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Optimizing cabbage (*Brassica oleracea* var.*capitata*) production through integrated nutrient management: Enhancing yield, quality, and sustainability

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Abstract

This study explores the synergistic effects of integrated nutrient management (INM) on the growth, yield, and quality attributes of cabbage (*Brassica oleracea* var. *capitata*). The present study was conducted during the Rabi season of 2022-23 at Lovely Professional University at a vegetable research farm in Punjab, India. The experiment was laid out in a completely randomized block design with ten treatments replicated three times. Various combinations of organic and inorganic fertilizers, including vermicompost and neem cake were evaluated alongside the recommended dose of fertilizers (RDF). Results indicated significant enhancements in most horticultural traits of cabbage across different treatments. Notably, the combination of RDF with vermicompost and neem cake (75% RDF: 5 t/ha: 2 t/ha) exhibited the most promising results, including increased head weight (125%), head formation percentage (22.17%), enhanced head yield (65.33%), improved compactness (98.60%), elevated ascorbic acid content (24.48%), and higher dry matter content (27.56%) than of control. These findings underscore the efficacy of integrated nutrient management strategies in optimizing cabbage production, emphasizing their potential for sustainable and high-quality vegetable cultivation.

Keywords

Quality production; organic manures; vermicompost; neem cake; sustainability

Introduction

Cabbage (*Brassica oleracea* var. *capitata*), is a Cole crop mostly cultivated all over the world. It has a diploid chromosome number i.e. 18. It originates from the Mediterranean region and the edible part is the head (1). It is grown in cold, humid climates, and sown as a winter crop on the lowlands. It may be cultivated in various soil types, from clay to sandy loam. The pH levels of the soil should range between 5.5 to 6.5, to get maximum productivity. Cabbage is not native to India, but it was introduced to the country during the British colonial period (2). It is believed that cabbage was first introduced to India in the late 19th century when the British started importing it from Europe (3). Regarding worldwide vegetable productivity, India is second next to China in terms of production. In the fiscal year 2021, vegetable output was projected to equal over 196 million metric tons. In a country like India, vegetables are essential for addressing poverty and malnutrition. Vegetables are an important component of the human diet that ensures food and nutritional security, as well as consistent cash production for a vegetable producer. It cannot be overstated according to the statement Vegetables are friends of physicians and glory of cook". Vegetables supply a variety of necessary elements for good health (4). These are essential elements of a healthy diet, especially in India, where many of the population is vegetarian. According to the Indian Council of Medical Research (ICMR) recommends that an adult requires 300 g of vegetables per day, which includes 125 g of leafy vegetables, 100 g of root vegetables, and 75 g of other vegetables (5). Cabbage could be a smart supply of protein with high biological price and edibleness (6). Its leaves are rich in vitamins A, B1, and B2, and minerals are a superb supply of vitamin C and possess anti-carcinogenic effects (7). It is important to consume vegetables in their whole form or minimally processed to obtain maximum nutritional benefits (8). It can be consumed raw and cooked. Nutrition plays a vital role in the control of cabbage growth and production (9). By avoiding chemical agriculture, the use of biological as well as organic fertilizers can enhance soil health, growth, production, and quality (6). Integrated nutrient management (INM) preserves soil as a source of plant nutrients required for vegetative development (2). INM's mission is to integrate the utilization of all-natural and man-made sources of plant nutrients to boost agricultural output in a cost-effective and ecologically friendly manner, without sacrificing the soil productivity of future generations (10). Several variables impact cabbage productivity, including soil fertility, variety, and climatic situations (11). As a result, to produce high -quality cabbage, organic fertilization is the best way to get better results. Bio-fertilizers and inorganic fertilizers are both necessary for optimum production (12, 13). Organic manures can replace nutrients where inorganic fertilizers are unavailable due to higher costs and insufficient availability. Integrated nutrient control helps to increase crop yields while also maintaining soil fertility (2). The utilization of renewable energy and other resources can be also considered a vital point for sustainable agriculture, to achieve maximum productivity with minimum environmental risk (6). To achieve this, there is a need to standardize the modulation of organic manures along with bio-fertilizers and synthetic fertilizers. Top of Form Cabbage farmers would benefit greatly from the precise details on advanced nutrient management for optimum yield and improved quality. The present study was initiated to achieve the objective of evaluating the various doses of organic and inorganic fertilizer application to enhance the growth, yield, and quality attributes of cabbage.

Materials and Methods

Experimental location

The investigation was done at the farm of Lovely Professional University (LPU), Phagwara district Kapurthala. During the Rabi season in 2022-2023. With a 252 m average elevation above mean sea level, the farm is located at 31022’31.81” North latitude and 75023’03.02” East longitude. It is 350 kilometers from India’s capital, Delhi, and is in the subtropical portion of the state’s Argo climatic region.

Treatment details

The experiment was laid out in a factorial randomized block design with 10 treatments and replicated 3 times with 30 treatment combinations. A total of 10 treatments including control. The treatments included in the experiment comprise, control, the recommended dose of fertilizers (100%), RDF: Vermicompost (75%:5 t/ha), RDF: Vermicompost (75%:2.5 t/ha), RDF: Vermicompost (50%: 5 t/ha), RDF: Vermicompost (50%: 2.5 t/ha), RDF : Vermicompost: Neem Cake (75%: 5 t/ha:2 t/ha), RDF: Vermicompost: Neem Cake (75%:2.5 t/ha:2 t/ha), RDF : Vermicompost: Neem Cake (50%:5 t/ha:2.5 t/ha), RDF: Vermicompost: Neem Cake (50%: 2.5 t/ha:2.5 t/ha). Transplanting was done in ridgelines, in a spacing of 45 cm × 45 cm. The data was recorded for various horticultural traits, from the five randomly tagged plants. The observations were recorded for various cabbage growth and yielding attributes namely, plant height (cm): 30 DAT, 45 DAT, 60 DAT at harvest, days to head initiation, days to 50% head initiation, number of non-wrapped leaves per plant, fresh weight of non-wrapped leaves (g/plant), days to harvest, diameter of head (cm), compactness of head, head formation percentage**.**

Cultural practices

The sowing of the cabbage seeds was carried out in September 2022. The protrays were filled with a growing media mixture consisting of coco peat, vermiculite, and perlite in a 3:1:1 ratio. Each cell of the protray received one seed, which was then covered with additional growing media or vermiculite. After sowing, the protrays were moved to a growing chamber. To encourage the growth of the seedlings water-soluble fertilizer i.e. 19:19:19 @ 3 g/l was applied twice a week. The transplanting was done in November 2022. After 25 to 30 days, the seedlings were ready for transplantation. The field was plowed using a tractor, cultivator, and rotavator to get decent tilth. Stubbles, weeds, and stones were cleared from the area. The experimental layout was created by dividing the area into ten equal plots and three replications after leveling the soil. The recommended dose of fertilizer (150:60:80 kg/ha) was calculated for each treatment and incorporated in the prepared plot. Before transplanting crop seedlings, the organic manures were also calculated and applied accordingly. Healthy cabbage seedlings were ready for transplanting after 45 days of sowing in a spacing of 45 × 30 cm. To maintain uniformity and optimum crop stand, gap filling must be done within one week after each transplanting. The recommended package and practices for Punjab conditions have been performed at regular intervals of time. The crop was harvested, from mid-January to March, when the head was solid and compact as it had reached its fullmaturity.

Growth parameters

Five plants were picked randomly from each plot and tagged for observation. As a result, numerous plant characters were tested to determine the influence of various treatments,as listed below:

Plant Height

Plant height was recorded 30 days after transplant, 60 days after transplant, and harvest. Plant height was determined by selecting five plants at random from each treatment. The plant height was measured from the ground level to the longest leaf before harvesting.

Number of days to 50% head initiation

Days were counted from the date of sowing to the date of fifty percent head formation for each treatment of each replication, and the mean value was calculated for the same.

Days taken for the initiation of Head

Days of transplantation to the first commencement of the head were observed at each plot from the selected plants that were tagged.

Number of non-wrapped leaves

Days of transplantation to the harvesting of the head the non-wrapped leaves were counted from the tagged plant.

Fresh weight of non-wrapped leaves (g/plant)

Days of transplanting to the harvesting of the plant the fresh weight of non-wrapped leaves of weight taken from the randomly five tagged plants:

Days to harvest

Days of transplanting to the number of days taken to harvest, the data was recorded from the randomly selected plants.

Head Formation Percentage

The total number of heads developed on several plants per plot was counted, and divided by the total number of plants grown in the plot of each treatment. The head formation percentage was calculated by using the following formula:

$$Head\ Formation\,\% = \frac{Number\ of\ head\ developed\ per\ plant}{Total\ number\ of\ plants} \times 100$$

Yield Parameters

Head Diameter (cm)

When five plants were harvested, the diameter of the heads was measured, and the average value was recorded and represented in centimeters. The instrument used for measuring the head diameter is the vernier caliper.

Head Weight (g)

Heads of cabbage were harvested after attaining physiological maturity and were firm and compact. The average weight of a head was computed using the fresh weight (g) of the heads.

Compactness of head (%)

Compactness of the head is measured in terms of the 'Z' value by using the following formula.

$$Compactness\ of\ head = \frac{Head\ weight\ (g)}{Diameter\ (cm^2)} \times 100$$

Yield per plot (kg)

The average head weight and fresh weight of the heads of cabbage were calculatedfrom the tagged plants by multiplying the number of plants present per meter square.

Total Yield (t/ha^2

The yield per hectare was determined represented in tons per hectare using theaverage weight of heads per m ^{2}.

Quality Parameters

Ascorbic acid (mg/100 g)

A random sample of 10 g of the head taken and the leaves crushed from each treatment was obtained to determine ascorbic acid content. The 2, 6- dichlorophenolindophenol technique is used to determine ascorbic acid content (9).

Dry matter content (%)

Randomly selected terminal head parts were taken from five plants in each treatment group. Chopping of these samples commenced after their weights were recorded. The samples were then oven-dried at 60°C until a consistent weight was achieved. After drying, the samples were weighed again, and the dry matter content was calculated as a percentage.

$$Dry\ matter\ content\,\% = \frac{Dry\ weight\ of\ sample}{Fresh\ weight\ of\ the\ sample} \times 100$$

SPAD Value

For each treatment and replication, the SPAD (Soil Plant Analysis Development) values were measured in the leaves of five labeled plants at the time of harvesting. This measurement was taken by manually attaching a SPAD chlorophyll meter to the leaf tissue on the day of harvesting.

Dry weight of head per plant (g)

The samples are taken and divided into two halves surrounded with paper and kept under a tray to keep it in a hot air oven for 3 days.

Economics

Cost of Cultivation (Rs)

The cost incurred for the cultivation was determined by using current pricing for all supplies and labor expenses at the time they were used.

Gross income (Rs)

The total revenue was calculated using the ongoing market value.

Net return (Rs)

The cost of cultivation was subtracted from the calculated gross income value

Benefit -Cost ratio

Benefit-cost ratio is obtained by using the formula below:

$$Benefit\ cost\ ratio = \frac{Net\ income}{Total\ cost\ of\ cultivation}$$

Statistical analysis

The exploratory information recorded was subjected to statistical analysis using analysis of variance methods suggested by Panse and Sukhatme, 1985. At the 5 % level, the F value wasused to evaluate statistical significance, and critical difference (CD). The statistical analysis was performed by using OPSTAT Software

Results and Discussion

Growth attributing traits

The study revealed that most cabbage traits were significantly impacted by the varied integrated fertilizer combinations, as detailed in Tables 1 and 2. The height of the cabbage plants was notably affected by the application of different nutrient mixes at 30, 45, and 60 days after transplanting (DAT), and at the final harvest. The tallest plants at the final harvest were observed with the RDF: Vermicompost (50% RDF: 5t/ha) treatment, achieving the highest growth. This was closely followed by treatments combining RDF, Vermicompost, and Neem Cake at ratios of (50%: 5t/ha: 2.5t/ha) and (75% RDF: 5t/ha: 2t/ha). The shortest plants were found in the control group.

Table 1. Effect of integrated nutrient management on growth attributing characters in cabbage.

	Treatments	Plant Height				50% head initiation	No of days to head initiation
		30 DAS	45 DAS	60 DAS	At Harvest		
T1	Control	17.50	22.27	31.00	40.87	37.67	31.93
T2	100% RDF (fertilizers)	18.53	28.00	31.57	53.17	41.00	35.33
T3	75% RDF + Vermicompost @ 5 t/ ha	19.93	27.43	32.00	50.53	46.67	36.93
T4	75% RDF + Vermicompost @ 2.5 t/ha	22.57	28.20	31.80	49.53	42.67	38.07
T5	50% RDF + Vermicompost@ 5t/ha	25.91	31.77	41.60	58.43	40.67	37.73
T6	50% RDF + Vermicompost @ 2.5t/ha	19.20	28.43	37.23	52.60	39.00	37.93
T7	75% RDF + Vermicompost @ 5t/ ha + Neem cake (2t/ha)	19.57	26.80	36.67	55.37	41.00	39.27
T8	75% RDF + Vermicompost@ 2.5 t/ha + Neem cake (2t/ha)	16.63	25.53	36.30	53.10	42.00	40.13
T9	50% RDF + Vermicompost@5t/ha + Neem cake (2.5t/ha)	19.13	27.23	36.67	56.23	41.00	39.93
T10	50% RDF + Vermicompost @ 2.5t/ha + Neem cake (2.5t/ha)	20.40	30.67	35.40	53.93	43.00	35.67
	C.D (5%)	1.702	2.064	2.520	3.418	3.074	3.045
	SE(m)	0.57	0.69	0.85	1.15	1.03	1.02
	SE(d)	0.81	0.98	1.20	1.63	1.46	1.45
	C.V	5.04	5.24	6.16	7.63	7.74	8.45

RDF: Recommended dose of fertilizers; **CD**: critical difference; **SE**: standard error; **CV**: Coefficient of Variation

Table 2. Effect of integrated nutrient management on growth and yield characters in cabbage.

	Treatment	No non-wrapped leaves	Weight of non-wrapped leaves	Days to harvest	Weight of head (grams)	Yield (Kg/m^2)	Head Yield (t/ha)
T_1	Control	10.30	312.40	89.00	420.000	2.420	24.203
T_2	100% RDF (fertilizers)	13.67	326.67	85.53	615.000	2.707	28.027
T_3	75% RDF + Vermicompost @ 5 t/ ha	11.73	305.93	84.37	620.003	2.730	27.280
T_4	75% RDF + Vermicompost @ 2.5 t/ha	11.53	334.67	83.93	730.000	3.210	32.117
T_5	50% RDF + Vermicompost@ 5t/ha	12.27	539.33	83.60	845.337	3.420	37.183
T_6	50% RDF + Vermicompost @ 2.5t/ha	12.67	487.93	83.53	606.003	3.180	31.810
T_7	75% RDF + Vermicompost @ 5t/ ha + Neem cake (2t/ha)	12.00	414.07	80.63	948.667	3.940	40.010
T_8	75% RDF + Vermicompost@ 2.5 t/ha + Neem cake (2t/ha)	11.07	453.73	82.70	659.997	3.480	34.800
T_9	50% RDF + Vermicompost@5t/ha + Neem cake (2.5t/ha)	13.67	485.67	83.23	791.003	2.860	28.600
T_{10}	50% RDF + Vermicompost @ 2.5t/ha + Neem cake (2.5t/ha)	11.33	393.53	83.33	783.333	2.727	27.280
	C.D. (5%)	1.894	9.734	3.519	74.375	2.095	4.114
	SE(m)	0.64	3.28	1.18	24.840	0.032	0.706
	SE(d)	0.90	4.63	1.68	35.129	0.045	0.998
	C.V	10.13	7.94	5.01	6.129	6.768	7.927

RDF: Recommended dose of fertilizers; **CD**: critical difference; **SE**: standard error; **CV**: Coefficient of Variation.

This growth enhancement is attributed to the synergistic effects of vermicompost and NPK fertilizers on plant development (14), which improve soil moisture retention and enhance soil fertility (15, 16).

Head initiation up to 50% recorded the highest value in RDF: Vermicompost (75%: 5 t/ha), followed by RDF: Vermicompost: Neem Cake (50%:5t/ha: 2.5t/ha), the lowest value recorded in control because the use of vermicompost and neem cake in combination with RDF has been found to significantly improve the growth and yield of cabbage (16). Vermicompost is a rich source of nutrients and beneficial microorganisms that improve soil health and plant growth, while neem cake is a natural pesticide and soil conditioner that protects plants from pests and diseases (17). The shortest duration required for initiating head formation, equivalent to the effectiveness of RDF (50%:5t/ha: 2.5t/ha) with Vermicompost and Neem Cake, and the longest duration observed in the control group. These results are improved by the stimulating effects of vermicompost and NPK on the initiation of the head. A lack of one or more nutrients causes the plant to mature early, resulting inreduced plant growth and development. Nutrient sufficiency results in longer crop duration and increased crop growth. Application of RDF: Vermicompost (50%: 50t/ha) enhanced the maturity of Heads and the least days taken for Head initiation was (35.58 days) which was inferior to the reports of (18).

Yielding attributing traits

The greatest number of non-wrapped leaves was recorded in the treatment combining RDF: Vermicompost: Neem Cake (50% RDF: 5t/ha: 2.5t/ha), as indicated in Fig. 1; Tables 2 and 3. This was followed by the recommended dose of fertilizers (100%). The lowest number of non-wrapped leaves was observed in the control group. These results are improved by the stimulating effects of vermicompost and NPK and similar results were found by (12, 13). Fresh weight of non-wrapped leaves per plant in cabbage which was done trials with the different combinations highest value shown with the average of RDF: Vermicompost (50%: 5t/ha), with the application of RDF: Vermicompost (50 %: 5t/ha), followed by RDF: Vermicompost (50%: 2.5 t/ha), and lowest value noted as with the combination of RDF: Vermicompost (75 %: 5 t/ ha) this is because of vermicompost's stimulating effects and NPK's adverse results added to these research results' enhancement same has been reported by (18). Different treatment combinations influenced the number of days required to harvest mature cabbage crops. The quickest harvest time was reported with the combination of RDF: Vermicompost: Neem Cake (75% RDF: 5t/ha: 2t/ha), followed by the mix of RDF: Vermicompost: Neem Cake (50% RDF: 5t/ha: 2.5t/ha). The longest time to harvest was observed in the control group. This acceleration in growth and development is attributed to the vermicompost and neem cake, which are rich in organic matter and beneficial microorganisms, enhancing soil health and promoting early cabbage head formation (17). The combination with RDF: Vermicompost: Neem Cake (75 %: 5t/ ha: 2t/ha) showed the greatest improvement in days to harvest compared to the other treatments. This may be due to the synergistic effect of vermicompost and neem cake in improving soil health and providing nutrients to the plants (17). The highest head weight was recorded in the treatment combining RDF, Vermicompost, and Neem Cake (75% RDF: 5t/ha: 2t/ha). This result was comparable to those of the RDF with Vermicompost (50% RDF: 5t/ha) and the RDF, Vermicompost, and Neem Cake (50% RDF: 5t/ha: 2.5t/ha) treatments. Plant head weightfor RDF: Vermicompost: Neem Cake (75%: 5t/ ha: 2t/ha), was found statistically significant than the remaining treatments while the lowest head weightwas recorded in control. The reason is that the nutrients for many plants are growth-promoting nutrients that aid in better cell division and greater protein synthesis which is activatedto increase growth and ultimately results in a higher head weight (10). Head yield showed the yield per m^2 data, which shows that there is a considerable variation

Fig. 1. Effect of various treatments on harvested cabbage heads. **T1** - Control, **T2** - 100% RDF(fertilizers), **T3** - 75% RDF +Vermicompost@ 2.5 t/ha, **T4** - 75% RDF +Vermicompost@ 5t/ha, **T5** - 50% RDF +Vermicompost@ 5t/ha, **T6** - 50% RDF +Vermicompost@ 2.5 t/ha, **T7** - 75% RDF +Vermicompost@ 5t/ha + Neem cake @2t/ha, **T8** - 75% RDF +Vermicompost@ 2.5t/ha + Neem cake @2t/ha, **T9** -50% RDF +Vermicompost@ 5t/ha + Neem cake @2.5t/ha, **T10** - 50% RDF +Vermicompost@ 2.5t/ha + Neem cake @2.5t/ha

between the treatments RDF: Vermicompost: Neem Cake (75%: 5t/ ha: 2t/ha), recorded the highest yield per m^2 followed by RDF: Vermicompost (50%: 5t/ha), and RDF: Vermicompost: Neem Cake (75%: 5t/ ha:2t/ha). However, the lowest yield per m^2 was observed in control. These results are improved by the stimulating effects of vermicompost and NPK on head yield (kg/m^2). The enhanced yield could be attributed to the vegetative growth's performance, which may have encouraged the generation of more carbohydrates collected in the head, resulting in a higher yield. This could be due to an optimalnitrogen dose, as nitrogen is a component of protein and chlorophyll and plays an important part in the photosynthesis process, increasing output per hectare (19). The use of diverse fertilizer sources has a substantial impact on cabbage yield per hectare. The highest yield was achieved with the treatment combining RDF: Vermicompost: Neem Cake (75% RDF: 5t/ha: 2t/ha). This was closely followed by the RDF: Vermicompost (50% RDF: 5t/ha) and similarly higher yields were again seen with the RDF: Vermicompost: Neem Cake (75% RDF: 5t/ha: 2t/ha) treatment. The lowest yields were observed in the control group. The increased yields are attributed to the enhancing effects of vermicompost and NPK on head yield (t/ha). These significant results are supported by references (20, 21). The head formation percentage of cabbage is significantly influenced by various sources of nutrition. The maximum percentage of the head was observed in RDF: Vermicompost: Neem Cake (75%: 5t/ ha: 2t/ha), followed by the recommended dose of fertilizers (100%). The lowest result was seen in control. By providing different nutrients to the soil for the growth of the plant to initiate the good compact and formation of head which has higher market value by these RDF: Vermicompost: Neem Cake (75 %: 5 t/ha: 2 t/ha) showed the good head formation percentage by various treatments. The use of vermicompost and neem cake in combination with RDF has been found to significantly increase the head formation percentage of cabbage (16). Vermicompost and neem cake contain organic matter and beneficial microorganisms that improve soil health and promote plant growth and development (17). The maximum diameter of the head was found in RDF: vermicompost (75%: 5 t/ha), followed by RDF: Vermicompost: Neem Cake (50%:5t/ha: 2.5t/ha), RDF: Vermicompost: Neem Cake (75%: 5t/ ha:2t/ ha). However, the smallest head diameter was observed in control. This could be because nutrients, particularly nitrogen, were freely accessible to plants in adequate amounts, increasing the amount of photosynthates they produce. This viewpoint was supported by the results of (2) and (5).

Quality attributing traits

The maximum head compactness was recorded in the treatment with RDF: Vermicompost: Neem Cake (75% RDF: 5t/ha: 2t/ha), closely followed by the RDF: Vermicompost (50% RDF: 5t/ha), as detailed in Fig. 1 and Table 3. The least compactness was observed in the control group. These results demonstrate the beneficial effects of NPK on enhancing the compactness of cabbage heads. These findings are consistent with those reported by (4). The ascorbic acid content of cabbage is significantly influenced by various sources of nutrition. Application of RDF: Vermicompost: Neem Cake (75%: 5t/ ha: 2t/ha), had the highest ascorbic acid concentration, followed by RDF: Vermicompost: Neem Cake (75%: 5t/ ha: 2t/ha), the lowest result was at control. Due to the stimulating effects of vermicompost, neem cake, and NPK on ascorbic acid concentration, these results are enhanced with the combination of 75% RDF, Vermicompost at 5 tons per hectare, and Neem Cake (2 tons per hectare) produced the greatest results. Since ascorbic acid is produced from carbohydrates, the elevation in ascorbic acid level in cabbage may be attributed to the synthesis of new carbohydrates. Similar reports were observed by (5). These findings are in close agreement with those reported earlier (1, 5, 22) in cabbage and (23) in cauliflower. The maximum dry matter content was observed in the treatment with RDF: Vermicompost: Neem Cake (75% RDF: 5t/ha: 2t/ha), which matched the levels seen with the recommended dose of

Table 3 Effect of integrated nutrient management on yield and quality traits of cabbage.

	Treatment	Head formation percentage	Diameter of head(cm)	Compactness of head	Ascorbic Acid	Dry matter content
T_1	Control	80.27	12.82	22.16	28.96	65.300
T_2	100% RDF (fertilizers)	90.67	13.50	33.99	32.36	82.907
T_3	75% RDF + Vermicompost @ 5 t/ ha	89.80	19.23	29.02	32.27	82.317
T_4	75% RDF + Vermicompost @ 2.5 t/ha	85.67	13.00	28.30	34.54	82.700
T_5	50% RDF + Vermicompost@ 5t/ha	86.53	12.73	42.85	32.07	81.700
T_6	50% RDF + Vermicompost @ 2.5t/ha	90.13	13.29	33.44	33.25	81.847
T_7	75% RDF + Vermicompost @ 5t/ ha + Neem cake (2t/ha)	98.07	18.03	44.01	37.21	83.303
T_8	75% RDF + Vermicompost@ 2.5 t/ha + Neem cake (2t/ha)	83.40	16.45	34.07	34.64	81.507
T_9	50% RDF + Vermicompost@5t/ha + Neem cake (2.5t/ha)	86.33	18.22	31.44	34.28	79.877
T_{10}	50% RDF + Vermicompost @ 2.5t/ha + Neem cake (2.5t/ha)	87.73	14.62	33.07	31.07	80.147
	C.D. (5%)	4.546	0.63	2.371	2.437	4.996
	SE(m)	1.53	0.89	0.80	0.82	1.668
	SE(d)	2.16	1.860	1.13	1.16	2.360
	C.V	7.99	7.74	5.75	6.10	3.605

RDF: Recommended dose of fertilizers; **CD**: critical difference; **SE**: standard error; **CV**: Coefficient of Variation.

fertilizers (100%) and RDF: Vermicompost (75% RDF: 2.5 t/ha). Specifically, the dry matter content in the 75% RDF: Vermicompost: Neem Cake (75% RDF: 5t/ha: 2t/ha) treatment was found to be statistically significant compared to other treatments. The lowest dry matter content was recorded in the control. Among the different nutrients in NPK, vermicompost and Neem cake the SPAD value reported the highest value in the combination of RDF: Vermicompost (75%: 2.5 t/ha), followed by the recommended dose of fertilizers (100%), and the lowest value reported in control plot control. Among the different nutrients in NPK, Vermicompost, and Neem Cake the dry weight of the head reported highest in RDF: Vermicompost: Neem Cake (75%: 5t/ ha: 2t/ha), followed by RDF: Vermicompost (50%: 5t/ha), RDF: Vermicompost: Neem Cake (50%:5t/ha: 2.5t/ha), and lowest in control. The application of organic manure along with chemical fertilizer RDF: Vermicompost: Neem Cake (75%: 5t/ ha: 2t/ha), and RDF: Vermicompost (50%: 5t/ha), has proven to be effective in enhancing the yield of cabbage. This can be attributed to the combined effect of organic and inorganic sources of nutrients, which provides a balanced nutrient supply to the crop throughout the growth period. Overall, the results underscore that integrating organic and inorganic fertilizers effectively boosts cabbage yield. This synergy likely arises from the complementary benefits of organic matter improving soil structure and microbial activity, while inorganic fertilizers provide immediate nutrient availability to plants. These findings corroborate previous research documented in reference (24), highlighting a consistent pattern across studies that both fertilizer types are crucial for maximizing agricultural productivity in cabbage cultivation. This approach not only enhances yield but also supports sustainable farming practices by optimizing nutrient use efficiency.

Conclusion

The findings of this study highlight the significant benefits of integrated nutrient management (INM) in enhancing the growth, yield, and quality attributes of cabbage (*Brassica oleracea* var. *capitata*). Through meticulous experimentation and analysis, we have demonstrated that the judicious combination of organic and inorganic fertilizers can profoundly impact various horticultural parameters, thereby optimizing cabbage production. The observed improvements in plant height, days to head initiation, head yield, compactness, ascorbic acid content, and dry matter content underscore the effectiveness of INM strategies, particularly when incorporating vermicompost and neem cake alongside the recommended dose of fertilizers (RDF). These results not only contribute to the scientific understanding of cabbage cultivation but also hold practical implications for farmers and stakeholders in the agricultural sector. By adopting INM practices, farmers can achieve higher yields, improve crop quality, and reduce reliance on chemical inputs, thereby promoting sustainability and environmental stewardship. Furthermore, the economic benefits stemming from increased productivity and premium-quality produce underscore the potential of INM to enhance farm profitability and livelihoods. Moving forward, it is imperative to further investigate the long-term effects of INM on soil health, pest and disease management, and overall ecosystem resilience. Additionally, efforts should be directed toward disseminating knowledge and facilitating the adoption of INM practices among farmers through extension services, training programs, and policy support. By fostering the widespread adoption of INM, we can not only meet the growing demand for nutritious and high-quality vegetables but also contribute to the broader goals of food security, environmental sustainability, and rural development.

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Authors' contributions

This work was carried out in collaboration among all the authors. Authors TR and AG, conducted the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors, SR and CC managed the analysis of the study. Authors VT MK, SKY, GVN, and HK managed the literature search. All the authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors declare that there is no conflict of interest.

Ethical issues: None.

References

1. Verma R, Maurya BR, Meena VS. Integrated effect of bio-organics with chemical fertilizer on growth, yield and quality of cabbage (*Brassica oleracea* var *capitata*). Indian Journal of Agricultural Science. 2014;84(8):914-19. https://doi.org/10.56093/ijas.v84i8.43042
2. Sahu D, Yadav RK, Yadav VK, Singh SS. Effect of organic and inorganic fertilizers on growth parameters of cabbage (*Brassica oleracea* var. *capitata* L.). Pharma Innovation Journal. 2023;12(4):945-47. https://doi.org/10.22271/tpi.2023.v12.i3e.18965
3. Swarup V, Chatterjee SS. Origin and genetic improvement of cabbage. Economic Botany. 1972;26(4):2381-93. https://doi.org/10.1007/BF02860710
4. Khatkar J, Shadap A, Longkumer T. Effect of integrated nutrient management on the performance of cabbage (*Brassica oleracea* var. *capitata* L.). Journal of Pharmacognosy and Phytochemistry. 2018;7(4):225-28.
5. Zargar J, Kumar M, Kumar S, Chopra S, Kumar S, Bhushan A, Gupta R. Integrated nutrient management studies in cabbage (*Brassica oleracea*) under subtropical plains of Jammu. Indian Journal Agricultural Science. 2022;92(1):59-62. https://doi.org/10.56093/ijas.v92i1.120832
6. Bahadur A, Singh J, Singh KP. Response of cabbage to organic manures and bio-fertilizers. Indian Journal of Horticulture. 2004;61(3):278-79.

7. Birt FD. Anti-carcinogenic factors in cruciferous vegetables. In: Quebdeaux B and Bliss FA (eds.). Horticulture and Human Health. 1988;160.

8. Bhat R, Rashid Z, Dar SB, Mufti S. Seed yield and quality parameters of cabbage (*Brassica oleracea* var. *capitata*) about different sources and levels of sulphur. Current Agriculture Research Journal. 2017;5(2):177. http://dx.doi.org/10.12944/carj.5.2.04

9. Anonymous. Ministry of Agriculture, Govt. of India. 2021; Gurgaon. http:/ /www.nhb.gov.in.

10. Chaudhary MM, Bhanvadia AS, Parmar PN. Effect of integrated nutrient management on growth, yield attributes and yield of cabbage (*Brassica oleracea* var. *capitata* L.) under middle Gujarat conditions. Trend in Bioscience. 2015;8(8):2164-68.

11. Singh PK, Pandey M. Study the effect of integrated nutrient management on yield and nutrient uptake in cabbage. Indian Journal of Hill Farm. 2010;23(2):39-41.

12. Singh A, Soni SS, Singh RK, Singh MK, Mishra SK. Effect of integrated nutrient management on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica*) cv. TSX-0788. Pharmma Innovation Journal. 2021;10(2):220-22.

13. Singh H, Kumar V. Response of INM, spacing and cycocel on quality attributes of cabbage (*Brassica oleracea* (L.) *var. capitata*) in Bundelkhand. Agricultural Science Digest. 2021. http://dx.doi.org/10.18805/ag.D-5383

14. Wani ABJ, Narayan R, Ahmed N, Singh AK, Chattoo MA, Narayan S. Influence of organic and inorganic sources of nutrients on growth, yield and quality of cauliflower (*Brassica oleracea* var *botrytis* L.). Environmental Economics. 2011;29(4):1941-47.

15. Ghulam S, Khan MJ, Usman K, Shakeeb U. Effect of different rates of press mud on plant growth and yield of lentils in calcareous soil. Sarhad Journal of Agriculture. 2012;28(2):249-52.

16. Sharma S, Pathania S, Sharma S. Effect of organic and inorganic fertilizers on growth and yield of cabbage (*Brassica oleracea* var. *capitata*) cv. golden acre. International Journal of Agricultural Science. 2015;7(11):757-59.

17. Singh R, Singh Y, Singh PK. Impact of organic and inorganic sources of nutrients on growth, yield and quality of cabbage. Journal of Pharmacognosy and Phytochemistry. 2019;8(2):2642-45.

18. Singh A, Kumar A, Yadav S, Singh S. Effect of integrated nutrient management on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.). International Journal of Communication Systems. 2020;8(3):1196- 200. https://doi.org/10.22271/chemi.2020.v8.i3p.9364

19. Komma M, Singh MK, Sunanda P. Effect of integrated nutrient management on growth and yield of red cabbage (*Brassica oleracea* var. *capitata*) under Punjab conditions. The Pharma Innovation Journal. 2022;11(6):831-33.

20. Gupta VK, Pandey G, Singh M. Effect of integrated nutrient management on growth yield and quality of cabbage. Journal of Pharmacognosy and Phytochemistry. 2018;SP2:278-80.

21. Kumar R, Sharma SK. Effect of integrated nutrient management on cabbage production in the dry temperate region of Himachal Pradesh. Journal of Krishi Vigyan. 2021;9(2):46-48. https://doi.org/10.5958/2349-4433.2021.00008.8

22. Rai R, Thapa U, Mandal AR, Roy B. Growth, yield and quality of cabbage (*Brassica oleracea* var *capitata* L.) as influenced by vermicompost. Environment Ecology Journal. 2013;31(1A):314-17.

23. Sable PB, Bhamare VK. Effect of biofertilizers (*Azotobacter* and *Azospirillum*) alone and in combination with reduced levels of nitrogen on quality of cauliflower cv. Snowball-16. Asian Journal of Horticulture. 2007;2(1):215-17.

24. Sarkar D, Rakshit A. Amalgamation of farmers' bio-priming knowledge in integrated nutrient management for sustainable management of red cabbage soil under middle Gangetic plains, India. Environmental Management. 2023;72(2):382-95. https://doi.org/10.1007/s00267-022-01638-3