



RESEARCH ARTICLE

Integrated nutrient management studies in cauliflower (*Brassica oleracea* L.) cv. Pusa Snowball K-1

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Abstract

The current study was laid during 2 consecutive rabi seasons at the Experimental farm, Dr. Yashwant Singh Parmar University of Horticulture and Forestry (UHF), Nauni, Himachal Pradesh, India. The experiment involved 9 treatments replicated thrice using a randomized complete block design (RCBD). A combination of organic and inorganic amendments was applied to evaluate their effects. The results from the study revealed that growth parameters viz. days to marketable curd maturity, plant height, leaf size index and number of leaves per plant showed maximum values in plots with recommended fertilisation package (125 N:75 P:65 K kg/ha + FYM (farmyard manure) at 250 q/ha). The scrutiny of purely organic module (50 % FYM (125 q/ha) + application of vermicompost (equivalent to N content of 50 % FYM + recommended dose of nitrogen, phosphorous and potassium (NPK) through FYM on N equivalent basis) was found to be statistically at par with respect to majority of growth characters. Similarly, the yield and related traits i.e., curd depth, size index, weight and yield also showed maximum values through the INM (integrated nutrient management) module. The B:C ratio was also found highest (2.57:1) in INM treatment with at par values in pure organic treatments, involving vermicompost (VC) and FYM (2.50:1) either alone or in the different combinations.

Keywords: cauliflower; curd weight; economics; farmyard manure; integrated nutrient management; vermicompost; yield

Introduction

Cauliflower (*Brassica oleracea* L. var. *botrytis* L.) is a widely cultivated crop of the Brassicaceae family. Originally native to the Mediterranean region of Southern Europe, cauliflower was introduced into Indian agriculture in 1822 through England (1). It provides essential minerals including potassium (K), sodium (Na), phosphorus (P), iron (Fe), calcium (Ca) and magnesium (Mg), along with notable levels of vitamin A (2). In India, cauliflower is one of the major vegetable, grown over 453000 ha, yielding 8668 thousand metric tonnes with productivity of 19.13 tonnes/hectare. Himachal Pradesh contributes significantly to cauliflower production, with a cultivated area of 5564 ha and an annual output of 131009 metric tonnes. The state records an average productivity of 23.54 t ha⁻¹, which is notably higher than the national average (3). The concept of organic farming emphasises the utilisation of locally available resources and eco-friendly technologies such as soil fertility management, biological control of pests and nutrient cycling. Vermicompost is another effective organic amendment that stimulates beneficial microbial activity, enhances enzyme action like dehydrogenase and improves soil texture, thereby creating favourable conditions for plant growth (4). It is also a good source of

macronutrients (N, P, K, Ca, Mg) and micronutrients (Fe, molybdenum (Mo), zinc (Zn) and copper (Cu)).

Integration of organic inputs such as farmyard manure, vermicompost and liquid bio-formulations with inorganic fertilisers has emerged as a viable strategy to enhance crop productivity while maintaining soil health (2). Farmyard manure improves soil structure, water-holding capacity and nutrient buffering, whereas vermicompost acts as a slow-release nutrient source and promotes microbial-mediated nutrient availability (2). When used in combination, these organic inputs complement inorganic fertilisers by improving nutrient use efficiency and reducing nutrient losses (3). Liquid organic formulations like jeevamrit further strengthen integrated nutrient management (INM) by accelerating microbial activity and nutrient mineralisation in the rhizosphere (3, 4). Their inclusion in nutrient modules supports sustainable crop growth by improving soil biological properties and enhancing nutrient uptake. Therefore, the integration of specific organic inputs with recommended fertiliser doses offers a balanced approach to achieving higher yield, improved quality and long-term soil fertility in cauliflower cultivation (4).

Cauliflower grows optimally in well-drained fertile soils, particularly sandy loam to loam soils, which ensure good aeration, moisture retention and root development (3, 5). Soils rich in organic matter with a slightly acidic to neutral pH (6.0–7.0) are considered ideal for achieving higher yield and better curd quality (6). Heavy clay soils with poor drainage and excessively sandy soils with low nutrient-holding capacity are generally less suitable for cauliflower cultivation, as they adversely affect nutrient uptake and curd formation (5, 7).

Jeevamrit, a fermented bio-formulation derived from cow-based products, is a cost-effective input that not only supports higher yields and better quality but also enriches the soil with indigenous microbial populations essential for nutrient mineralisation (5, 7). Zero budget natural farming (ZBNF) is another approach that replaces chemical fertilisers and pesticides with biological alternatives derived from cow dung, urine and botanical extracts. This approach has been reported to reduce manual labor by up to 80 % while maintaining ecological balance (6). Moreover, ZBNF is gaining attention for its ability to minimise production costs and resource use while enhancing yield outcomes (7). The present study was planned with the objective to see the influence of INM, involving both organic and inorganic inputs, on the yield and quality of cauliflower, along with the economic viability of different treatment combinations.

Materials and Methods

The investigation was planned out during rabi season of 2 consecutive years at the Experimental Research Farm of the Department of Vegetable Science, UHF, Nauni, Solan, Himachal Pradesh, India. The variety 'Pusa Snowball K-1' was selected for this investigation. Seeds were sourced from the Indian Agricultural Research Institute (IARI) Regional Station, Katrain (Kullu Valley), where the variety was originally developed. The experimental design followed a randomized layout (RCBD) with 3 replications and included 9 treatment combinations, as represented in Table 1. Jeevamrit was prepared as per standard method (8). Analysis of variance was calculated as per suggested by Panse and Sukhatme (9). The data taken was analysed using SPSS 16.0 package.

Results and Discussion

The data related to the number of days required for marketable curd maturity are presented in Table 2. Pooled analysis revealed significant differences among the various nutrient management treatments. The earliest maturity was observed under treatment T2 (127.33 days), closely followed by T4 (127.83 days) and T7 (129.00 days). In contrast, the longest duration to maturity (131.33 days) was recorded in T6. Similar trends have been reported previous works, who found that higher nutrient availability tends to accelerate plant development and reduce maturity duration, while lower fertility levels delay growth processes (10). Interestingly, treatments T6 and T8 had similar fertility levels but differed in organic input types FYM and vermicompost, or their combinations. The days to curd maturity for these treatments were statistically comparable, with T8 at 129.50 days and T6 at 131.33 days. The variation in maturity periods under organic treatments may result from the differing nutrient release patterns and soil conditioning effects of the amendments used (11). Although the year $\times$ treatment interaction was not statistically significant, a significant difference between the two study years was noted, with earlier maturity (128.33 days) observed in 2017–18. As per the present study (Table 2), the tallest plants were recorded under treatment T2, where a combination of recommended FYM (250 q/ha) and NPK (125:75:65 kg/ha) was applied, showing 53.73 cm and 48.15 cm in 2017–18 and 2018–19 respectively. The pooled mean also confirmed T2 as the best-performing treatment (50.94 cm), significantly surpassing all others. Conversely, the lowest plant height (44.29 cm) was observed under T1 (absolute control with no inputs). Plant height differed significantly across years, with higher values recorded in 2017–18 (50.14 cm). The interaction between treatment and year was also significant, again favoring T2 in 2017–18. The superior plant growth under T2 may be attributed to the synergistic effect of organic and inorganic fertilisers, which likely improved the structure of soil and nutrient availability (12). In the present investigation, pooled data (Table 2) revealed that the highest leaf size index (1036.68 cm²) was recorded under treatment T2, where the recommended doses of FYM (250 q/ha) and NPK (125:75:65 kg/ha) were applied. This treatment was statistically at par with T8 (998.20 cm²) and T6 (980.63 cm²). Though year-wise interaction with treatments was not significant, higher values were obtained during 2017–18 (970.48 cm²), suggesting favourable climatic or soil conditions. The enhanced leaf size index in T2 may be

Table 1. Details of the treatments used in the study

Treatment code	Treatment details
T ₁	No application of manures and fertilisers (Negative /Absolute control)
T ₂	Application of recommended dose of FYM (250 q/ha) and NPK (125 kg N, 75 kg P ₂ O ₅ and 65 kg K ₂ O/ha) {control/positive control}
T ₃	Application of 5 % Jeevamrit (Soil application at fortnightly interval)
T ₄	Application of recommended dose of FYM (250 q/ha) + recommended dose of NPK through FYM on N equivalent basis (Soil application at planting)
T ₅	Application of recommended dose of FYM (250 q/ha) {soil application at planting} + Application of 5 % Jeevamrit (Soil application at fortnightly interval through irrigation)
T ₆	Application of vermi compost (equivalent to N content of recommended FYM - soil application at planting) + recommended dose of NPK through FYM on N equivalent basis
T ₇	Application of vermi compost (equivalent to N content of recommended FYM - soil application at planting) + application of 5 % Jeevamrit (soil application at fortnightly interval)
T ₈	Application of 50 % FYM (125 q/ha) {soil application at planting} + application of vermi compost (equivalent to N content of 50 % FYM -soil application at planting) + recommended dose of NPK through FYM on N equivalent basis.
T ₉	Application of 50 % FYM (125q/ha) {Soil application at planting} + application of vermi compost (equivalent to N content of 50 % FYM -soil application at planting) + application of 5 % Jeevamrit (Soil application at fortnightly interval)

Note: For the control of insect pests, neem-based products were used.

Table 2. Effect of organic and inorganic amendments on days to marketable curd maturity, plant height (cm), leaf size index (cm²), number of leaves per plant, curd depth (cm) and curd size index (cm) in cauliflower

Treatment code	Days to marketable curd maturity	Plant height (cm)	Leaf size index (cm ²)	Number of leaves per plant	Curd depth (cm)	Curd size index (cm ²)
T ₁	130.33	44.29	825.28	18.47	7.75	1.35
T ₂	127.33	50.94	1036.68	21.23	9.02	1.95
T ₃	129.67	44.47	869.72	18.89	7.67	1.41
T ₄	127.83	47.82	943.00	20.20	8.03	1.70
T ₅	129.83	44.78	900.47	19.32	7.77	1.47
T ₆	131.33	48.80	980.63	20.42	8.11	1.76
T ₇	129.00	45.23	918.90	19.79	7.83	1.52
T ₈	129.50	49.15	998.20	20.98	8.20	1.83
T ₉	130.00	47.09	926.56	20.00	7.92	1.68
Mean	129.43	46.95	933.27	19.92	8.03	1.65
Y	1.11	0.61	33.99	0.46	0.16	5.13
T	2.48	1.36	76.00	1.03	0.37	11.47
Y × T	NS	1.92	NS	NS	NS	16.22

attributed to the combined influence of organic and inorganic inputs that likely enhanced soil fertility along with water retention (4). The increased leaf dimensions and plant spread in broccoli due to balanced nutrient application from both organic and inorganic sources (12, 13).

The highest number of leaves contributes to increased assimilate production, enhancing curd size and marketable yield. In current study (Table 2), highest number of leaves were recorded in treatment T₂ where recommended doses of FYM (250 q/ha) and NPK (125 kg, 75 kg and 65 kg) were applied, yielding 21.63 and 20.83 leaves during 2017–18 and 2018–19 respectively. Pooled analysis confirmed T₂ as the superior treatment (21.23 leaves), followed closely by T₈ (20.98), T₆ (20.42) and T₄ (20.20). Conversely, the lowest leaf count (18.47) was observed in T₁ (absolute control). Differences across years were significant, with 2017–18 showing higher leaf numbers (20.49), though the interaction between treatments and years remained non-significant. The notable improvement in leaf production under INM treatments may be attributed to a synergistic effect of organic and inorganic sources that improve the soil's biological and chemical fertility, promoting enhanced nutrient availability and root development (14). The results were found to be in conformity with previous works in onion, where compost significantly increased growth traits including leaf number (15).

In the current study, the highest curd depth (9.02 cm) was observed under treatment T₂, where farmyard manure (250 q/ha) was supplemented with a dose of inorganic fertilisers (125 kg N, 75 kg P₂O₅ and 65 kg K₂O per hectare) (Table 2). This was closely followed by T₈ (8.20 cm) and both treatments showed statistically significant superiority over the rest. Although the interaction between treatment and year was not significant, the curd depth varied notably between the years, with higher values recorded in 2017–18 (8.38 cm). Similar results were made by early results who reported that robust vegetative growth boosts sink capacity, facilitating better curd development (16). In the present study (Table 2), treatment T₂, which included application of FYM (250 q/ha) along with the recommended dose of NPK (125 kg N, 75 kg P₂O₅ and 65 kg K₂O/ha), recorded the highest curd size index (271.86 cm²). This treatment outperformed T₈ (253.46 cm²), which ranked second. The treatment × year interaction (Table 2) revealed significant variation among the treatments. The highest curd size index across the years (313.18 cm²) was also recorded in T₂ during 2017–18. Year-wise

comparison showed significant differences, with a maximum mean value of 249.78 cm² observed in 2017–18. The larger curd size index in T₂ could be attributed to enhanced photosynthetic activity and greater metabolic processes resulting from the combined use of organic and chemical fertilisers, which likely promoted cell division and elongation (17). Comparable outcomes were also reported under mid-hill conditions in Himachal Pradesh (18).

Firmer curds are considered superior for marketability. In the present study (Table 3), the highest curd solidity was recorded in T₈ (91.05 g/cm), closely followed by T₄ (90.82 g/cm). Pooled data revealed that although treatment × year interactions were non-significant, significant differences were observed between the years, with greater solidity (85.51 g/cm) noted in 2018–19. Curd solidity is a standard parameter for assessing curd compactness and overall quality. The higher solidity observed in T₈ might be attributed to a steady and prolonged nutrient release from vermicompost, which potentially enhanced curd compactness, curd weight and overall volume. The N supplied through FYM and vermicompost likely promoted chlorophyll formation and improved physiological processes, contributing to increased curd size. These findings are supported by early works in broccoli (19) and in cabbage (10). The organic nutrient sources enhance curd compactness and vitamin C content, likely due to better nutrient availability that activates enzyme systems essential for metabolic processes governing curd firmness (18).

Gross curd weight plays a vital role as it directly and positively correlates with overall yield. As presented in Table 3, the pooled data showed significant variation in gross curd weight across treatments. The highest average curd weight (1.95 kg) was recorded in T₂, where the recommended dose of FYM (250 q/ha) was applied along with 125 kg N, 75 kg P₂O₅ and 65 kg K₂O/ha. This was followed by T₈ (1.83 kg). A significant difference was also observed between the 2 years, with greater values obtained in 2017–18 (1.69 kg). Interaction effects between years and treatments were also significant, with T₂ in 2017–18 producing the highest curd weight (1.99 kg), followed by T₈ (1.83 kg). The increased curd weight under T₂ may be attributed to enhanced vegetative growth driven by integrated nutrient application, resulting in improved carbohydrate synthesis via enhanced photosynthetic activity (12).

The success of cauliflower production is closely linked to

Table 3. Effect of organic and inorganic amendments on curd solidity ((g/cm), gross curd weight (kg), marketable yield (per plot kg) and (per hectare q) in cauliflower

Treatment code	Curd solidity (g/cm)	Gross curd weight (kg)	Marketable curd weight (g)	Marketable yield per plot (kg)	Marketable yield per hectare (q)
T ₁	57.66	1.35	445.49	8.91	140.25
T ₂	88.82	1.95	799.48	15.99	251.69
T ₃	62.27	1.41	476.57	9.53	150.03
T ₄	90.82	1.70	727.17	14.54	228.92
T ₅	88.33	1.47	685.33	13.71	215.75
T ₆	90.39	1.76	731.47	14.63	230.28
T ₇	88.89	1.52	694.41	13.89	218.61
T ₈	91.05	1.83	745.20	14.90	234.60
T ₉	89.62	1.68	706.60	14.13	222.45
Mean	83.09	1.65	667.97	13.36	210.29
Y	1.71	0.15	32.04	0.14	18.35
T	3.81	0.21	34.57	1.10	19.21
Y × T	NS	0.25	36.46	1.14	19.86

curd weight and overall yield, which are critical indicators of productivity and quality. The results of the present study (Table 3) clearly demonstrated that the application of a recommended dose of FYM at 250 q/ha combined with NPK (125 kg N, 75 kg P₂O₅ and 65 kg K₂O/ha) in treatment T₂ significantly enhanced marketable curd weight (799.48 g), with the highest value (805.17 g) was recorded during the season. These values were notably superior to all other treatments, especially T₈ (745.20 g) and considerably higher than the control (T₁), which recorded the lowest curd weight (442.43 g). Significant interactions between treatments and years were also observed, reflecting the stability and efficacy of INM across seasons.

Yield per plot and per hectare followed a similar trend, with T₂ outperforming all treatments. The pooled mean yield was 15.99 kg per plot, equating to 251.69 q/ha. The highest yield was recorded in T₂ during 2017–18 (16.10 kg/plot or 253.48 q/ha), closely followed by T₈ and T₆. Interestingly, while the nutrient application in T₆ and T₈ was organic dominated, they still achieved comparable results, emphasising the potential of organic sources like vermicompost in sustaining productivity. The superior performance of T₂ is further explained by the improved nutrient uptake, prolonged availability of macro and micronutrients, enhanced root activity and better soil biological health due to combined use of the organic & inorganic sources. Treatments involving vermicompost (T₈) also contributed significantly to yield due to their role in enhancing soil structure, microbial activity and sustained nutrient release, consistent with previous results (18).

The economic analysed data of various INM treatments revealed substantial differences in profitability across the treatments (Table 4). The highest net income (362397 ha⁻¹) was recorded in T₂, which involved the application of FYM (250 q/ha) combined with NPK fertilisers (125 kg N, 75 kg P₂O₅ and 65 kg K₂O/ha). This

treatment also achieved a high benefit-cost (B:C) ratio of 2.57:1. Closely following this was T₈, which combined 50 % FYM (125 q/ha), vermicompost (providing N=50 % FYM) and a full dose of NPK supplied through FYM on an N-equivalent basis. T₈ resulted in a net income of 335345/ha with a B:C ratio of 2.50:1. The higher profitability observed in these treatments can be attributed to the production of better quality, well-sized curds that commanded higher prices due to their superior market acceptability. These findings corroborate those of previous results, who reported higher economic returns under INM in bell pepper (20, 21).

Conclusion

From the current investigation, it can easily be concluded that treatment T₂ (125 N: 75 P: 65 K kg/ha + farmyard manure (FYM) at 250 q/ha) produced best results in terms of yield and related traits as well as B: C ratio. However, the module T₈ besides excelling at par with T₂ (predominantly synthetic module) in growth and yield traits also resulted in at par build-up of macronutrients (NPK) at the end of experiment. Therefore, the module T₈ (50 % FYM (125 q/ha) + application of vermicompost (equivalent to N content of 50 % FYM) + recommended dose of nitrogen, phosphorous and potassium (NPK) through FYM on N equivalent basis) owing to an at par excellence in yield. Long-term investigations are needed to examine the sustained performance of organic and integrated nutrient modules and their influence on soil fertility. Greater attention should be given to changes in soil biological activity, carbon sequestration and nutrient efficiency over successive seasons. These efforts will support the development of location-specific, sustainable and cost-effective nutrient management practices.

Table 4. Economics of cauliflower as affected by different integrated nutrient management treatments

Treatment code	Yield (q/ha)	Cost of cultivation (Rs.)	Gross income (Rs.)	Net income (Rs.)	B:C ratio
T ₁	140.25	61500	140250	78750	1.28
T ₂	251.69	140983	503380	362397	2.57
T ₃	150.03	78450	180036	101586	1.29
T ₄	228.92	199875	457840	257965	1.29
T ₅	215.75	149910	431500	281590	1.87
T ₆	230.28	199450	460560	261110	1.30
T ₇	218.61	148410	437220	288810	1.94
T ₈	234.60	133855	469200	335345	2.50
T ₉	222.45	149160	444900	295740	1.98

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Authors' contributions

CY and PS performed the experiment. CY, YRS designed the research. PS, AP, SK wrote the manuscript. PS, SK, AK and HT revised and corrected the manuscript. All authors have contributed for different sections of writing, reviewing, correction and statistical analysis. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflict of interest.

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