depletion therefore, for the optimum growth and good market yield of the crop a constant supply of nutrients through organic or inorganic sources are required (Subedi *et al.* 2019)[3]. Ongoing nutrient depletion through continuous biomass removal without sufficient nutrient restoration, coupled with unbalanced fertilization practices, poses a substantial threat to sustainable crop production and soil health. The use of inorganic fertilizers for crop production serves as the fastest way of replenishing the depletion of the nutrients, but escalating fertilizer prices, limited input availability and detrimental effects on soil health deter the farmers from using these to the required level.

Hence, the use of organic manures such as vermicompost, which contributes as a good source of nutrients, can be a better alternative to synthetic fertilizers for sustaining productivity and quality of the crop. Information related to the replacement of inorganic fertilizers through vermicompost with respect to cauliflower is insufficient. Therefore, the present investigation was planned.

2. MATERIAL AND METHODS

A field trial was executed at the Experimental Farm of the College of Horticulture and Forestry, Neri, Hamirpur (31°41′47.6″ N, 76°28′06.3″ E, 650 m elevation). The studied area falls under the Sub-Montane and low hills Sub-Tropical Zone (Zone I) of Himachal Pradesh. Annually, this region records 1220 mm of precipitation, out of which 82.00 per cent is experienced from June to September. The soil of experimental site was classified as sandy loam in texture, neutral in reaction (pH 6.77), low in available N (185.20 kg ha^{-1}) with medium levels of organic carbon, P and K (4.30 g kg^{-1}, 14.34 and 167.53 kg ha^{-1}, respectively).

A randomized block design was used for field setup, with eleven treatments each repeated three times. The treatment combinations were [T_1 (Absolute Control), T_2 (100% RDF), T_3 (75% RDF+ 25 % RDN through vermicompost), T_4 (50% RDF+50 % RDN through vermicompost, T_5 (25% RDF+ 75 % RDN through vermicompost), T_6 (100% RDN through vermicompost), T_7 (100 % RDF+ *Azotobacter*), T_8 (75% RDF+25 % RDN through vermicompost+ *Azotobacter*, T_9 (50% RDF+50% RDN through vermicompost+ *Azotobacter*, T_{10} (25% RDF+75% RDN through vermicompost+ *Azotobacter*) and T_{11} (100% RDN through vermicompost + *Azotobacter*)]. At the time of field preparation, Urea was applied in split doses, SSP and MOP in full doses, whereas, the application of vermicompost was based on its nitrogen content and dry weight. Control plots used for comparison received no fertilizer or manure. The late-maturing cauliflower cultivar ‘Pusa Snowball K-1’ was transplanted one month after sowing maintaining a spacing of 60 cm × 45 cm. Root dipping with *Azotobacter* was carried out according to the treatments before transplanting.

Crop growth and productivity traits, including plant height, leaf count per plant, curd diameter and curd weight were recorded. Yield was recorded plot-wise by summating the weight of curds from all the harvestings and converting it to q ha^{-1}.

The N content of curd samples was determined by the Micro Kjeldahl method as outlined in A.O.A.C. 1970[4], P content by vanadomolybdate phosphoric acid yellow colour method and K content by flame photometry method as suggested by Jackson, 1973[5]. The turbidimetric method outlined by Chesnin and Yien, 1950[6], was used to determine Sulphur content and flame photometer assessed the Calcium content of the sample. Mg and micronutrients were evaluated by means of atomic absorption spectrophotometer using the procedure given by Jackson, 1973[5]. The ascorbic acid content of cauliflower curds was determined by 2, 6-dichlorophenolindo-phenol visual titration method. Total soluble solids were estimated with the help of a hand refractometer and their observations were recorded in ^{0}Brix by the method given by Ranganna, 2014[7]. Crude protein was calculated by multiplying the total nitrogen content in the curd sample by a factor of 6.25, as suggested by Jones, 1941[8] and was expressed in percent (%).

3. RESULTS AND DISCUSSION

A. Growth Parameters

Plant height

Complete substitution of the recommended nitrogen dose with vermicompost in addition to *Azotobacter* recorded maximum plant height (51.36 cm). In contrast, minimum plant height

(30.45 cm) was reported in absolute control where no inorganic fertilizer, manure or bio-fertilizer was applied (Table 1.) By increasing the recommended nitrogen dose *via* vermicompost, the height of the crop was increased. *Azotobacter* addition further increases plant height when used with either inorganic fertilizer or vermicompost or both. The increase in the plant height of the cauliflower is attributable to the influence of vermicompost, which might have improved the nutrient pool in the soil. Additional application of *Azotobacter* helped to increase the biological nitrogen fixation and P availability which is required for the completion of vegetative cycle of the crop (Islam *et al.* 2021[9], Rabindra *et al.* 2021[10] and Sharma *et al*. 2022[11]).

Leaf count per plant

A notable rise in the number of leaves per plant was observed when organic amendment was combined with the application of bio-fertilizer. Replacing the entire recommended nitrogen dose with vermicompost, in the absence of *Azotobacter*, enhanced the leaf number per plant by 12.74% compared to full RDF. The highest leaf count (23.68) was observed when 100% RDN through vermicompost was united with *Azotobacter,* while the lowest (14.64) was in the control (Table1.). The single use of inorganic fertilizers improved leaf count over the control, but the full substitution of nitrogen through vermicompost with *Azotobacter* showed better results than inorganic fertilizers alone. The observed increase in leaf count per plant with the substitution of RDN by vermicompost may be attributed to its ability to solubilize soil nutrients, chelate metal ions and thereby improve overall nutrient availability. Bio-fertilizers by producing plant growth substances that activate enzymes and stimulate cell division further promote vegetative growth whereas; less leaf count might be due to insufficient nutritional support (Neupane *et al.* 2020[12], Islam *et al*. 2021[9] and Sharma *et al.* 2022[11]).

B. Yield Attributes

Curd diameter

Incorporation of full recommended nitrogen dose *via* vermicompost in association with *Azotobacter*, gave largest curd diameter (15.13 cm) outperforming all other treatments. Lowest curd diameter (8.67 cm) was found in control plot receiving no nutrient sources (Table 1.). Treatments using *Azotobacter* with RDN continuously showed superior results over their counterparts without *Azotobacter*. No addition of nutrients in the control plots resulted in the lowest curd diameter, whereas application of inorganic fertilizers, manures or bio-fertilizers increased the availability of NPK, due to which growth might have been boosted as they increase in photosynthetic activity and chlorophyll content of plant, which leads to better nourishment of curd (Kaur *et al*. 2020[13], Komma *et al*. 2020[14], Neupane *et al.* 2020[12], Rabindra *et al*. 2021[10] and Sharma *et al.* 2022[11]).

Curd Depth

The maximum curd depth (14.87 cm) was obtained with 100% RDN applied through vermicompost combined with *Azotobacter*, while the minimum (8.67 cm) was observed in the control (Table1.). The combination of vermicompost with *Azotobacter* significantly increased curd depth over all the treatments. The increase in curd depth with vermicompost application can be attributed to its improvement of increasing soil properties, enhancing nutrient absorption and curd development. Bio-fertilizers further helped in nutrient mobilization and root development (Kaur *et al.* 2020[13], Neupane *et al.* 2020[12], Devkota *et al.* 2021[15] and Sharma *et al.* 2022[11]).

Curd weight

The highest curd weight (906.23 g) was attained with 100% RDN applied through vermicompost with *Azotobacter*, whereas the control recorded the lowest value (387.20 g) (Table1). Curd weight was increased by 86.53% and 134.04% with 100% RDN through vermicompost alone or combined with *Azotobacter,* respectively, over the control. Using 100% RDF alone enhanced curd weight by 257.53 g over control and further increased it by 358.10 g

when combined with *Azotobacter*. Synergistic effect of *Azotobacter* was highlighted when combined with vermicompost or inorganic fertilizers in different doses.

The lowest curd weight in the control was due to the absence of fertilizers, manures or bio-fertilizers, resulting in poor soil nutrition. The increase in curd weight with *Azotobacter* application can be attributed to improved uptake of both nutrients and water. Collaboration of organic manure with inorganic fertilizers enhanced NPK availability, soil fertility and productivity, boosting yield attributes (Komma *et al.* 2020[14], Neupane *et al.* 2020[12], Singh *et al.* 2020[16], Rabindra *et al.* 2021[10] and Sharma *et al.* 2022[11]).

C. Curd yield

The curd yield varied from a minimum of 112.47 q ha^{-1} in control to a maximum of 268.37 q ha^{-1} in plots receiving 100 per cent RDN through vermicompost + *Azotobacter* (T_{11}) (Fig.1.). Application of recommended doses of fertilizers alone (T_2) or in conjunction with *Azotobacter* (T_7) enhanced the curd yield of cauliflower by 89.86 and 125.80 q ha^{-1} respectively, over control (T_1). The curd yield of cauliflower increased when vermicompost was used as a replacement for recommended dose of nitrogen. It is cleared from the data that with the increase in the replacement of recommended dose of nitrogen with vermicompost there was increase in curd yield of cauliflower. Among the treatments where nitrogen is applied through vermicompost and *Azotobacter* was not used (T_3 to T_6), application of 100 per cent of RDN through vermicompost (T_6) reported maximum curd yield (235.00 q ha^{-1}) followed by 25 per cent RDF through inorganic fertilizers + 75 per cent RDN through vermicompost (T_5) and 50 per cent RDF through inorganic fertilizers + 50 per cent RDN through vermicompost (T_4) and minimum curd yield (208.17 q ha^{-1}) was reported with the application of 75 per cent RDF through inorganic fertilizers + 25 per cent RDN through vermicompost (T_3). Application of *Azotobacter* also showed positive influences on curd yield of cauliflower and similar trend was observed among the treatments where RDN was replaced by vermicompost and *Azotobacter* was not applied. The application of 100 per cent RDF through vermicompost + *Azotobacter* (T_{11}) reported maximum curd yield (268.37 q ha^{-1}) followed by application of 25 per cent RDF through inorganic fertilizers + 75 per cent RDN through vermicompost + *Azotobacter* (T_{10}) and 50 per cent RDF through inorganic fertilizers + 50 per cent RDN through vermicompost + *Azotobacter* (T_9). Whereas, amid these treatments minimum (238.27 q ha^{-1}) curd yield was reported with the application of 100 per cent RDF through inorganic fertilizers + *Azotobacter* (T_7).

Lowest curd yield in control treatment is attributed to poor nutritional status of these plots where no fertilizers or manure or bio-fertilizers was added. Use of vermicompost promotes soil aggregation and stabilizes soil structure. This improves air-water relationship of soil, thus increasing the water retention capacity and encourages extensive development of root system of plants. The increase in yield also may be due to the solubilization effect of the nutrients as well as the chelating effect of vermicompost, thereby, the availability of essential nutrients gets increased. Use of bio-fertilizers in combination with chemical fertilizers was efficient in yield increase over the exclusive application of chemical fertilizers and can be attributed to increase in uptake of nutrients resulting in faster synthesis and translocation of photosynthates from leaves to curd (Devkota *et al*. 2021[15], Islam *et al.* 2021[9], Rabindra *et al.* 2021[10] and Sharma *et al*. 2022[11]).

D. Quality Parameters

Crude Protein Content

Application of 100% RDN *via* vermicompost along with *Azotobacter* yielded in the highest crude protein content (24.17%), while the control exhibited the lowest content (19.58%) (Table 2.). Application of recommended fertilizers alone or with *Azotobacter* increased crude protein by 1.07% and 19.15%, respectively, over control. Substitution of RDN with

vermicompost led to a progressive increase in protein content, attributed to the slow and sustained release of nutrients. The additional use of *Azotobacter* further enhanced crude protein levels by improving nitrogen availability and uptake (Wani *et al.* 2011[17] and Batabyal *et al.* 2016[1]).

Total Soluble Solids (TSS) Content

The TSS varied from 7.21˚B to 6.10˚B with 100% RDN through vermicompost with *Azotobacter* and control respectively. Progressive substitution of RDN with vermicompost increased TSS, with 100% RDN through vermicompost achieving the highest (6.78˚B) among such treatments (Table2.). A similar trend was observed when *Azotobacter* was incorporated, with complete replacement of RDN through vermicompost, showing the highest TSS. The control had the lowest TSS due to the absence of fertilizers. The increase in TSS with vermicompost may be attributed to the secretion of growth-promoting substances that enhance carbohydrate synthesis, while *Azotobacter* enhances chlorophyll function and metabolic enzyme activity (Singh *et al.* 2018[18] and Kaur *et al.* 2020[13]).

Nutrient Content

The nutrient content in cauliflower curd was highest when RDN was entirely substituted with vermicompost and *Azotobacter*. The macronutrient composition was recorded as nitrogen (0.27%), phosphorus (0.03%), potassium (0.16%), calcium (0.24%), magnesium (0.28%) and sulfur (0.02%). Additionally, the micronutrient concentrations were zinc (34.4 ppm), copper (25.8 ppm), iron (149.5 ppm) and manganese (44.7 ppm). *Azotobacter* inoculation's benefits can be ascribed to the synergistic interaction between organic and microbial strategies, which enhance soil health and plant nutrition. Vermicompost enriches the soil with essential nutrients, steadily improving their availability to plants. Additionally, it enhances soil structure, microbial biomass and enzymatic activity, creating a favorable rhizosphere for nutrient uptake. *Azotobacter*, being a free-living nitrogen-fixing bacterium, further augments the nitrogen supply by biologically fixing atmospheric nitrogen, thereby meeting the plant's nitrogen demands sustainably. Moreover, *Azotobacter* secretes growth-promoting substances like indole acetic acid (IAA), stimulating root growth and increasing nutrient absorption efficiency. The combined use of vermicompost and *Azotobacter* improves not only the availability of major nutrients like nitrogen, phosphorus and potassium but also enhances the uptake of secondary and micronutrients such as calcium, magnesium, sulfur, zinc, copper, iron and manganese (Rabindra *et al.* 2021[10] and Sharma *et al.* 2022[11]).

217 **Table1. Effect of nitrogen substitution through vermicompost on growth and yield attributes of cauliflower**
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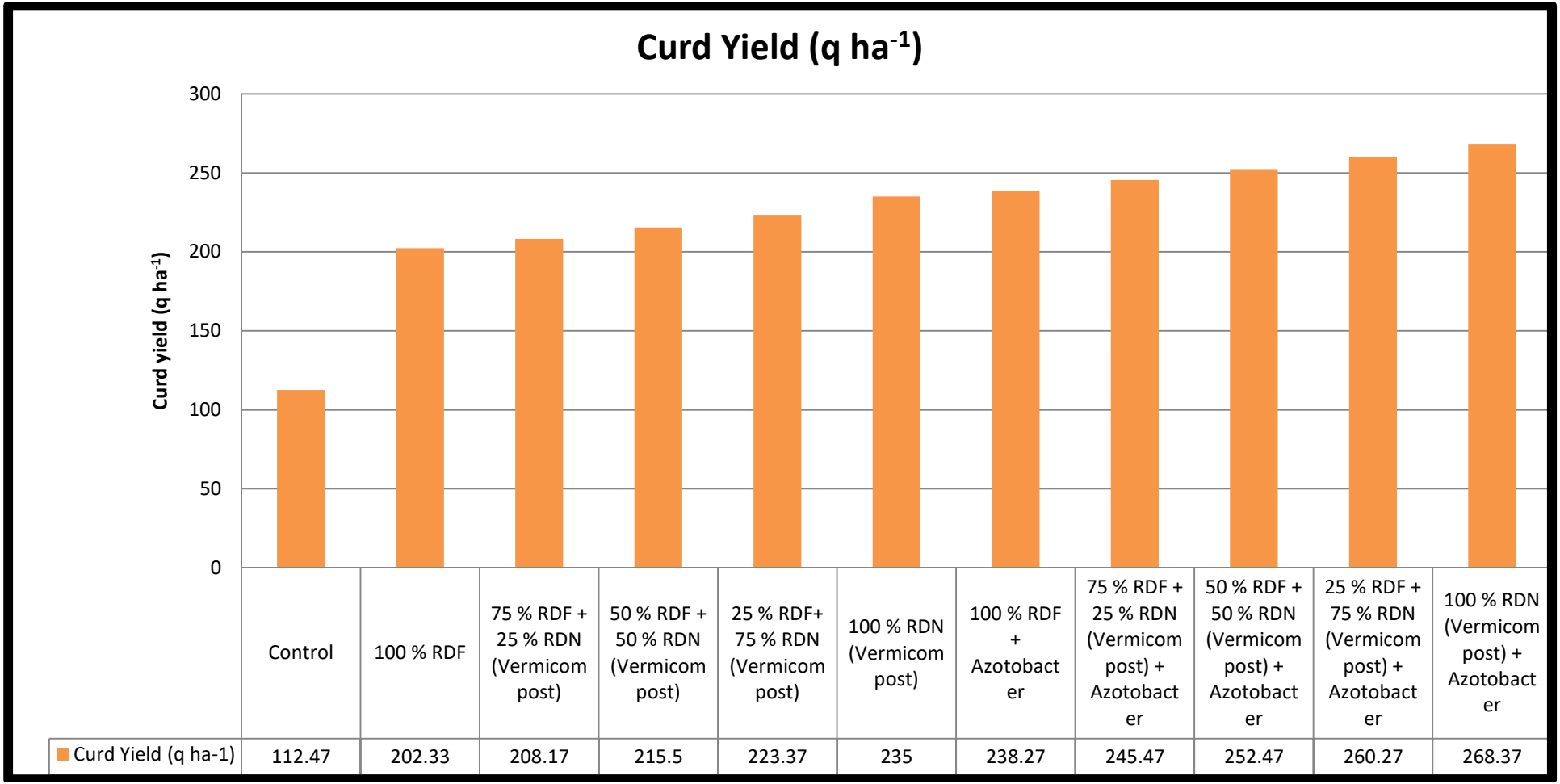
Treatments		Plant height (cm)	No. of leaves	Curd diameter (cm)	Curd depth (cm)	Head weight (g)
T_1	Control	30.45	14.64	8.94	8.67	387.20
T_2	100%RDF	41.52	17.50	11.68	10.91	644.73
T_3	75%RDF+25%RDN (Vermicompost)	41.83	17.86	11.97	11.56	663.20
T_4	50%RDF+50%RDN (Vermicompost)	42.27	18.73	12.03	11.98	688.47
T_5	25%RDF+75%RDN (Vermicompost)	42.66	19.06	12.31	12.10	704.13
T_6	100%RDN (Vermicompost)	42.74	19.73	12.98	12.33	722.27
T_7	100 %RDF+ *Azotobacter*	47.33	20.73	13.16	12.67	745.30
T_8	75%RDF +25%RDN (Vermicompost) + *Azotobacter*	48.92	21.66	13.70	13.17	801.40
T_9	50%RDF +50%RDN (Vermicompost) + *Azotobacter*	49.12	22.48	14.04	13.92	834.61
T_{10}	25%RDF +75%RDN (Vermicompost) +*Azotobacter*	50.24	23.02	14.97	14.32	872.30
T_{11}	100%RDN (Vermicompost) + *Azotobacter*	51.36	23.68	15.13	14.87	906.23
CD(P=0.05)		5.05	2.31	1.98	2.23	34.92

Table2. Effect of nitrogen substitution through vermicompost on quality parameters of cauliflower

	Treatment	TSS (˚Brix)	Ascorbic acid (mg 100 g^{-1})
T_1	Control	6.10	53.80
T_2	100% RDF	6.37	56.71
T_3	75% RDF+25% RDN (Vermicompost)	6.40	57.23
T_4	50% RDF+50% RDN (Vermicompost)	6.51	57.56
T_5	25% RDF+75% RDN (Vermicompost)	6.67	57.59
T_6	100% RDN (Vermicompost)	6.78	57.82
T_7	100 % RDF+ *Azotobacter*	6.84	58.07
T_8	75% RDF +25% RDN (Vermicompost)+*Azotobacter*	6.91	58.14
T_9	50% RDF +50% RDN (Vermicompost)+*Azotobacter*	7.02	58.25
T_{10}	25% RDF +75% RDN (Vermicompost)+*Azotobacter*	7.14	58.35
T_{11}	100%RDN (Vermicompost) + *Azotobacter*	7.21	58.67
	CD (P=0.05)	0.30	0.84

Fig.1. Effect of nitrogen substitution through vermicompost on curd yield (q ha^{-1})



4. CONCLUSION

The findings suggest that fully replacing the recommended dose of nitrogen (RDN) with vermicompost, along with *Azotobacter* application, effectively maintains yield and quality while enhancing soil health, presenting a sustainable alternative to chemical fertilizers in cauliflower cultivation.

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