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Research Article

Effect of different sources of organic fertilizers on crop growth and yield of cabbage

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Abstract

Cabbage is (*Brassica oleracea* var. capitata) a popular leafy vegetable in Nepal, but depleted soil fertility and inefficient production techniques can limit productivity. To address this, we conducted a study in the Jumla district of Karnali Province, Nepal during the 2022 main cropping season. We evaluated the impact of different organic fertilizers on the growth and yield of cabbage using a Randomized Complete Block Design with seven treatments and three replications with the hybrid cultivar 'Green Coronet'. The treatments included Farm Yard Manure, Poultry Manure, FYM + Vermicompost, Vermicompost, Black Wonder, FYM + Poultry Manure, and Sheep Manure. The parameters, including plant height, stem diameter, leaf length and width, head weight, polar and equatorial diameter, head circumference, root and shoot weight, and weight of the head (g) of cabbage were taken for measurement. Our findings showed that organic fertilizers significantly influenced the growth and yield of cabbage, with Vermicompost showing the most potential as a nutrient source for achieving higher growth and yield. The Vermicompost treatment resulted in the largest size of cabbage head (1026 g), while the Farm Yard Manure and Poultry Manure treatments had limited impact. Our results suggest that the use of organic fertilizers such as Vermicompost can lead to higher cabbage production, improved soil fertility, and reduced reliance on chemical fertilizers and pesticides. This has significant implications for promoting sustainable agriculture practices, improving food security, and providing economic benefits for farmers and communities in Nepal and beyond.

Introduction

Cabbage is one of the oldest vegetables with a high nutritional content and has been cultivated and marketed commercially globally. It is a member of the Cruciferae or Brassicaceae family. The scientific name of cabbage is

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Brassica oleracea var. *capitata*, and its somatic chromosome number is 2n = 18 (Chiang et al., 1993). Domestication of *B. oleracea* crops occurred in the Eastern Mediterranean region (Makenzie et al., 2021). Cabbage is an herbaceous annual or biennial vegetable. Cabbage can endure significant frost and thrives in humid, cool climates (Červenski et al., 2022). Cabbage is typically grown as a spring or fall crop in temperate areas, whereas in warmer regions, it is primarily grown in the winter and early spring. Cabbage can be grown on a wide range of soils and thrives on well-drained, moisture-retentive loamy soils efficiently supplied with organic matter. The pH range considered ideal for soil is between 5.5 to 6.5 (Teshome & Aside, 2020). The French word Caboche, which means the head, is the origin of the English term cabbage (Rana, 2020). The edible portion of the cabbage plant is the head terminal vegetative bud, which consists of compacted layers of leaves with a wide range of sizes, colors, and textures (Moreb et al., 2020). Cabbage is a nutrient-dense vegetable that is high in fiber, essential minerals such as minerals (Ca, P, and K), and vitamins (C, K, A, and folate) (Jonatan & Campos, 2021). Cabbage juice helps to reduce inflammation, enhance immune function, and promote healthy digestion. It is prepared in several ways for eating, that is, stewed, shredded, steamed, pickled, fermented, boiled, sautéed, or eaten raw (Moreb et al., 2020).

Cabbage, a significant contributor to the world's vegetable market originated in Europe and has since spread to Asia and the Americas. In 2020, more than three-fourths of the world's vegetable crop was produced in Asia, with cabbage ranking fourth, behind tomatoes, onions, and cucumbers (Shahbandeh, 2022). The Ministry of Agriculture and Livestock Development of Nepal reported that in the fiscal year 2020/21, the fresh vegetable farming area in Nepal was approximately 2,84,121 hectares with a productivity rate of 14.05 mt ha^{-1} (Ministry of Agriculture and Livestock Development, 2022). Cabbage is one of the most popular cole crops in Nepal. Nepal produced 9.02 thousand mt Cabbage and other brassicas in 2020, placing it in 18th place overall in the Asia-Pacific region (Ganbold, 2022). Cabbage exports from Nepal were 7,756 tonnes in 2019. The mountainous district of Nepal, Jumla, is renowned for its high-altitude agroecosystem, which has enormous potential for organic farming. In recent years, cabbage production has gained popularity among farmers due to its longer shelf life and low vulnerability to pests and diseases. With its ideal environment for cabbage cultivation, Jumla has made significant strides in vegetable farming, utilizing 112 hectares of land for cabbage production and achieving a yield of 6.89 mt ha^{-1} in the fiscal year 2020/21 (Ministry of Agriculture and Livestock Development, 2022). As a result, vegetable farming has become a lucrative alternative for farmers, and it has replaced the cultivation of paddy and other crops in Jumla.

Cabbage needs a constant supply of water and nutrients to develop, as it quickly depletes the soil of its nutrients. To achieve higher productivity and maximize profits in cabbage cultivation, farmers must provide the appropriate amount of nutrients. Excessive and inappropriate use of chemical fertilizers causes soil degradation, environmental pollution, and health hazards for farmers and consumers, undermining sustainable farming practices, despite their role in boosting crop yields. Consequently, the preference should be for organic fertilizers. Organic fertilizer has the potential to replace chemical fertilizer. The use of organic nutrients in various forms, including vermicompost, farmyard manure, poultry manure, and biofertilizer, has shown significant effects on the physical and biological characteristics of different crops. Organic fertilizers are a sustainable source of nutrients for cabbage plants and influence the environment and soil quality. They contribute to the soil's ability to retain water, reduce bulk density, and have a high cation exchange capacity. Additionally, they promote the growth of a diverse range of beneficial microorganisms in the soil (Islam et al., 2017). The nutritional value and keeping quality of cabbage heads can be improved by applying organic manure. Different organic manures had a noticeable impact on vegetative development and the number of days needed for head initiation and harvest in cabbage. The addition of organic fertilizer enhances root development, which indirectly enhances plant nutrient availability and leads to improvements in leaf area development and crop output. This research aims to study the effects of various locally available organic manure and fertilizers on cabbage growth and yield.

Materials and methods

Location

Jumla district, located in the mid-western region of Nepal in the Karnali province, covers an area of 2531 km^2 and lies between 81^0 28' E to 82^0 18' E longitude and 28^0 58' N to 29^0 30' N latitude. The elevation of Jumla varies from 915 m to 4679 m above sea level and divides into three regions: higher himalayan, higher mountain, and mid-mountains. The Experimental Farm was located at Simkhada Chandanath-3, which is about 10 km away from the District Agriculture Development Office in Jumla, at a longitude of 82°11' 04" E and latitude of 29^0 17' 30" N.

Climate

During the cropping season, the average monthly temperature varied between 12°C and 14°C, and the average monthly relative humidity ranged from 40% to 88%. The average monthly rainfall was between 10.4 mm and 112 mm, with the highest rainfall occurring in July (112.2 mm) and the lowest in April (10.4 mm) which is represent in Figure 1. During April 2022 to September 2022, the average cloud and humidity percentages were 51.4% and 68.6%, respectively.

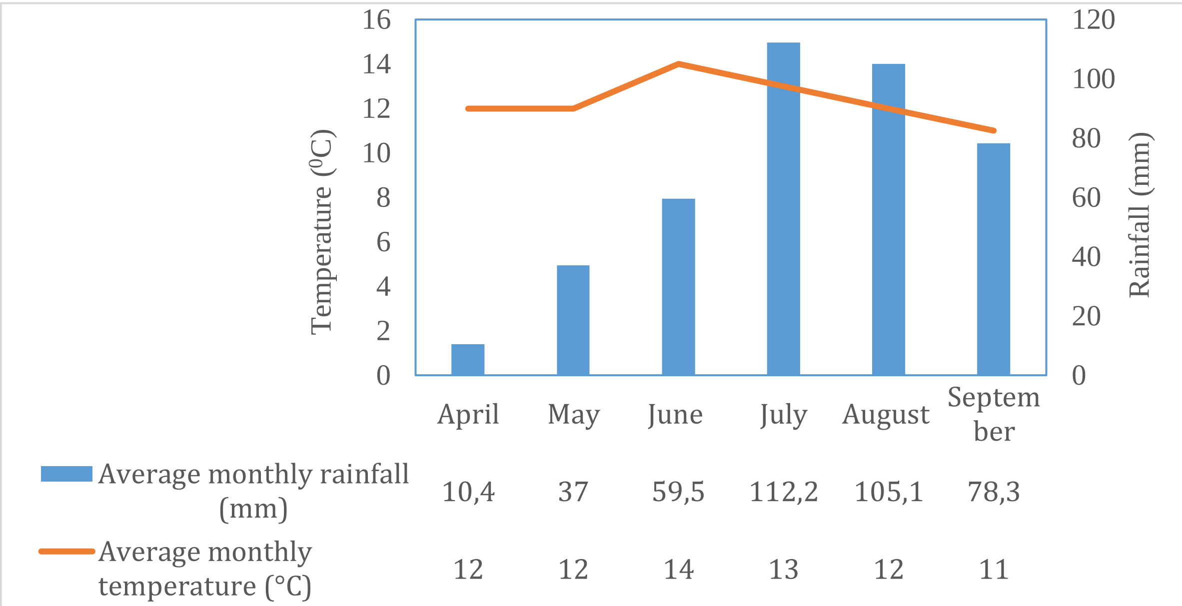

Figure 1. Graphical representation of average monthly climate data during the crop season

Characteristics of soil

Before laying out the experiment, soil samples from various spots of the experimental field at a depth of 15 cm were randomly collected. The composite sample prepared afterward was then analyzed to determine the physiochemical properties of the soil. Soil testing is crucial before growing any crop. The following Table 1 summarizes the physical and chemical characteristics of the soil in the experimental area.

Table 1. Physical and chemical properties of the soil

Soil type	pH	Available N (%)	Available P_2O_5 (%)	Available K_2O (%)	Average Carbon (%)
Loamy	6.6	0.19	0.23	0.7	4

Treatments detail

For the experiment, the cabbage variety "Green Coronet" was selected. It is a hybrid cabbage variety used for fresh market consumption. The experiment was carried out in a Completely Randomized Block Design (RCBD) consisting of 7 treatments (Table 2) and three replications. Each experimental unit had a size of 2.1 m x 2.1 m, with a spacing of 40 cm x 40 cm maintained between plants. A border gap of 10 cm was also maintained in each experimental unit. About 15 cm and 30 cm distance were kept between two treatments and replication plots respectively to carry out intercultural operations such as watering, weeding, etc. Each experimental unit consisted of 25 cabbage plants.

Table 2. Details of treatments used for the study

Treatment number	Treatments codes	Fertilizers	Doses (t ha^{-1})
T1	FYM	Farm Yard Manure (FYM)	29.40
T2	PM	Poultry Manure (PM)	4.80
T3	FYM+VC	FYM (50%) + Vermicompost (50%)	14.70+4.60
T4	VC	Vermicompost (VC)	9.20
T5	BW	Black wonder	0.23
T6	FYM+PM	FYM (50%) + Poultry Manure (50%)	14.70+2.40
T7	SM	Sheep manure	4.80

Experimental setup

The experiment involved growing cabbage during the Kharif growing season. To plant one hectare, approximately 300-500 g of cabbage seed was required. A good tilth seedbed was prepared before sowing, and Trichoderma viride (@4 g/kg seed) was applied to prevent damping-off disease. Excess seedlings were thinned out to prevent overcrowding. After final field preparation, the recommended doses of manure and fertilizer (20 t ha^{-1} FYM and 200:120:80 kg ha^{-1} NPK) were uniformly broadcasted in each plot. Healthy and uniformly-sized cabbage seedlings (6-7 weeks old) were transplanted onto the flat land, maintaining a planting distance of 40x40 cm (25 seedlings per experimental unit). Intercultural operations, such as irrigation, weeding, hoeing, and earthing up, were practiced. The first irrigation was applied immediately following the transplanting of the seedlings, and successive irrigations were applied every 10 to 15 days. 1 to 3 hand weeding and hoeing were practiced to keep weeds out of the crop, and earthing up was done 45 days after transplanting to prevent plant toppling during head formation.

Observation recorded

Five randomly chosen plants from each plot were tagged and observed for data collection. The means of these observations for statistical analysis was calculated. The following list includes plant parameters evaluated to ascertain the effects of various treatments.

Growth parameter

The growth parameters of cabbage were observed and evaluated at 40 DAT, 70 DAT, and at harvesting. These included plant height, number of leaves per plant, leaf length, leaf width, stem diameter, and plant spread. Plant height, number of leaves per plant, leaf length, and leaf width were measured from randomly selected five plants at 30-day intervals. Stem diameter was measured at the basal portion of the stem every month, starting from 45 days after transplantation to harvest. Plant spread was determined by measuring the horizontal and vertical spread lengths of the plant and averaging them.

Phenological parameters

The study recorded the number of days taken for visible head formation after transplantation was recorded for each plot. Additionally, the time taken for marketable size heads of 50% of plants to be harvested and the time taken for 90% of the heads in the plot to reach maturity were also recorded.

Yield parameters

Various yield parameters were observed, including polar and equatorial diameter, head circumference, root and shoot length, root and shoot weight, compactness of head, harvest index, net head weight, yield per plot, and yield per hectare. The polar and equatorial diameter of the head were measured, as well as the head circumference. The Compactness of the head is measured in terms of the 'Z' value by using the following formula shown below (Bhat et al., 2017), and the harvest index was calculated as the ratio of net head weight to gross head weight (Ananda et al., 2018). Net head weight was measured by collecting five heads separately and weighing them, and the yield per plot and yield per hectare were calculated accordingly.

$$Compactness\ of\ head = \frac{head\ weight(g)}{Average\ of\ polar\ and\ equatorial\ diameter^3} * 100$$

Results

Effect of different treatments on the growth parameter of Cabbage

In this study, the growth and development of cabbage plants were investigated under the application of various sources of nutrients. The plant height was measured at different days after transplanting (40, 70, and 100 DAT). The results presented in Table 3 showed that different sources of fertilizer had a significant effect on plant height at different stages of plant growth. The average plant height at 40 DAT was 20.91 cm. At 70 DAT, the mean height of the plant was 25.38 cm, and vermicompost was found to be the most effective in increasing the plant height, with a mean height of 30.62 cm. At harvest, treatment T4 (Vermicompost) showed the maximum height of plants (34.38 cm), followed by T5 (Black Wonder) with a plant height of 34.07 cm, T7 (Sheep manure) with a plant height of 30.21 cm, and T6 (FYM and poultry manure combination) with a plant height of 30 cm. The number of leaves did not show any significant difference between different treatments (Table 3). The mean number of leaves developed from transplanting to harvest days was 14. The length and width of unwrapped leaves of cabbage also showed a significant difference under the application of different sources of nutrients (Table 4). The leaf length of cabbage from transplanting to 40 days was found to be highest (20.17 cm) under treatment T4 (Vermicompost) and lowest (10.79 cm) under treatment T7 (Sheep manure). The treatments T5 (Black Wonder) showed the greatest increase in leaf length at harvest which was on par with T4 (Vermicompost) at harvest. The plants treated with T3 (FYM+PM) and T2 (PM) had the smallest leaf length at harvest. Similarly, the width of unwrapped leaves of cabbage showed significant differences among treatments. Treatment T4 (Vermicompost) had the highest leaf width of 18.16 cm between transplanting and 40 days, while treatment T7 (Sheep manure) had the lowest of 8.42 cm. At harvest, the mean leaf width was 23.40 cm, which was on par with treatment T4 (FYM) with 21.35 cm, T2 (PM) with 22.71 cm, T3 (FYM+VC) with 22.79 cm, and T6 (FYM+PM) with 22.63 cm. Cabbage plants treated with T7 (SM) showed the least increase in leaf width at all stages of plant growth. Overall, incorporating vermicompost into the soil was found to be beneficial in enhancing the growth of cabbage plants. Additionally, treatments T1, T2, and T3 also showed significant effects on the growth of cabbage plants.

The effects of various nutrient sources on the stem diameter and plant spread of cabbage plants were investigated in this study. The results (Table 5) indicated that there were significant differences ($p<0.05$; LSD) in the stem diameter of cabbage plants at different stages of growth after transplanting, with the application of different nutrient sources playing a crucial role in these differences. Treatment T5 (Black Wonder) was found to be significantly superior in promoting stem diameter growth at 70 days after transplanting (66.25 mm) and at harvest (73.87 mm), while treatment T4 (Vermicompost) also supported stem diameter growth from 41.85 mm at 40 days after transplanting to 69.13 mm at harvest. On the other hand, treatments T1 (FYM) and T3 (FYM + VC) resulted in the least stem diameter growth, with values of 58.27 mm and 61.60 mm, respectively. The interaction of different fertilizer treatments also had a significant impact on the plant spread of the cabbage plants at different days after transplantation. The average plant spread at 40 and 70 days after transplanting was 24.12 cm and 35.42 cm, respectively. While T4 (Vermicompost) followed by T3 (FYM+VC) and T5 (Black Wonder) showed the highest plant spread at harvest, the minimum plant spread was observed in the plot treated with T7 (Sheep manure), where the plant spread was only 36.90 cm at harvest. These findings suggest that altering the planting distance for cabbage cultivation under different fertilizers may be beneficial, as lower plant spread allows for more plants to be accommodated in a given plot. The superiority of vermicompost over farmyard manure may be attributed to its nutrient richness, quick mineralization, and availability of nitrogen and other plant nutrients. Overall, these results highlight the importance of selecting appropriate nutrient sources for promoting optimal growth and yield of cabbage plants.

Table 3. Effect of different treatments on plant height and number of leaves of plant

T.N.	Treatments	Plant height (cm)			No. of leaves		
		40 DAT	70 DAT	At harvest	40 DAT	70 DAT	At harvest
T1	FYM	17.13	24.05	27.39	10	14	14
T2	PM	20.47	24.47	28.43	10	14	14
T3	FYM+VC	20.24	25.40	28.28	10	14	14
T4	VC	24.16	30.62	34.38	10	15	15
T5	BW	24.54	26.92	34.07	10	13	13
T6	FYM+PM	22.52	23.98	30.00	9	13	13
T7	SM	17.31	22.24	30.21	10	13	13
	Mean	20.91	25.38	30.39	10	13	14
	LSD	1.742	1.329	2.414	1.098	1.132	1.132
	$C.V_{5\%}$	4.7	2.9	4.5	6.5	4.7	4.7
	F-Test	***	***	***	NS	*	*

*CV = Coefficient of variation, LSD= Least Significant Difference, *Significant at 5% level of significance, ***Significant at 0.1% level of significance, ^{NS}Non-significant,*

Table 4. Effect of different treatments on leaf width, Stem diameter and plant spread of plant

T.N.	Treatments	Leaf length (cm)			Leaf width (cm)		
		40 DAT	70 DAT	At harvest	40 DAT	70 DAT	At harvest
T1	FYM	11.90	14.47	25.29	11.13	17.11	21.35
T2	PM	16.31	19.10	22.61	14.98	17.29	22.71
T3	FYM+VC	14.86	17.16	22.10	14.18	17.48	22.79
T4	VC	20.17	23.90	32.17	18.16	22.21	30
T5	BW	16.15	19.59	33.14	17.57	19.45	24.47
T6	FYM+PM	14.14	17.11	28.59	13.73	17.14	22.63
T7	SM	10.79	17.38	27.09	8.42	15.34	19.85
	Mean	14.90	18.39	27.29	14.03	18.04	23.40
	LSD	3.347	2.389	2.832	2.648	2.085	2.405
	$C.V_{5\%}$	12.6	7.3	5.8	10.6	6.5	5.8
	F-Test	***	***	***	***	***	***

*CV = Coefficient of variation, LSD= Least Significant Difference, ***Significant at 0.1% level of significance*

Table 5. Effect of different treatments on stem diameter and plant spread

T.N.	Treatments	Stem diameter (mm)			Plant spread (cm)		
		40 DAT	70 DAT	At harvest	40 DAT	70 DAT	At harvest
T1	FYM	33.14	53.04^{a}	58.27^{a}	22.07	32.89	37.27
T2	PM	36.61	57.26^{b}	63.80^{ab}	24.52	34.76	40.64
T3	FYM+VC	36.42	55.60^{ab}	61.60^{a}	24.08	35.36	42.29
T4	VC	41.85	62.60^{c}	69.13^{bc}	28.19	39.96	46.69
T5	BW	40.44	66.25^{c}	73.87^{c}	25.76	38.51	42.41
T6	FYM+PM	38.21	52.25^{a}	68.67^{bc}	23.77	35.01	40.82
T7	SM	30.37	54.20^{ab}	67.47^{b}	20.43	31.45	36.90
	Mean	36.72	57.31	66.11	24.12	35.42	41
	LSD	3.816	3.786	5.401	2.425	3.382	2.702
	$C.V_{5\%}$	5.8	3.7	4.6	5.7	5.4	3.7
	F-Test	***	***	***	***	**	***

*CV = Coefficient of variation, LSD= Least Significant Difference, ***Significant at 0.1% level of significance*

Effect of different treatments on yield parameters of cabbage

The study investigated the effect of different organic sources of nutrients on the growth and yield parameters of cabbage plants (Table 6 and Table 7). After transplantation, the visible commencement of head formation was observed 7 to 8 weeks later, and 50% head maturity was achieved in 4 to 5 weeks after initiation. Harvesting started 14 weeks after transplanting. The size and shape of cabbage heads are important cultivar traits that can be influenced by cultivation factors such as fertilization. The results showed that the size of cabbage heads was significantly influenced by different organic sources of nutrients. The mean polar diameter of the head was 12.49 cm, while the mean equatorial diameter was 15.76 cm. The highest polar diameters were observed in plots treated with T5 (Black Wonder) and T7 (Sheep Manure), which were significantly different from the mean values. The highest equatorial diameter was observed in plots treated with T4 (Vermicompost) and T5 (Black Wonder). The minimum polar diameter, equatorial diameter, and head circumference were observed in plants treated with T1 (Farm Yard Manure). The head circumference of cabbage was highest in plots treated with T4 (Vermicompost), followed by T5 (Black Wonder) and T7 (Sheep Manure). The root length and shoot length of cabbage plants were highest in plots treated with T4 (Vermicompost) and T5 (Black Wonder), respectively. The mean root length of cabbage was not significantly different among plants treated with T2 (Poultry Manure), T3 (Farm Yard Manure + Vermicompost), T6 (Farm Yard Manure + Poultry Manure), and T7 (Sheep Manure). The average shoot length of cabbage was 8.06 cm, and plants treated with sheep manure and vermicompost showed exactly similar shoot lengths (8.60 cm). The minimum root length and shoot length were observed in plants treated with T1 (Farm Yard Manure). The average root weight and shoot weight of cabbage plants were 49.97 g and 89.2 g, respectively. The treatment with T1, T2, T3, T6, and T7 showed significantly lower root weights compared to other treatments. Vermicompost and Black Wonder showed higher shoot weights. The study suggests that different organic sources of nutrients can significantly influence the growth and yield parameters of cabbage plants.

The study further investigated the effect of different organic sources of nutrients on the growth and yield of cabbage. The compactness of the cabbage head was evaluated and found to range from 11.7% to 53.6%, with significant differences observed among the treatments. Treatment T1, which involved the application of Farm Yard Manure (FYM), resulted in the highest compactness of 53.6%, followed by T2 and T3 with compactness values of 38.5% and 37.6%, respectively. In contrast, the plot treated with Sheep manure (T7) showed the lowest compactness of 11.7%. Harvest index values ranged from 0.7263 to 0.7503, with the highest index recorded in T5, followed by T1 (FYM) and T3 (FYM+VC), and these were at par with T6 and T7. The weight of cabbage heads was also evaluated, with the largest head weight (1062 g) recorded in T4 (Vermicompost) compared to the average head weight of 756 g. T1, T2, and T6 showed similar head weights of 667 g, 682 g, and 643 g, respectively, while T7 had the lowest head weight of 518 g. Significant variations in cabbage yield were observed among the different treatments, with the highest yield (26.55 kg) obtained in T4 (Vermicompost) on a plot area of 3.24m^2. Another treatment that produced a significantly higher yield was T5 (Black Wonder) with 24.05 kg/plot. The average yield per plot was 18.91 kg, except for T7, which showed significantly lower yield/plot (518 g). The remaining treatments T1, T2, T3, and T6 measured similar yield per plot. The yield per hectare also varied significantly among the treatments, ranging from 39 to 81 tha^{-1}. The plot treated with vermicompost showed a significantly higher yield (81.94 t ha^{-1}) than all other treatments, and the average yield per hectare was 58.37 t ha^{-1}. This was statistically similar to T3 (58.72 t ha^{-1}) and slightly comparable to T1 (51.44 t ha^{-1}) and T2 (52.65 t ha^{-1}). However, T7 showed a significantly lower yield per hectare of 39.97 t ha^{-1}.

Table 6. Effect of different treatments on yield parameters of plants

T.N.	Treatments	PD	ED	HC	RL	SL	HD
T1	FYM	8.63^{a}	12.93^{a}	54.73^{a}	5.33	6.87	667
T2	PM	10.83^{b}	13.87^{a}	57.13^{ab}	8.80	7.40	682
T3	FYM+VC	11.33^{b}	14.60^{a}	58.67^{ab}	8.89	7.20	761
T4	VC	13.97^{cd}	18.33^{b}	67.73^{c}	12.17	8.60	1062
T5	BW	15.07^{d}	18.13^{b}	66.80^{c}	10.13	9.47	962
T6	FYM+PM	12.53^{bc}	14.67^{a}	56.67^{ab}	8.33	8.27	643
T7	SM	15.07^{d}	17.80^{b}	59.60^{b}	8.95	8.60	518
	Mean	12.49	15.76	60.19	8.94	8.06	756
	LSD	2.070	2.304	4.224	1.050	1.449	84.3
	$C.V_{5\%}$	9.3	8.2	3.9	6.6	10.1	6.3
	F-Test	***	***	***	***	*	***

*PD: Polar diameter (cm), ED: Equatorial diameter (cm), HC: Head circumference (cm), RL: Root length (cm), SL: Shoot length (cm), HD: Head weight (g), CV = Coefficient of variation, LSD= Least Significant Difference, *Significant at 5% level of significance, ***Significant at 0.1% level of significance*

Table 7. Effect of different treatments on yield parameters of plants

T.N.	Treatments	RW	SW	CC	Y/P	Y/H	HI
T1	FYM	41.20	80.8	53.6	16.67	51.44	0.7457
T2	PM	42.60	81.9	38.5	17.06	52.65	0.7287
T3	FYM+VC	46.33	84.4	37.6	19.03	58.72	0.7420
T4	VC	63.33	100.5	25.8	26.55	81.94	0.7263
T5	BW	65.67	95.7	21.1	24.05	74.23	0.7503
T6	FYM+PM	43	86.4	26	16.08	49.64	0.7387
T7	SM	47.67	94.73	11.7	12.95	39.97	0.7330
	Mean	49.97	89.2	30.6	18.91	58.37	0.7378
	LSD	7.840	9.55	14.61	2.107	6.504	0.038
	$C.V_{5\%}$	8.8	6	26.8	6.3	6.3	2.95
	F-Test	***	**	***	***	***	NS

*RW: Root weight (g), SW: Shoot weight (g), CC: Compactness of cabbage (Z%), Y/P: Yield per plot (kg/m^2), Y/H: Yield per hectare (t/ha), HI: Harvesting index, CV = Coefficient of variation, LSD= Least Significant Difference, **Significant at 1% level of significance, ***Significant at 0.1% level of significance, ^{NS}Non-significant*

Discussion

The use of organic manure in soil has been shown to improve the growth and yield of various plants (Khatri et al., 2019). In this study, we investigated the effects of vermicompost (VC), a type of organic fertilizer, on the growth and yield parameters of cabbage plants. Our results indicate that plants treated with VC had the highest growth parameters and yield. This may be due to the nutrient content of VC, which has been found to act as a "growth promoter and protector" for crop plants (Sinha et al., 2010). VC has a higher porosity, aeration, drainage, and water holding capacity than regular compost, as well as a higher humus content. This allows it to provide balanced nutrients to plant roots, increase organic matter content in soils, and introduce beneficial microbes to improve soil biology and fertility (Sinha et al., 2010). The increased root growth and rhizosphere development resulting from VC application can lead to improved nutrition and water absorption, increased leaf area development, and a higher rate of photosynthetic activity, ultimately resulting in a heavier head weight for cabbage (Chaudhary et al., 2018). Studies have shown that VC is superior to farmyard manure in terms of nutritional richness, rapid mineralization, and greater availability of nitrogen and other plant nutrients (Chaudhary et al., 2015). This is consistent with the findings of Canellas et al., (2002), who suggested that humic acid excreted by earthworms in humus content can promote plant growth even in small doses. Furthermore, VC can maintain nutrients for a longer period of time than regular compost and provide plants with the necessary levels of macro and micronutrients, including nitrogen, phosphorus, and potassium (Liu, 2021). This has been shown to enhance root function and leaf photosynthesis, resulting in increased levels of chlorophyll, nitrogen, and potassium in the leaves (Liu, 2021). In addition to VC, we also evaluated the effects of a commercial organic fertilizer, Black Wonder (BW), with a total organic matter content of 20%. We found that BW had a slightly similar effect on growth and yield (74.23 t ha^{-1}) of cabbage plants compared to VC. This is consistent with the findings of Sundararasu (2019), who reported an increase in yield parameters and yield of soybean due to vermicompost application. In conclusion, our study demonstrates the positive effects of incorporating organic fertilizer, specifically VC, on the growth and yield of cabbage plants. The nutrient content and physical properties of VC, including its ability to introduce beneficial microbes and maintain nutrients over time, contribute to its effectiveness in promoting plant growth and increasing yield.

The incorporation of organic fertilizers into soil can have a positive impact on plant growth and yield. One such fertilizer, which contains micro and macro nutrients that improve soil structure and increase water absorption and circulation, is reported to have a significant nutrient release effect. However, not all types of organic fertilizers produce the same results. Sheep manure, for example, was found to be least effective for cabbage growth and yield in the current study, with a yield of only 39.97 t ha^{-1} and minimum compactness of cabbage (11.7%). This may be due to the slow-release nature of the nutrients found in sheep manure (Gammal & Salama, 2016). Other studies have shown positive effects of sheep manure application on plant growth and nutrient concentration (Khalid & Mubarak, 2016; Mahmoodabadi et al., 2011; Ahmet, 2019), indicating that the quality of the locally available sheep manure may need to be improved to achieve better results. In contrast, vermicompost was found to be highly effective for cabbage growth and yield in the current study, with the highest growth parameters and yield observed in plants fertilized with vermicompost. This is consistent with previous studies that have shown the potential of vermicompost to act as a growth promoter and protector for crop plants due to its high porosity, aeration, drainage, and water holding capacity, humus content, and ability to provide balanced nutrients to plant roots (Sinha et al., 2010; Liu, 2021).

The use of poultry manure and farmyard manure also had a moderate impact on cabbage growth and yield, with larger yields obtained by combining farmyard manure and vermicompost. Chicken litter, specifically, has been shown to improve vegetative growth and yield quality and quantity of broccoli (Hammad et al., 2019). Overall, these findings suggest that the choice of organic fertilizer can have a significant impact on plant growth and yield, and that the quality of locally available fertilizers may need to be improved to achieve optimal results. These results have practical relevance for farmers seeking to optimize their fertilizer use practices to achieve desirable crop yields.

Poultry manure is a rich source of nitrogen (N), phosphorus (P), and potassium (K), as well as other secondary nutrients and amino acids that are required for enhanced photosynthesis, cell division, and cell enlargement in plants (Sunassee, 2001). The high amount of nitrogen in poultry manure is primarily in the urea or ammonium form, which is readily available to plants (Sunassee, 2001). Poultry manure has been reported to promote root growth and development, resulting in improved growth, photosynthetic activity, and dry matter accumulation (Abou-El-Magd, 2006). Moreover, the use of chicken manure has been observed to enhance the growth and yield of maize crops, as evidenced by an increase in the number of leaves per plant, thicker stems, and higher grain yield (Asfaw, 2022). Farmyard manure (FYM) application has also been found to enhance vegetative growth, increase yield, and improve pod quality traits of okra (Alam et al., 2019). Nutrients in most soils are optimally available at pH 6.2 - 6.8 (Sugiono & Krismawati, 2020), and the results of soil analysis in this experiment showed that the pH of the soil was 6.6. However, the moderate impact on growth and yield parameters of FYM may be attributed to nutrient loss resulting from improper handling and storage practices, as well as the limited availability of nutrient-rich manure due to a decreasing number of livestock and a reduction in available land for application. The use of FYM excelled the cabbage head's compactness (53.6%), although there was no significant difference in the number of unfolded leaves among the various treatments. Khatiwada (2000) reported that the head compactness from the close spacing is quite acceptable to the local market. Additionally, the use of poultry manure resulted in significant plant spread (40.64 cm), which was comparable to the spacing used in research (Ratna, 2012). The maximum leaf spread (46.69 cm) was observed under the treatment of vermicompost (Ratna, 2012). The primary nutrient content of chicken litter is 3.03% N, 2.63% P2O5, and 1.4% K2O (Reddy, 1995). The maximum equatorial diameter of cabbage head was 18.33 cm, and its fresh weight was 1062 g in this experiment. Wszelaki and Kleinhenz (2003) reported a clear polynomial correlation between head weight and diameter, showing that as head diameter increased, so did head weight consistently. Moreover, Ratna (2012) suggests that plants tend to increase their leaf area as a strategy to maximize light energy absorption for photosynthesis, especially when there is insufficient light intensity. Organic fertilizers that supply the required nitrogen for plants to thrive promote the growth of leaf area (Ratna, 2012). In conclusion, proper handling and storage practices should be implemented to minimize nutrient loss and optimize the utilization of manure as a source of nutrients for crops. The addition of organic matter to the soil can improve the efficiency of nitrogen absorption by plants. Combining different types of manure, such as farmyard manure and vermicompost, may result in increased yields and improved crop growth.

Conclusion

The present study investigated the effect of different organic fertilizers on the growth and yield parameters of cabbage. The results demonstrated that all treatments significantly affected most of the observed traits, except for the number of open leaves. Vermicompost was found to be the best treatment, followed by commercially available organic fertilizer Black Wonder, while Farm Yard Manure and Poultry Manure had a limited influence on cabbage growth and yield. Organic manures, such as Farm Yard Manure and Vermicompost, are rich in organic matter that increases the nitrogen content in the soil. However, excessive addition of $NH4^{+}$ may cause ammonia toxicity and rhizosphere acidification, which can impede plant growth. Therefore, it is important to use organic fertilizers judiciously to avoid negative impacts on plant growth. Although Black Wonder was found to be the most effective treatment, its availability on the market may not be consistent for all agriculture seasons, and its use may raise the cost of production and reduce the farmer's profitability. Therefore, it can be concluded that the application of Vermicompost @9.20 t ha^{-1} is a suitable organic fertilizer for the improved growth and yield of cabbage. These findings suggest that proper management and selection of organic fertilizers can enhance the productivity of cabbage and potentially other crops.

Author's declaration and contribution

The authors declare no conflicts of interest. All authors contributed equally in all stages of the preparation of this manuscript. Similarly, the final version of the manuscript was approved by all authors.

References

Abou-El-Magd, M. E.-B. (2006). Effect of organic manure with or without chemical fertilizers on growth yield and quality of some varieties of broccoli plants. *Applied Science*, 2, 791-798.

Ahmet, P. (2019). The effect of sheep manure on yield and quality in production of organic sugar beet. *Israel Journal of Plant Sciences*. *66*(3-4), 238-242. CrossRef

Alam, S. M., Arshadullah, M., Haider, S. I., Syeda, S., Syeda, A., & Mahmood, I. (2019). Effect of farm yard manure and planting densities on growth, yield and quality of okra under natural farming. *International Journal of Research in Agriculture and Forestry*, *6*(4), 21-25.

Ananda, A., Devi, A. B., Barik, S. P., Konthoujam, J., & Bairwa, M. K. (2018). Effect of growth, physiological aspects and yield of cabbage (*Brassica oleracea* L. cv Rareball) in Knolkhol and broad bean intercropping system under Imphal West condition. *International Journal of Current Microbiology and Applied Sciences*, *7*(10), 1111-1117. CrossRef

Asfaw, M. D. (2022). Effects of animal manures on growth and yield of maize (*Zea mays* L.). *Journal of Plant Science and Phytopathology*, 33-39. CrossRef

Bhat, R., Rashid, Z., DaR, S. B., & Mufti, S. (2017). Seed yield and quality parameters of cabbage (*Brassica oleracea* var. capitata) in relation to different sources and levels of sulphur. *Current Agriculture Research Journal*, *5*(2), 177. CrossRef

Canellas, L. P., Olivares, F. L., Okorokova-Façanha, A. L., & Façanha, A. R. (2002). Humic acids isolated from earthworm compost enhance root elongation, lateral root emergence, and plasma membrane H+-ATPase activity in maize roots. *Plant Physiology*, *130*(4), 1951-1957. CrossRef

Červenski*, J., Vlajić, S., Ignjatov, M., Tamindžić, G., & Zec, S. (2022). Agroclimatic conditions for cabbage production. *Journal Ratarstvo*, *59*(2), 43-50.

Chaudhary, M. M., Bhanvadia, A. S., & Parmar, P. N. (2015). Effect of integrated nutrient management on growth, yield attributes and yield of cabbage (*Brassica oleracea* var. capitata L.) under middle Gujarat conditions. *Trends in Biosciences*, *8*(8), 2164-2168.

Chaudhary, S. K., Yadav, S. K., Mahto, D. K., Sharma, R. P., & Kumar, M. (2018). Response of growth, yield attributes and yield of cabbage (*Brassica oleracea* var. capitata) to different organic and inorganic sources of nutrients in Magadha plain of Bihar. *International Journal of Current Microbiology and Applied Sciences*, *7*, 4748-4756.

Chiang, M., Chong, C., Landry, B., & Crete, R. (1993). Cabbage: *Brassica oleracea* subsp. capitata L. In B.B.G. Kalloo (Ed.), Genetic improvement of vegetable crops (pp. 191-218). Elsevier. CrossRef

Gammal, O. H. M., & Salama, A. S. M. (2016). Effect of sheep manure application rate and method on growth, fruiting and fruit quality of Balady guava trees grown under mid-Sinai conditions. *Journal of Agriculture and Veterinary Science*, *9*, 59-72.

Ganbold, S. (2022). Cabbage and other brassicas production APAC 2020, by country. Statista. Direct Link.

Hammad, H., Al-Mandalawi, A., & Hamdi, G. (2019). Effect of manure on growth and yield of broccoli. *International Journal of Vegetable Science*, *25*(4), 400-406. CrossRef

Islam, M., Ferdous, G., Akter, A., & Hossain, M. (2017). Effect of organic, inorganic fertilizers and plant spacing on the growth and yield of cabbage. *Agriculture*, *7*(4), Article 31. CrossRef

Jonatan, N., & Campos, M. (2021). Cabbage (*Brassica oleracea* var. capitata): A food with functional properties aimed to type 2 diabetes prevention and management. *Journal of Food Science*, *86*, 3-12. CrossRef

Khalid, A. M., & Mubarak, A. R. (2016). Characterization of compost as affected by manipulation of C/N ratio. *Agricultural Science Digest-A Research Journal*, *36*(1), 44-47. CrossRef

Khatiwada, P. (2001). Plant spacing: A key husbandry practice for rainy season cabbage production. *Nepal Agricultural Research Journal*, 4, 48-55. CrossRef

Khatri, K. B., Ojha, R. B., Pande, K. R., & Khanal, B. R. (2019). Effects of different sources of organic manures in growth and yield of radish (*Raphanus sativus* L.). *International Journal of Applied Sciences and Biotechnology*, *7*(1), 39-42. CrossRef

Liu, X. C. (2021). Effects of vermicompost fertilization on soil, tomato yield and quality in greenhouse. *Journal of Applied Ecology, 32*(2), 699-707. CrossRef

Mahmoodabadi, M. R., Ronaghi, A. M., Khayyat, M., & Amirabadi, Z. (2011). Effects of sheep manure on vegetative and reproductive growth and nutrient concentrations of soybean plants under leaching and non-leaching conditions. *Journal of Plant Nutrition*, *34*(11), 1593-1601. CrossRef

Makenzie, M., Sarah, T., Gallagher, E., McAlvay, A., Hong, A., E.P., P., & Jonathan D Moore, D. A. (2021). The evolutionary history of wild, domesticated, and feral *Brassica oleracea* (Brassicaceae). *Molecular Biology and Evolution*, *38*(10), 4419–4434. CrossRef

Ministry of Agriculture and Livestock Development (MOALD). (2022). Statistical Information on Nepalese Agriculture (2077/78).

Moreb, N., Murphy, A., & Jaiswal, S. (2020). Nutritional composition and antioxidant properties of fruits and vegetables. In A. K. Jaiswal (Ed.), Advances in food and nutrition research (Vol. 91, pp. 69-124). Academic Press. CrossRef

Rana, S. T. (2020). Effect of biofertilizers and micronutrients on growth and quality attributes of cabbage (*Brassica oleracea* var. capitata L.). *International Journal of Chemical Studies*, *8*(1X), 1656-1660. CrossRef

Ratna, D. I. (2012). Effect of combination of biofertilizer concentration with liquid organic fertilizer on quality and quantity of results of tea plants (*Camellia sinensis* L.) O. Kuntze) Gambung clones. *Journal of Agriculture Science*, *10*, 17-25.

Reddy, T. Y., & Reddi, G. S. (1995). Principles of agronomy. Kalyani Publishers. Direct Link.

Shahbandeh, M. (2020). Vegetables production worldwide by type 2017. Statista. Direct Link.

Sinha, R. K., Agarwal, S., Chauhan, K., & Valani, D. (2010). The wonders of earthworms & its vermicompost in farm production: Charles Darwin's 'friends of farmers', with potential to replace destructive chemical fertilizers. *Agricultural Sciences, 1*(2), 76-94. CrossRef

Sugiono, S., & Krismawati, A. (2020). Effectiveness of organic fertilizer on growth and production of cabbage plant (*Brassica oleraceae*). *El-Hayah Jurnal Biologi*, *7*(4), 152-159. CrossRef

Sunassee, S. (2001). Use of poultry litter for vegetable production. In Lalouette A.J. and Bachraz Y.D. (Eds.), Proceedings of the Fifth Annual Meeting of Agricultural Scientists in Mauritius (pp.280-289). Mauritius: Food and Agricultural Research Council.

Sundararasu, K. (2019). Growth and yield effects of vermicompost and vermicompost rubbish on selected vegetable crop. *International Journal of Current Microbiology and Applied Sciences*, *8*(2), 975-984. CrossRef

Teshome, S., & Aside, A. (2020). Response of head cabbage (*Brassica oleracea* L.) yield to application of different rates of inorganic nitrogen and phosphorus fertilizers at Bore, southern Ethiopia. *American Journal of BioScience*, *5*, 18-28. CrossRef

Wszelaki, A., & Kleinhenz, M. D. (2003). Yield and relationships among head traits in cabbage as influenced by planting date and cultivar. *HortScience*, *38*(7), 1355-1359. CrossRef