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*CORRESPONDENCE
Jay Chaurasia
jaychaurasia82@gmail.com

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Organic fertilizers and their efficacy on soil characteristics, growth and yield of cauliflower (*Brassica oleraceae* var. botrytis) in sandy loam soil of Nepal

Vivek Ghimirey[1], Jay Chaurasia[2*], Roshni Dhungana[1] and Balika Poudel[3]

[1]Department of Soil Science and Agri-Engineering, Agriculture and Forestry University, Chitwan, Nepal, [2]Department of Agricultural Extension and Rural Sociology, Institute of Agriculture and Animal Science, Tribhuvan University, Kathmandu, Nepal, [3]Department of Agronomy, Institute of Agriculture and Animal Science, Rupandehi, Nepal

Background: The application of organic fertilizers not only stimulates cauliflower growth and development but also helps to attain sustainable improvement of soil health. A field experiment was conducted in Chitwan, Nepal from December to March of 2022 and 2023 to explore the effect of different organic fertilizers on the growth, development, and yield of cauliflower.

Methods: This study also analyzed the changes in soil physicochemical properties on sandy loam soil. The research was taken in a one factorial Randomized Complete Block Design (RCBD) with three replications. MS Excel and R-studio were used to analyze the obtained data.

Results: After the research, the plant height (54.24 cm), leaf length (42.33 cm), curd diameter (18.26 cm), curd height (11.03 cm), and yield (41.91 t/ha) were significantly higher when poultry manure was applied at 4.63 t/ha in the soil. Similarly, the application of poultry manure revealed significantly higher organic matter (3.93%), total soil nitrogen (0.28%), and soil available phosphorous (110.04 kg/ha). In addition, soil available potassium (187.77 kg/ha) and soil pH (6.84) were seen significantly higher in goat manure (18.94 t/ha) and obifert (10.36 t/ha) respectively which were statistically similar to poultry manure.

Conclusion: Application of organic fertilizers was shown to be beneficial; nevertheless, in the long run, poultry manure (4.63 t/ha) can be recommended for sandy loam soil and similar environmental conditions present at the study site to improve cauliflower performance and overall health of the soil.

KEYWORDS
curd diameter, farm yard manure, organic matter, poultry manure, soil pH

1 Introduction

Fertilizers serve a crucial role in crop production and productivity. However, the constant and indiscriminate use of chemical fertilizers has a detrimental impact on crop yield and soil health (1). As a result, the majority of the fertile soils became infertile, and the problems in soils rose due to excessive fertilizer use (2). Continuous utilization of inorganic fertilizers without organic supplements adversely affects the soil structure, water-holding capacity, moisture, bulk density, organic matter content, and soil microbial activity. These effects on the physical, chemical, and biological properties of soil lead to environmental pollution (3). In addition, global observations have confirmed a decrease in crop yields as a result of the ongoing utilization of inorganic fertilizers (4). Hence, there is a growing necessity to use organic fertilizer sources to rejuvenate soil health.

Organic fertilizers are those materials that are naturally derived from plant, animal, or microbial sources that are used to improve soil fertility and influence plant growth (5, 6). These manures are abundant in several micronutrients as well as important nutrients like nitrogen, phosphorus, and potassium (7). These include compost, animal dung, green manure, and biofertilizers. For a country like Nepal, transportation is difficult, and the chemical fertilizer supply is entirely dependent on imports (8). The manufacturing and use of organic fertilizer at the local level is critical for following sustainable agricultural practices. In Nepal, most of the farmers in rural areas prefer to use animal dung for other organic fertilizers (9). Organic fertilizers, as opposed to synthetic fertilizers gradually release nutrients into the soil, encouraging environmentally friendly farming practices. It ultimately lowers the chance of pollution (3). Additionally, these sources enhance microbial activity, soil structure, and water retention, resulting in healthier and more resilient crops (10). Organic fertilizers improve soil structure, water retention, erosion control, and nutrient release. In addition, it also provides environmental benefits such as carbon sequestration, and reduction in chemical runoff. Thus, organic fertilizers are vital in promoting ecological balance and biodiversity in agricultural ecosystems (3, 11).

Due to its unique geography and wide variation of weather in Nepal, a wide range of fruits, grains, legumes, and vegetables can be produced throughout the year (12). To meet demand, rational production techniques must be intensified due to the growing population and degradation of soil. The application of organic fertilizers is very important because it affects crop yield and soil fertility directly (13). Furthermore, by increasing the soil's capacity to hold onto water and nutrients, organic fertilizers assist in strengthening the structure of the soil. Improved soil structure lowers the chance of nutrient loss and erosion (14, 15). Moreover, the organic substance in these manures feeds by soil microbes, encouraging their diversity and activity. Over time, increased microbial activity improves soil fertility by assisting in the breakdown of organic matter and the cycling of nutrients. Therefore, in organic farming systems, the combined impacts of improved soil structure, microbial activity, and nutrient delivery lead to higher crop yields and overall soil health (16).

Cauliflower (*Brassica oleraceae* var. botrytis), one of the most popular crops in Nepal belongs to the Brassicaceae family. Due to the most favored vegetables in Nepalese kitchens, it is eaten cooked, fried, boiled, and used to make pickles (17). In Nepal, cauliflower ranks first among all other vegetables under cultivation and production. It covers approximately 357 ha, with a total production of 574795 mt and productivity of 16.07 mt/ha (18). Given the enormous potential for commercial production, it is mainly grown in Nepal's Terai to mid-hill region, especially in places with sufficient irrigation (19). These days, experts are more concerned with the effective use of organic fertilizers than just applying them. Research on the behavior of organic fertilizers is required to determine soil fertility and support suitable management techniques. As we know, there is increasing and haphazard use of chemical fertilizers causing nutrient imbalance, nutrient toxicities and deficiencies, soil erosion, and leaching. This not only disrupts microbial activities but also degrades the physicochemical properties of the soil (20). Moreover, there are very limited findings on the effect of organic fertilizers on the growth and yield of cauliflower and soil properties. It is hypothesized that improvement in the soil properties brought about by the adoption of organic fertilizers has an impact on plant growth and yield. This paper aims to determine the effects of different organic manures on the growth and development of cauliflower. This study also examines the physicochemical properties of soil (pH, organic matter, bulk density, total soil nitrogen, soil available phosphorous, and soil available potassium) after experimentation. In addition, this study was carried out to study trials on various organic fertilizers to inspire producers to such a promising crop. This study will help to close the communication gap that exists between the growers and the production-related data. To help smallholder farmers make better decisions about the use of organic fertilizers, the study will determine which organic fertilizers will be more beneficial with optimal doses for cauliflower production.

2 Materials and methods

2.1 Experimental site

The study was conducted in two growing seasons (from December to March of 2022 and 2023) in the experimental field of Padampur, Chitwan. The area is located at 27°54' N latitude and 84°51' E longitude with an elevation of 256 m above mean sea level in the central tropical part of Nepal. An experiment was carried out in the research area in which Maize had been planted for the previous 2 years. Composite soil samples were taken at a depth of 20 cm and analyzed to determine the initial physicochemical properties as mentioned in Table 1.

TABLE 1 Initial physicochemical properties of the experimental site at Padampur, Chitwan, Nepal, 2022.

Soil parameters	Methods	Values	Rating
Bulk density (g/cm^3)	Core ring method (21)	1.36	Medium
Soil texture	Hydrometer (22)		Sandy loam
Sand (%)		57.10	
Silt (%)		30.25	
Clay (%)		11.460	
Soil pH	pH meter (23)	5.79	Acidic
Soil organic matter (%)	Wet digestion (24)	2.24	High
Total soil nitrogen (%)	The Kjeldahl digestion method (25)	0.11	Medium
Soil available phosphorous (kg/ha)	The Modified Olsen's (26)	33.25	Low
Soil available potassium (kg/ha)	Ammonium acetate extraction method (27)	75.16	Low

2.2 Weather conditions during the experimental period

The experimental site falls under the tropical climate zone of Nepal. The agro-meteorological data were collected from the agro-meteorological station of the National Maize Research Program, Rampur, Chitwan. These agro-meteorological data were maximum air temperature, minimum air temperature, mean temperature, and 24-hour accumulated precipitation The data recorded in the study area over two growing seasons (2022 and 2023) are illustrated in Figure 1. In 2022, March registered the highest mean temperature of 23.1°C, and February recorded the lowest mean temperature of 13.55°C. Furthermore, the maximum and minimum 24-hour accumulated precipitation were observed in January (4 mm) and December (0 mm), respectively. In March 2023, the mean temperature reached its highest point of 24.3°C, whereas February had a minimum mean temperature of 16.85°C. Additionally, the maximum and minimum 24-hour accumulated precipitation were measured in January (3.9 mm) and December (0 mm), respectively. The mean temperature and precipitation during the two growing seasons were suitable for cauliflower production. However, low precipitation levels during the early phase of cauliflower could severely affect the growth and yield of the crop (28).

2.3 Initial physicochemical properties of the experimental site

According to the USDA, the soil had a pH of 5.79, indicating acidity, and had a sandy loam texture (29). indicated that soils with a fine texture contain the highest quantity of accessible P, while soils with a coarse texture have the lowest amount. The optimal bulk density range for sandy loam is 1.55-1.75 g/cm^3. Table 1 shows that the soil organic matter content for sandy loam soil typically falls between 2.0% and 2.5%, which is considered high (30). The soil exhibited a moderate level of total nitrogen and a high level of organic matter. However, its accessible potassium and phosphorus levels were found to be low, as reported by (31).

2.4 Experimental details

The experiment was carried out for two growing seasons using a Randomized Complete Block Design (RCBD). The entire experimental area was divided into nine treatments viz. T_1; Control, T_2; Carbon based, T_3; Vermicompost, T_4; Obifert, T_5; Neem seed cake, T_6; Poultry manure, T_7; Farm yard manure, T_8; Mustard oil seed cake and T_9; Goat manure with three replications (Table 2). Carbon-based organic fertilizer is produced by blending oil seed cakes, lime, ash, water hyacinth, and bone meal. The utilization of effective bacteria facilitates the process of decomposition. Vermicompost is an organic fertilizer created by the organic matter decomposition carried out by earthworms. Obifert is an organic fertilizer produced through the process of window-aerobic composting. The temperature in the composting process naturally reaches a maximum of 70°C without the need for any chemicals for a specific duration. Towards the end of the composting process, the temperature gradually decreases to 20°C. The materials utilized to create obifert include poultry manure, cow dung, biochar, and forest-derived value products. Neem seeds are processed by crushing them and extracting the oil by methods such as solvent extraction or cold pressing. This oil is then used to produce neem seed cake, which serves as an organic fertilizer. Poultry manure is an organic waste generated by domesticated avian species such as chickens, turkeys, ducks, and so on. FYM is an indigenous organic fertilizer composed of a mixture of animal excrement, bedding material, and decomposing organic refuse. These materials are collected from various livestock species such as horses, goats, sheep, and cattle. Mustard seed oil cake, a residual byproduct of the oil extraction process from mustard seeds, is commonly utilized as an organic fertilizer. Goat dung refers to the waste product generated by domesticated goats, comprising their urine and feces. It is commonly employed as an organic fertilizer to enhance crop development and soil fertility.

The nutrient content, pH, moisture percentage, and amount of organic fertilizers used in the experiment are shown in Table 3.

2.5 Field layout

Each of the 27 experimental plots measured 9 m^2 (3m x 3m). The experiment net area was (12 m x 31.5m) 378 m^2 (Figure 2A). The Kathmandu local variety of cauliflower was sown and transplanted at 30 DAS. Plants were spaced at 60 cm in between rows and 50 cm in between plants. The spacing between the plots was 0.5 m and between the blocks was 1m. Each plot consisted of 5 rows with 6 plants in each row. The nutrient dose of the organic source was calculated according to the recommended dose of

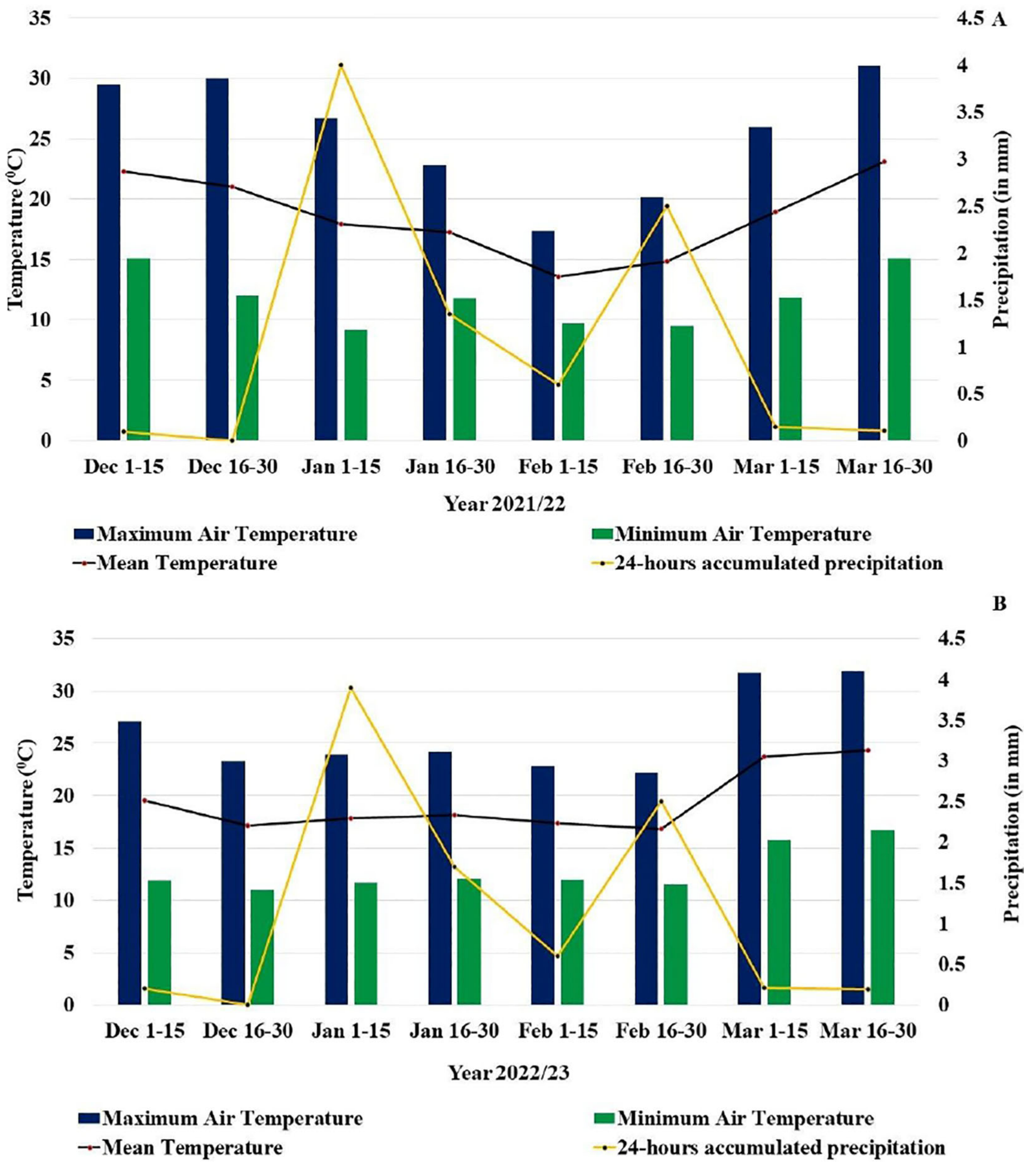

FIGURE 1
Maximum, minimum, mean temperature, and 24-hour accumulated precipitation during the cauliflower growing season of 2021–22 **(A)** and 2022–23 **(B)**.

nutrients which is 200:120:80 NPK Kg/ha (32). The central 5 plants were tagged for data collection as shown in Figure 2C. The morphological characteristics of the 5 tagged plants were recorded every 20-day interval starting from 20 days after transplanting till harvesting and their mean was calculated as shown in Figure 2B.

2.6 Agronomical practices

The cultural practices used during the experiment on cauliflower in two growing seasons are mentioned in Table 4.

2.6.1 Preparation of seed bed and raising of seedlings

After selection of the proper size, the soil was plowed, pulverized, and made into fine tilth. All the grassroots, bricks and stones were collected and thrown out. The bed was prepared and finally leveled. The seeds were sown separately in plots in lines at a depth of about 4 cm. After sowing, the bed was watered with the help of a watering can. Well-prepared FYM was used as manure in the seedbed. After sowing, seeds were covered with a thin film of soil. The sown seedbed was finally covered with a plastic tunnel. Weeds were removed as and when necessary. The seedlings were provided with light irrigation as and when required.

TABLE 2 Treatment details used for the field experiment, 2022 and 2023.

Treatment number	Details
T_1	Control (Recommended dose of fertilizer)
T_2	Carbon-based
T_3	Vermicompost
T_4	Obifert
T_5	Neem seed cake
T_6	Poultry manure
T_7	Farm Yard Manure
T_8	Mustard oil seed cake
T_9	Goat manure

2.6.2 Transplanting of seedlings

The nursery bed was irrigated a few hours earlier before uprooting the seedlings. Seedlings of five weeks old having 4-5 leaves and of uniform size, well developed, and healthy were uprooted with the utmost care in the afternoon. Plants were carefully observed from 2nd day of transplanting. The sign of permanent wilting and the advent of new growth were considered as indicators of mortality and survival respectively. Exchanging the seedlings showing such mortality symptoms with uniform, healthy, and well-developed seedlings of the same age was done up to 4 days after initial transplanting.

2.6.3 Fertilizer application

Fertilizers at the rate of 200 kg N, 120 kg P, and 80 kg K per hectare were applied. The total amount of P and K as well as half the amount of N was applied as basal dose, remaining half of nitrogen was applied in two split doses, first at 30 Days after transplanting (DAT) and second at 45 DAT as top dressing and was applied about four inches away from the root zone at a depth of about 2 inches.

2.6.4 Irrigation

Transplanting was followed by irrigation with the help of a watering can in the morning till the plant was established properly. After proper establishment irrigation was given whenever necessary.

2.6.5 Earthing up and intercultural operations

Earthing-ups were done twice at 30 DAT and 45 DAT. For earthing up the root zone soil was carefully loosened and proper earthing up was done and it was also accompanied by the removal of weeds.

2.6.6 Harvesting

Harvesting was done when the plants reached the horticultural maturity level and data were collected on the same day of harvesting.

2.7 Soil sample collection

For this study, soil samples were collected three times: once at the beginning of the study and twice during the cauliflower harvest in the years 2022 and 2023. The soil sample was collected at a depth of 0–20 cm by removing the topsoil that was 1 cm deep. This was done using a five-spot sampling procedure for each treatment. We gathered 27 composite soil samples and conveyed them to the laboratory. The soil samples from each treatment were meticulously blended to exclude stones, roots, plastic film debris, and other contaminants. After that, the soil was filtered through a 2 mm sieve. The residual soil was subjected to a controlled drying process in a well-ventilated laboratory setting until it achieved a stable weight. Afterward, its physical and chemical characteristics were analyzed and evaluated.

2.8 Statistical analysis

All plant and soil parameters of the respective crops were recorded and entered in MS Excel. Data validation was carried out in MS Excel. After cleaning, the data were analyzed using R-studio software. The significant differences between the treatments were determined using the least significant difference (LSD) and

TABLE 3 Nutrient content, pH, moisture percentage, and amount of organic fertilizers used.

Manures	Nutrient content			Moisture percentage	pH	Amount (t/ha)
	N (%)	P_2O_5 (%)	K_2O (%)			
Carbon-based	1.50	1.66	1.19	42.6	5.4	12.9
Vermicompost	2.03	7.73	2.03	54.7	7.1	10.67
Obifert	1.83	6.42	5.13	35.4	8.2	10.36
Neem seed cake	1.68	0.71	2.96	32.6	6.3	11.05
Poultry manure	3.82	3.30	3.68	26.3	8.9	4.63
Farm Yard Manure	2.16	2.18	2.44	79.9	8.5	11.66
Mustard oil seed cake	4.59	3.24	2.05	11.7	5.3	3.41
Goat manure	1.04	1.41	2.08	40.7	8.47	18.94

FIGURE 2
(A) Field layout and randomization of treatment **(B)** Data collection **(C)** Experiment site in Chitwan, Nepal in 2022 and 2023.

Duncan's Multiple Range Test (DMRT) at a 1% or 5% level of significance (33).

3 Results

3.1 Soil parameters

3.1.1 Bulk density

The bulk density was not significantly influenced by the application of the organic fertilizers for two consecutive growing seasons. However, the maximum bulk density was observed in the control (1.35 g/cm^3) which was followed by carbon-based (1.33 g/cm^3). Similarly, the minimum bulk density was recorded in poultry manure, FYM, and goat manure (1.31 g/cm^3) as shown in Figure 3A.

3.1.2 Organic matter

From Figure 3A, the application of organic fertilizers significantly improved the soil organic matter, however at the end of the experiment maximum organic matter content in the soil was found in poultry manure (3.93%) followed by vermicompost (3.88%) while the lowest was recorded in control (1.27%) as shown in Figure 3B.

3.1.3 Soil pH

The soil pH was found non-significant in the first year of the experiment, however, it was significantly affected in the second year (Figure 4A). The highest soil pH was recorded from the application of obifert in 1st year (6.60) and 2nd year (6.84) respectively. Similarly, the lowest pH observed was from control in 1st year (6.03) and 2nd year (6.08) respectively as shown in Figure 4A.

3.1.4 Soil available nitrogen

At the end of two years of the experiment, the application of organic fertilizers significantly improved the soil's available nitrogen. The highest soil available nitrogen was seen in poultry manure (0.28%) followed by vermicompost (0.27%). The lowest soil available nitrogen was found in the soil treated with control (0.10%) as illustrated in Figure 4B.

3.1.5 Soil available phosphorus

The application of organic fertilizers significantly affected the soil's available phosphorus. The maximum soil available phosphorus was recorded in poultry manure (110.04 Kg/ha) followed by mustard seed cake (104.46 Kg/ha) in 2nd year. Similarly, the minimum soil available phosphorus observed was in control (39.64 Kg/ha) compared to the other treatments as shown in Figure 5A.

3.1.6 Soil available potassium

There was a significant difference among treatments in the soil available potassium. The highest soil available potassium in 1st year (177.81 Kg/ha) and 2nd year (187.77 Kg/ha) was observed in goat

TABLE 4 Agronomical practices during the field experiment in 2022 and 2023.

Cultural practices	Year 1st	Year 2nd
Nursery bed preparation	2 December	1 December
Transplanting	9 January	8 January
Fertilizer application	9 February	8 February
	24 February	23 February

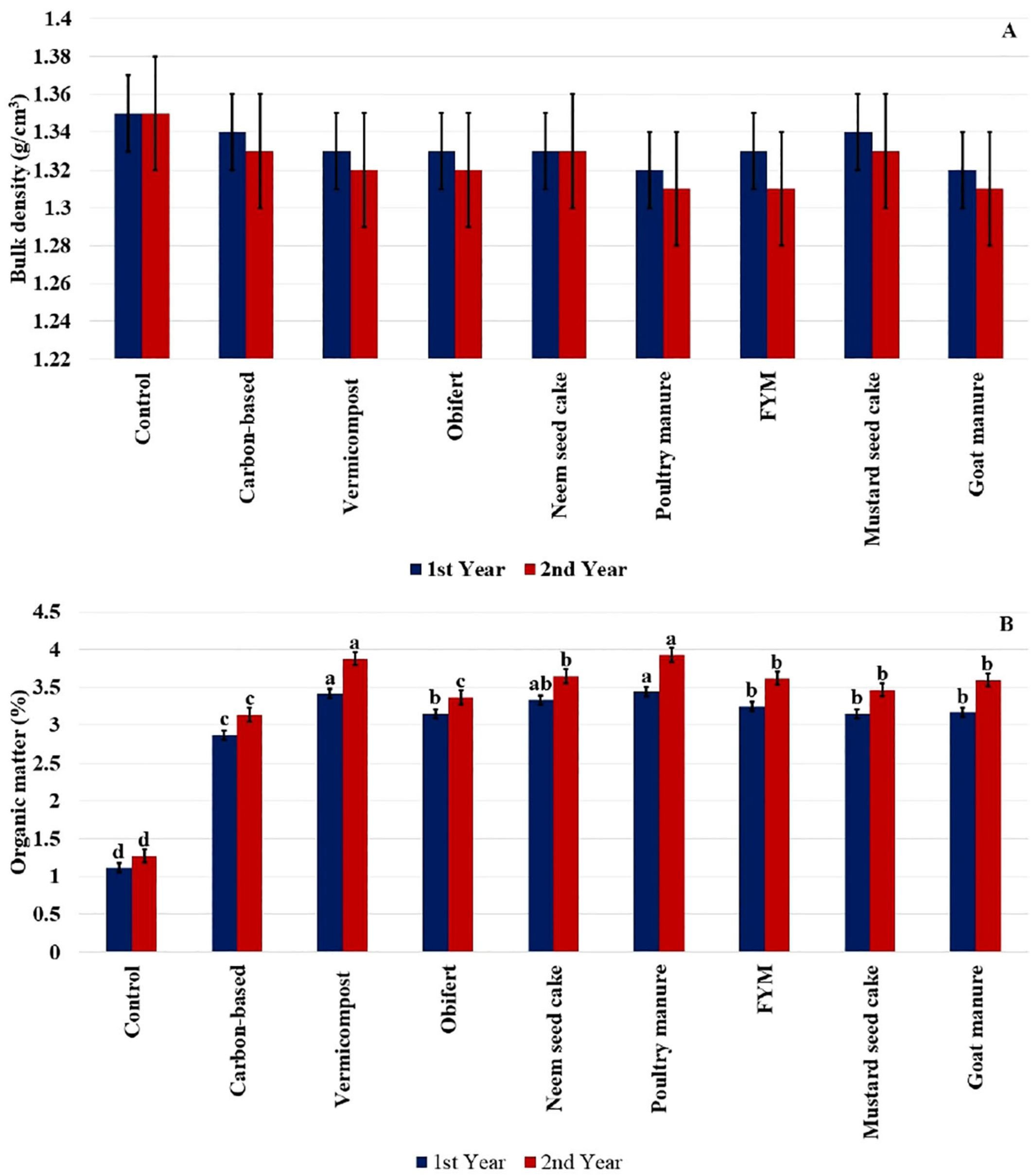

FIGURE 3
Effect of organic fertilizers on soil bulk density **(A)** and organic matter **(B)** during the field experiment in 2022 and 2023. Treatments that share the same (lowercase) letters are not significantly different from each other, while treatments with different letters are significantly different.

manure followed by FYM in 1st year (160.31 Kg/ha) and 2nd year (167.56 Kg/ha) Likewise, the lowest soil-available potassium in 1st year (48.94 Kg/ha) and 2nd year (50.89 Kg/ha) was recorded in the control as shown in Figure 5B.

3.2 Growth parameters of cauliflower

Plant height, number of leaves per plant, and length of leaves were significantly influenced by the application of organic fertilizers in both growing years. The highest mean value recorded for plant height was from poultry manure (54.24 cm) followed by neem seed cake (53.41 cm), while the least was recorded from the control (50.23 cm) after two years of experiment. Similarly, the plant treated with FYM (21.00) and control (16.56) had the highest number and lowest number of leaves per plant respectively. The highest length of leaves was observed in poultry manure (42.33 cm) while the lowest was recorded in control (35.16 cm) as illustrated in Table 5.

3.3 Yield parameters of cauliflower

The yield parameters of cauliflower including the diameter of curd, height of curd, and the total yield were significant due to the application of organic fertilizers. After two years of experimentation, the highest diameter of curd was recorded from poultry manure (18.26 cm) followed by obifert (17.99 cm) compared to other treatments. Control (13.76 cm) recorded the

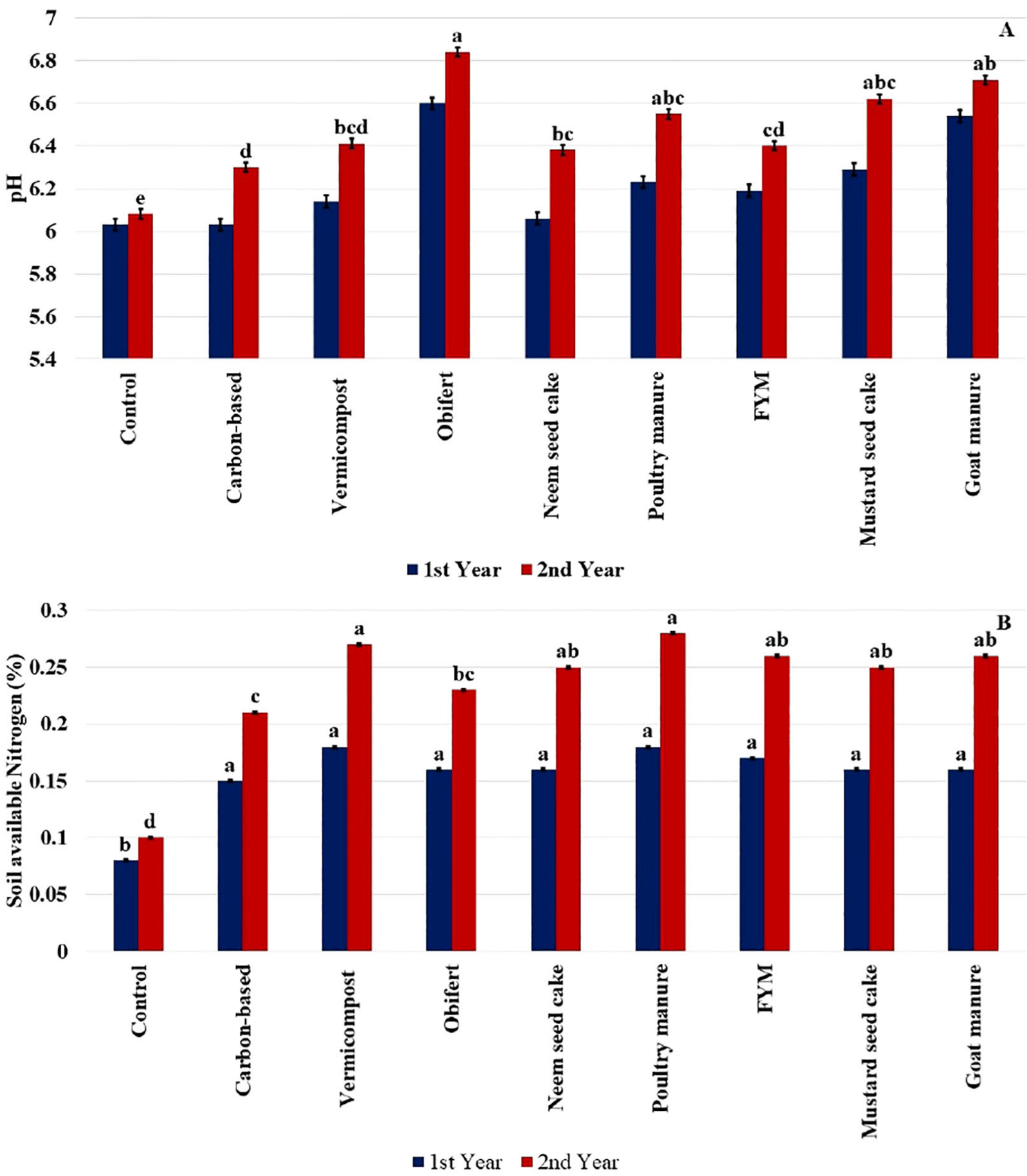

FIGURE 4
Effect of organic fertilizers on soil pH **(A)** and soil available nitrogen **(B)** during the field experiment in 2022 and 2023. Treatments that share the same (lowercase) letters are not significantly different from each other, while treatments with different letters are significantly different.

lowest diameter of curd at the end of the two-year research. The height of the curd was observed to be highest in poultry manure (11.03 cm) followed by vermicompost (11.01 cm) whereas the lowest height was recorded in control (8.53 cm). Moreover, plants treated with poultry manure (41.91 t/ha) had the highest yield while goat manure (39.85 t/ha) had the lowest yield (Table 6).

4 Discussion

4.1 Soil parameters

From the result, the bulk density of soil has not been evident, it may be due to improvement of soil structure and porosity of soil requiring longer period of research (Figure 3A). In addition, the decomposition process might not have advanced far enough in such an amount of time to have a major effect on bulk density but a slight decrease in bulk density resulted in an improvement in fertility status (5). Furthermore, it can take a longer duration of time for the impacts of organic matter on the aggregation and structure of the soil to become apparent, even though they may have an impact on bulk density (34, 35).

There is a significant increment of organic matter content in the soil (Figure 3B). It might be due to the poultry fertilizers having a huge amount of complex carbohydrates, lignin, and other organic residues. The addition of decomposable plant and animal components, such as plant debris, animal dung, etc., progressively breaks down and integrates into the soil's organic matter pool, ultimately raising the

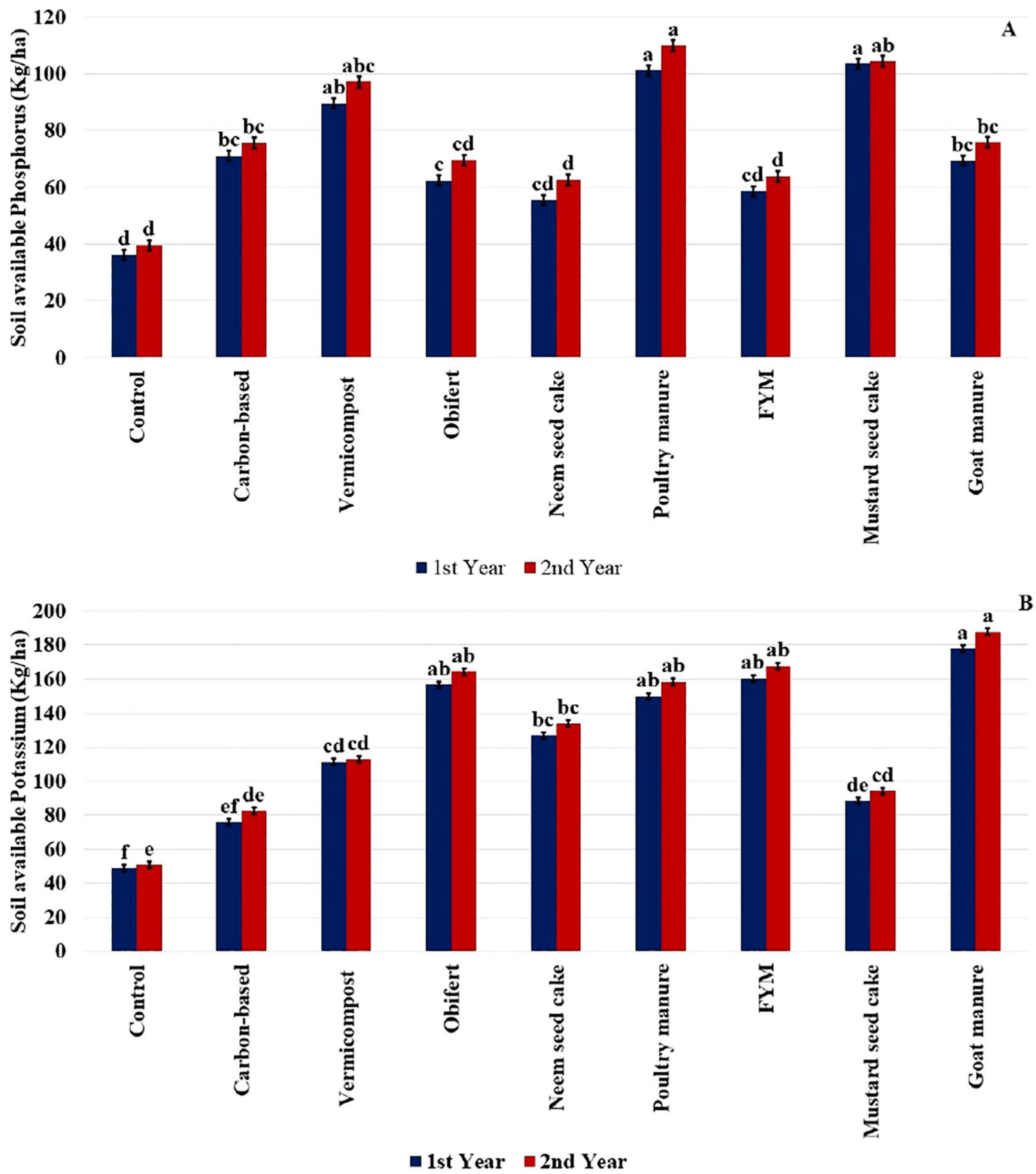

FIGURE 5
Effect of organic fertilizers on soil-available phosphorus **(A)** and soil-available potassium **(B)** during the field experiment in 2022 and 2023. Treatments that share the same (lowercase) letters are not significantly different from each other, while treatments with different letters are significantly different.

amount of organic matter in the soil (36). The soil's overall organic matter content increases as a result of the decomposition of these organic components, which helps the soil's stable organic carbon accumulate (37). The initial alkaline nature of organic fertilizers and their high concentration of carboxyl and phenolic functional groups, humic substances may have taken up H+, which could explain the rise in soil pH caused by the addition of organic fertilizers (38).

From the experiment, it can be seen that the nitrogen content in the soil has increased (Figure 4B). It may be due to proteins and other nitrogen-containing substances, such as amines, which are abundant in organic fertilizers. Moreover, when these substances are added to soil, soil microorganisms break them down, releasing nitrogen in the form of nitrates and ammonium (39–41). The available nitrogen content of the soil is increased by these forms of nitrogen, which plants soluble in water easily absorb. Organic matter in organic fertilizer also improves soil fertility and microbial activity, which helps convert organic nitrogen into forms that plants can use (10, 42).

The phosphorus in the soil is seen to increase (Figure 5A). It might be due to the addition of orthophosphate (H_2PO_4- and $H_2PO_4^{2-}$).The organic compounds in poultry manure undergo mineralization, solubilization, and chelation processes, which convert the phosphorus into plant-available forms (43, 44). Additionally, the pH-adjusting effect of poultry manure can further enhance the availability of phosphorus in the soil (45). A similar kind of result was observed when poultry manure was applied in the soil (46).

TABLE 5 Effect of organic manures on growth parameters of cauliflower during the field experiment in 2022 and 2023.

Treatment	Plant height (cm)		No. of leaves per plant		Length of leaves (cm)	
	1st Year	2nd Year	1st Year	2nd Year	1st Year	2nd Year
Control	49.40cd	50.23cd	16.84c	16.56c	34.43c	35.16d
Carbon-based	52.26ab	53.28ab	18.47bc	18.80b	37.10bc	37.35cd
Vermicompost	51.74abc	52.57ab	17.96bc	18.53bc	40.90a	42.79a
Obifert	50.45bcd	51.46abcd	17.44bc	17.85bc	38.95ab	39.89abc
Neem seed cake	53.50a	53.41ab	18.44bc	18.45bc	37.21bc	37.64bcd
Poultry manure	53.84a	54.24a	18.95ab	19.41ab	40.66a	42.33a
FYM	51.21abc	51.47abcd	21.00a	21.81a	39.74ab	40.74ab
Mustard seed cake	50.37bcd	50.09bcd	18.53bc	19.33ab	37.98ab	38.63bcd
Goat manure	49.25d	49.49d	18.13bc	18.32bc	36.71bc	37.50cd
Grand Mean	51.34	51.80	17.31	17.67	38.22	38.97
P value	**	**	*	*	*	**
CV %	7.12	13.33	5.57	4.34	6.98	8.89
SEM	1.642	1.453	0.785	0.777	0.543	0.698
LSD (0.05)	2.78	3.01	2.05	2.01	3.12	3.16

Means with the same letter/s are not significantly different at a 5% level of significance. *, ** indicate significant at 5%, and 1% level of significance respectively; LSD, Least significant difference; CV (%), Coefficient of variation; SEM, Standard error of Mean.

In the study, goat manure played a crucial role in the increase of soil available potassium content (Figure 5B). It may be due to the richness of water-soluble potassium and the enhancement of the cation exchange capacity of soil. Application of goat manure to sandy loam soil enhanced its potassium concentration and release into the soil (47, 48). As organic fertilizers break down, some of the potassium-containing minerals in the soil dissolve due to the action of organic acids such as fulvic and humic acids (29). This causes the potassium ions to be released into the soil and raises their concentration in the soil solution (49).

TABLE 6 Effect of organic manures on yield parameters of cauliflower during the field experiment in 2022 and 2023.

Treatment	Diameter of curd (cm)		Height of curd (cm)		Total yield (t/ha)	
	1st Year	2nd Year	1st Year	2nd Year	1st Year	2nd Year
Control	12.95c	13.76c	8.20c	8.53d	39.16f	40.13e
Carbon-based	14.86bc	15.91abc	9.43b	9.63b	39.91de	40.61d
Vermicompost	16.84a	17.76ab	10.60a	11.01a	40.61c	41.38b
Obifert	17.33a	17.99ab	10.54a	10.88a	41.03b	41.73a
Neem seed cake	15.41ab	16.10abc	9.51b	9.68b	39.62e	40.43d
Poultry manure	17.49a	18.26a	10.55a	11.03a	42.31a	41.91a
FYM	16.13ab	17.06ab	9.14b	9.47bc	39.99d	40.89c
Mustard seed cake	14.95bc	15.62bc	9.00b	8.93cd	39.17f	39.85f
Goat manure	16.61ab	16.88abc	9.57b	9.69b	40.59c	41.42b
Grand Mean	15.84	16.59	9.62	9.84	40.26	40.93
P value	*	*	*	**	***	***
CV %	11.23	13.87	14.21	12.56	0.96	6.78
SEM	0.489	0.53	0.234	0.214	0.39	0.345
LSD (0.05)	2.12	2.52	0.67	0.55	0.36	0.25

Means with the same letter/s are not significantly different at a 5% level of significance. *, **, *** indicate significant at 5%, 1%, and 0.01% level of significance respectively; LSD, Least significant difference; CV (%), Coefficient of variation; SEM, Standard error of Mean.

4.2 Plant parameters

From the experiment, poultry manure helped to increase the plant height of cauliflower (Table 5). It might be due to the increase of microbial activity in the soil which enhances nutrient mineralization. Poultry manure gives cauliflower plants the right amount of nitrogen, phosphorus, and potassium, these three elements that are essential to their growth (50). These nutrients promote strong stem elongation, which in turn leads to taller cauliflower plants by increasing cellular activity and chlorophyll production (51).

Farmyard manure increased the number of leaves in cauliflower (Table 5). It may be due to farmyard manure provides natural nutrition since it is rich in organic matter and minerals. Additionally, slow nutrient release from its breakdown guarantees a consistent supply for leaf growth (52, 53). Furthermore, the microbial activity it stimulates improves soil health, making it easier for roots to penetrate and absorb nutrients, which in turn encourages the creation of leaves (54).

The vermicompost helped to increase the length of the leaves of cauliflower (Table 5). It might be due to the humus content in the soil which is extracted by earthworms that contain humic acid. The tea-like structure of vermicompost may have increased the porosity, water-holding capacity, and nutrient availability (35, 55). Furthermore, the availability of nutrients that promote plant growth and increase the length of cauliflower leaves (56).

From the study, vermicompost helped to enhance the curd size of cauliflower (Table 6). It may be due to the presence of beneficial bacteria in vermicompost aids in the plant's uptake of nutrients and ensures that the nutrients are used effectively for the creation of curd (57). Vermicompost also improves the cation exchange capacity and ability to hold water, which helps for the ideal environment for curd height of cauliflower (58).

Poultry manure played a crucial role in the increase of curd diameter of cauliflower (Table 6). It might be due to the rich source of minerals, especially phosphorus and potassium. These nutrients are crucial for curd growth and enlargement, it have a substantial impact on cauliflower curd diameter (59). Larger curd diameters in cauliflower plants are produced by the steady release of these nutrients from poultry manure (19).

The application of poultry manure increased the yield of cauliflower (Table 6). It may be due to the poultry manure provides essential nutrients, which improves the crop yield. The addition of vital nutrients like nitrogen, phosphorus, potassium, etc. is necessary for plant growth and development, which ultimately leads to an increase in yield (60, 61). Additionally, improved soil fertility brought about by its organic content encourages root growth and nutrient uptake, both of which increase cauliflower yields (62). A similar kind of result was found in the study of vegetables (63).

5 Conclusions

It was concluded that applying poultry manure at a rate of 4.63 t/ha improves cauliflower yield and performance. Compared to other organic and inorganic fertilizers, soils treated with poultry manure showed higher levels of organic matter content, favorable soil pH level, total soil nitrogen, and soil available phosphorus. Adoption of poultry manure showed higher efficiency in increasing crop sustainability and general soil health when viewed holistically. Adding organic fertilizers improves the soil quality and creates an atmosphere that allows cauliflower plants to have better access to nutrients. So, adding poultry manure turns out to be an alternative way to maximize the yield of cauliflower while also improving soil fertility and sustainability.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

VG: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. JC: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Supervision, Writing – original draft, Writing – review & editing. RD: Data curation, Formal Analysis, Methodology, Software, Writing – original draft, Writing – review & editing. BP: Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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