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Sustainable methods for growing turmeric: Evaluating the effects of synthetic and organic fertilizers on vegetative and reproductive attributes

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ABSTRACT

This study aimed to assess the influence of various biofertilizer sources on turmeric (*Curcuma longa* L.) cultivation in Eastern Nepal. The research was conducted at G.P Koirala College of Agriculture and Research Centre, Sundarharaicha, Morang, Nepal, from April 2023 to January 2024. The experiment utilized a randomized complete block design (RCBD) with seven treatments including T1: Recommended dose (RD) of NPK, T2: Goat manure (GM), T3: Organic manure (OM), T4: Poultry manure (PM), T5: Vermicompost (VC), T6: Farmyard manure (FYM), T7: Control, replicated three times. Turmeric cultivation practices were implemented following standard agronomic procedures. The recommended dose of synthetic fertilizer, NPK, exhibited the highest enhancement across multiple vegetative and reproductive growth parameters of turmeric, with notable increases in plant height, leaf number, tillers per plant, primary and secondary fingers per clump, fresh rhizome yield, dry yield, and dry recovery percentage. Among the organic sources, goat manure and poultry manure also showed promising results in enhancing turmeric yield and quality. Specifically, NPK recorded the highest fresh rhizome yield at 21.30 tons ha^{-1}, while goat manure and poultry manure yielded 20.35 tons ha^{-1} and 18.69 tons ha^{-1}, respectively. In contrast, the lowest fresh rhizome yield was observed in the control group, indicating minimal enhancement in yield without fertilizer supplementation. The results highlight how organic farming methods may be a good substitute for traditional chemical fertilizers in the context of sustainable turmeric production.

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1. Introduction

Turmeric (*Curcuma longa* L.) is a perennial herbaceous plant belonging to the ginger family, Zingiberaceae (Ferdous et al., 2018), extensively cultivated in the tropical and subtropical regions of the world, including Nepal (Baral et al., 2021; Chandana et al., 2024a). It holds significant cultural, culinary, and medicinal value (Chapagain et al., 2021), with its rhizomes being prized for their vibrant color, Flavors, and therapeutic properties (Hossain et al., 2007). Turmeric has been cultivated across diverse ecological zones of Nepal, spanning from the eastern to western regions, encompassing the inner terai, foothills, and mid-hills up to an altitude of 1600 meters above sea level (Mehata et al., 2022a; Rajbanshi et al., 2023;). Its cultivation demands minimal care and management, making it a popular choice either as a standalone crop or for intercropping within fruit orchards or agro-forestry setups on less fertile land (Khan et al., 2023; Majhi et al., 2024). Serving as a vital source of income, turmeric holds immense importance in Nepal's agricultural landscape, playing a crucial role in supporting the livelihoods of numerous farmers nationwide (Bairagi, 2022). As of 2078/79 BS, the total yield of turmeric per hectare in Eastern Nepal, averaging between 18 to 22 tons ha^{-1} under favorable conditions, has been reported by (Timsina et al., 2011). In Eastern Nepal, turmeric cultivation serves as a vital component of agricultural practices and plays a crucial role in the socio-economic fabric of the region (Chapagain et al., 2021; Datta et al., 2017). The cultivation of turmeric in Eastern Nepal is typically characterized by smallholder farmers employing traditional farming techniques (Chapagain et al., 2021). However, despite its importance, turmeric production faces various challenges, including declining soil fertility, pest and disease pressures, erratic weather patterns, and fluctuating market prices (Baka et al., 2021). Among these challenges, maintaining soil health and fertility stand out as critical factors influencing turmeric growth and yield (Chávez-Mejía et al., 2021).

In recent years, Nepal's turmeric production has seen fluctuations due to various factors like climate, soil health, and farming practices (Yadav et al., 2024b). Despite being a major global producer, with yields averaging 18 to 22 tons per hectare annually, the sector faces challenges hindering its full potential (Timsina et al., 2011; Mehata et al., 2023c). Reliance on chemical fertilizers has led to environmental degradation, soil depletion, and food safety concerns (Mehata et al., 2023b). Transitioning to sustainable agriculture is imperative to mitigate these issues and enhance soil fertility while bolstering community resilience (Mekonnen and Garedew, 2019). Synthetic fertilizers, prevalent in conventional farming, pose risks such as soil degradation, water pollution, and health hazards for farmers and consumers alike (Ojikpong, 2018; Ishwar et al., 2024). Thus, urgent action is needed to shift towards environmentally friendly practices for the long-term viability of Nepal's turmeric industry (Chandana et al., 2022b). Considering these challenges, there exists a compelling imperative to explore alternative approaches (Chhetri et al., 2020), particularly focusing on organic farming methods, to foster a more ecologically harmonious and economically viable agricultural system in Nepal. Organic manures, derived from plant or animal sources, offer a holistic solution for enhancing soil fertility, improving soil structure, and promoting balanced nutrient uptake by crops (Kumar et al., 2023). Moreover, organic farming practices contribute to the conservation of biodiversity (Yadav et al., 2024a), reduction of greenhouse gas emissions, and overall resilience of agroecosystems (Baral et al., 2021).

Despite the recognized benefits of organic manures, their efficacy in enhancing turmeric growth and yield in the specific agroclimatic conditions of Eastern Nepal remains underexplored. This study systematically assesses various organic manure sources, including compost, farmyard manure, green manure, and biofertilizers, to elucidate their comparative effectiveness in enhancing soil fertility, promoting healthy plant growth, and maximizing turmeric yield, with the specific aim of evaluating their impact on the growth and yield of turmeric in Eastern Nepal.

2. Materials and methods

2.1. Experimental site

The field experiment was carried out from April 2023 to January 2024, in the research field of G.P Koirala College of Agriculture and Research Centre located at Sundarharaicha, Morang, Nepal, to evaluate the efficacy of several biofertilizer sources on vegetative and reproductive traits of Turmeric. The climate of this area is tropical type.

The average annual temperature of this area ranges between 21.81 to 34.46 °C, and the average yearly precipitation is 131.88 mm. Geographically it is located at 26⁰ 40′ 49.9″ North latitude and 87⁰ 21′ 16.7″ East longitudes with an elevation of 151 m. The soil characteristics of the experimental site were analyzed in qualitative measures with the help of a soil test kit box (Table 1). A soil test kit box is a portable tool used to assess soil health by measuring pH, nutrient levels, and sometimes moisture content. It measures soil properties through colorimetric tests, where chemical reactions produce color changes that are compared to a reference chart. While these kits offer quick and convenient assessments, they provide less accurate and detailed results compared to laboratory analyses, making them less reliable for critical agricultural decisions. The nutrient content of the soil was analyzed only once before the research was conducted just to check the available nutrient level. The average highest temperature and lowest temperature throughout the study period were 36.74 °C and 11.08 °C, respectively, with an average amount of precipitation of 209.03 mm. The meteorological data of the research area throughout the study period was presented in Figure 1.

2.2. Plant materials

The 'Kapor Kot Haledo-1' variety was used for a study which was obtained from the National Agricultural Research Council (NARC). The main characteristics of this variety is that the rhizomes have a tough brown skin and bright orange flesh, known for their pungent and bitter taste. This variety, known for its adaptability, has a growth cycle of approximately 180-200 d. It exhibits promising yields and is typically harvested when the leaves start to turn yellow and dry, signaling optimal rhizome development.

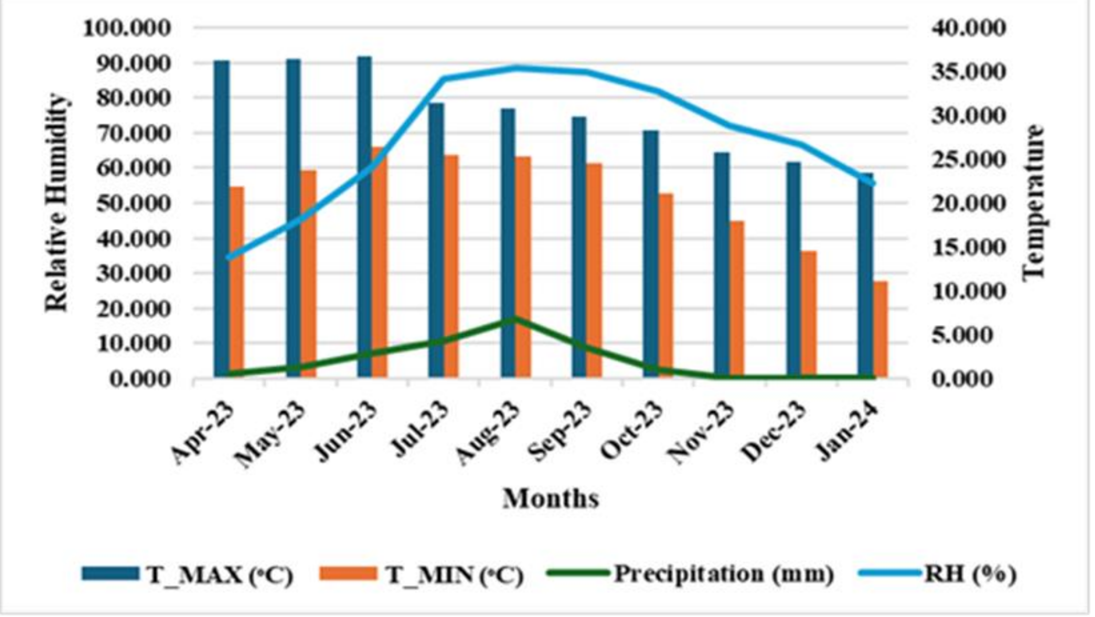

Figure 1. Meteorological data of the study site during the study period

Table 1. Soil characteristics of experimental site

Serial Number	Soil Characteristics	Nutrient Content	Properties
1	Nitrogen (N)	0.15%	Slightly High
2	Phosphorous (P)	58.83 mg kg^{-1}	Medium
3	Potassium (K)	221.33 mg kg^{-1}	Low
4	Organic matter	3.68%	Medium
5	Soil texture	-	Clay loam soil
6	Soil pH	-	6.8

2.3. Research design and cultural practices

The research was designated in RCBD with seven treatments replicated three times. There were altogether 21 plots. Each plot was designated 6 m² (3 m x 2 m) with a total area of 126 m². The gap between the two replications was maintained at 1m, and between the two treatments was 0.5 m. 80 plants per plot were kept with spacing between rows to row 0.3m and plant to plant 0.25 m. Turmeric cultivation began with land preparation, which involved ploughing and levelling to ensure proper drainage. Rhizome selection was crucial, with growers opting for disease-free, healthy ones. Planting depth was around 5-7 cm, with a spacing of 30 cm between rows and 25 cm between plants. Full dose of potassium and phosphorous and half dose of nitrogen was applied prior to planting in the specific plot whereas full dose of all biofertilizer sources were applied in their respective research plot one week prior to planting. Half dose of nitrogen was applied during rhizome development phase after weeding. Regular weeding was conducted to remove competing vegetation that could hinder the growth and yield of turmeric. Manual weeding techniques were utilized, with special focus given during the early growth stages when turmeric plants are most vulnerable. Effective irrigation ensured consistent soil moisture for turmeric growth. We used a mix of furrow and ridge systems, supplemented by manual watering as needed, to maintain ideal conditions for rhizome development while preventing waterlogging. The irrigation was applied at 5-7 days interval during germination, vegetative growth phase and rhizome development phase, however, during maturity phase the frequency of irrigation was reduced and light irrigation was done. The details of all treatments and their respective doses employed in our research are outlined in Table 2.

Table 2. List of treatments and their doses

Serial Number	Treatments	Symbol	Doses
1	RD of NPK	T1	60: 50: 120 kg ha^{-1}
2	Goat manure	T2	10 tons ha^{-1}
3	Organic manure	T3	6 tons ha^{-1}
4	Poultry Manure	T4	7 tons ha^{-1}
5	Vermicompost	T5	4 tons ha^{-1}
6	Farmyard Manure	T6	30 tons ha^{-1}
7	Control	T7	untreated

2.4. Data collection

From each experimental plot, twelve plants were randomly selected to gather the required data. Data collection occurred every fifteen days. The raw data encompassed vegetative parameters such as plant height, leaf number per plant, tillers per plant, leaf length, leaf area, and days to 50% sprouting. Additionally, reproductive traits including the number of primary fingers per clump, number of secondary fingers per clump, fresh rhizome yield, dry yield, and dry recovery were recorded.

2.5. Statistical analysis

The data was initially input in chronological order for both the replication and treatment blocks utilizing MS Excel 2021 (Microsoft Corporation, Washington, USA). Following this, ANOVA analysis was carried out using statistical software (R Studio, Version 4.2.2, Boston, Massachusetts, USA). To assess mean differences among different treatments at a significant level of 5%, Duncan's Multiple Range Test (DMRT) was employed.

3. Results and discussion

3.1. Effects of different sources fertilizers on vegetative growth parameters

Table 3 presents the data on turmeric plant height across various fertilizer treatments investigated during our study period. The results reveal significant differences in plant height among these treatments at a level of significance 0.1%, 1% & 5%. Initially, the average plant height was 32.43 cm, progressively increasing to a peak of 102.66 cm at 180 days post-planting.

The treatment receiving the recommended NPK dose exhibited the tallest plants at 90 days post-planting (39.33 cm), reaching a height of 109.63 cm at harvest. This finding aligns with Kadam and Kamble (2020), who also observed similar trends in plant height with organic manures. The consistent and optimized nutrient release from NPK fertilizers likely contributed to sustained growth throughout the plant's life cycle. Biofertilizers such as organic manure, goat manure, vermicompost, and poultry manure showed the second-highest plant heights, ranging from 103-105 cm at harvest. This pattern is consistent with Datta et al. (2017), who reported comparable results, particularly noting vermicompost's effectiveness. The gradual nutrient release from these organic sources supports steady nutrient availability, fostering robust and sustained plant growth across developmental stages. Unlike the rapid nutrient release of NPK fertilizers, organic sources offer balanced and prolonged nutrient availability, promoting healthier plant growth. The control group, receiving no fertilizer, recorded the lowest height (92.88 cm) at harvest, echoing findings by Kadam and Kamble (2020) with a similar control group height of 93.33 cm.

The application of different fertilizers reveals noteworthy variances in the leaf count of turmeric plants throughout our research period, as depicted in Table 3. These results exhibit significant differences in leaf numbers across various fertilizer treatments at a significant level at 0.1% and 1%. This finding is consistent with the study conducted by Kadam and Kamble (2020), aligning closely with our own observations. The notable disparities in leaf count among fertilizer treatments, observed in both studies, likely arise from variations in nutrient compositions and release rates. These factors profoundly influence leaf development and foliage growth, demonstrating statistical significance at a level of less than 0.01%. The mean leaf count recorded at harvest stands at 8.93. In contrast, Chapagain et al. (2021) reported leaf count of just 7.69 slightly lower results compared to our findings. The highest leaf count observed in our study could be attributed to various factors, including differences in soil fertility, climatic conditions, cultivation techniques, and varietal disparities, all of which influence leaf development and overall plant vigor. Notably, the recommended NPK dose yielded the maximum number of leaves, reaching 10.86, a result consistent with findings from Kadam and Kamble (2020). This dominance of leaf count with NPK fertilizers in both studies, compared to various biofertilizer sources, likely stems from the balanced nutrient composition tailored to specific variety needs, optimal environmental conditions supporting robust foliage growth, and genetic factors enhancing leaf proliferation. Additionally, the precise nutrient delivery of NPK fertilizers likely played a role in maximizing leaf production compared to biofertilizer alternatives, a conclusion also supported by Khan et al. (2023). Among the biofertilizer sources, organic manure and vermicompost recorded the highest leaf numbers at 9.20 and 9.40, respectively, followed by goat manure at 9.00. Similar results were noted by Kadam and Kamble (2020) with different organic manure sources. Poultry manure, on the other hand, exhibited the second-lowest leaf count at 8.53. Although Kadam and Kamble (2020) reported slightly higher leaf numbers with poultry manure, this discrepancy may arise from variations in nutrient release rates, composition, and soil interactions. The lowest leaf count was observed in treatments without any fertilizer input, i.e., the control group, at 7.26. This finding aligns with those reported by Hossain et al. (2007) and Datta et al. (2017), indicating that inadequate nutrient supply hampers optimal plant growth. The absence of fertilizer input deprives plants of essential nutrients, hindering leaf development and overall foliage abundance compared to fertilized counterparts.

Likewise, the tillers per plant exhibit significant differences across the various treatments employed in the study, as illustrated in Table 4. These results demonstrate very high significance levels at less than 0.001%. The overall average of tillers per plant stands at 2.49. The highest number of tillers was observed in the group receiving the recommended NPK dose, reaching 3.76, followed by poultry manure at 3.21 and goat manure at 2.80. In contrast, Chandana et al. (2022b) reported significantly higher tiller counts with poultry manure and vermicompost, nearly double our findings. This discrepancy could be attributed to variations in nutrient availability influenced by soil composition, microbial activity, environmental conditions like temperature and moisture levels, genetic factors of the cultivars used, and cultivation practices, all contributing to these differences. Similarly, a study by Hossain et al. (2007) recorded tiller counts with the recommended NPK dose at 5.2, almost twice our findings. This variance may stem from differences in soil fertility, climatic conditions, varietal characteristics, and cultivation practices, all potentially accounting for the twofold difference in tiller numbers. The tiller count per plant varied significantly across treatments, with the control group recording the lowest count at 1.36, findings supported by Ferdous et al. (2018) and Datta et al. (2017).

Conversely, the recommended NPK dose resulted in the highest leaf length (35.58 cm), leaf width (14.20 cm), leaf area (326.33 cm^2), and days to 50% sprouting. Chandana et al. (2022b) reported similar leaf area results, while Datta et al. (2017) and Ferdous et al. (2018) documented comparable findings for leaf length, width, and area with the recommended NPK dose. These parameters were notably higher with NPK due to its balanced nutrient composition, vital for robust leaf development and timely sprouting. Among biofertilizer sources, goat manure and poultry manure demonstrated noteworthy results, with goat manure treatments exhibiting a leaf length of 32.93 cm, leaf width of 13.44 cm, leaf area of 285.56 cm^2, and requiring 27.00 days for 50% sprouting, while poultry manure treatments showed a leaf length of 31.07 cm, leaf width of 13.20 cm, leaf area of 264.47 cm^2, and 26.66 days for 50% sprouting. However, Ferdous et al. (2018) noted longer leaf lengths ranging from 25 cm to 50 cm with green manure treatments, potentially influenced by environmental factors like temperature and light intensity. The control group exhibited the lowest values for leaf length (25.45 cm), leaf width (10.84 cm), leaf area (178.23 cm^2), and days to 50% sprouting (24.33 days), findings corroborated by Chávez-Mejía et al. (2021) and Datta et al. (2017). These minimal results can be attributed to inadequate nutrient supply for optimal vegetative growth and development in the absence of fertilizers.

Table 3. Effects of various sources of fertilizers on plant heights and leaf number of turmeric

Treatments	Plant height (cm)							Leaf number							
	90 DAP	105 DAP	120 DAP	135 DAP	150 DAP	165 DAP	180 DAP	90 DAP	105 DAP	120 DAP	135 DAP	150 DAP	165 DAP	180 DAP
NPK	39.33^a	65.39^a	73.06^a	93.12^a	101.83^a	105.80^a	109.63^a	3.06^a	3.73^a	4.80^a	6.60^a	9.40^a	10.80^a	10.86^a
Goat manure	32.52^b	58.70^b	65.11^{bc}	85.16^b	94.24^b	99.84^b	104.55^b	2.80^{ab}	3.20^{bc}	3.60^{bc}	5.53^c	8.26^c	8.93^{bc}	9.00b^c
Organic manure	32.59^b	59.08^b	67.52^{bc}	87.05^{ab}	96.29^{ab}	99.60^b	103.02^b	2.73^{ab}	3.13^{bcd}	3.53^{bc}	5.60^c	8.40^c	8.93^{bc}	9.20^b
Poultry manure	32.94^b	58.34^b	66.52^{bc}	88.72^{ab}	97.84^{ab}	100.13^b	103.00^b	2.80^{ab}	3.20^{bc}	3.60^{bc}	5.60^c	8.13^{cd}	8.40^{cd}	8.53^{cd}
Vermicompost	31.48^{bc}	58.38^b	68.74^{ab}	91.12^{ab}	99.28^{ab}	101.59^b	103.81^b	2.86^{ab}	3.46^{ab}	4.06^b	6.13^b	8.86^b	9.20^b	9.40^b
FYM	30.47^{bc}	55.91^b	62.89^{cd}	84.59^b	94.82^b	98.06^b	101.70^b	2.33^b	2.800^{cd}	3.13^c	5.20^{cd}	7.86^d	8.20^d	8.26^d
Control	27.68^c	53.25^b	59.51^d	77.64^c	86.82^c	89.67^c	92.88^c	2.26^b	2.66^d	3.12^c	4.86^d	7.00^e	7.20^e	7.26^e
Grand mean	32.433	58.439	66.196	86.775	95.878	99.244	102.66	2.695	3.171	3.695	5.647	8.276	8.809	8.933
SEM	1.688	2.770	2.178	2.794	2.427	1.491	1.489	2.9295	0.213	0.235	0.198	0.173	0.237	0.275
CV (%)	6.375	5.806	4.029	3.943	3.100	1.839	1.776	11.862	8.218	7.789	4.291	2.556	3.291	3.767
F-value	***	*	**	**	**	***	***	NS	**	***	***	***	***	***

*: Significant at 5% level of significance. **: Significant at 1% level of significance. ***: Significant at 0.1% level of significance. NS: Non-significant. SEM: Standard error of the mean. CV: Coefficient of difference. DAP: Days after planting

3.2. Effect of different sources of fertilizers on reproductive growth parameters

Table 4 showcases the response of various reproductive traits to different fertilizer sources utilized in the study, including primary fingers per clump, secondary fingers per clump, fresh rhizome yield, dry yield, and dry recovery percentage. Significant variations among these metrics were recorded at a significant level ($p< 0.001$). The 'Kapor Kot Haledo-1' variety of turmeric treated with the recommended dose of synthetic fertilizer, NPK, exhibited the highest reproductive growth across all mentioned parameters. The NPK treatments yielded the highest number of primary and secondary fingers, at 4.57 and 5.23, respectively. This outcome can be attributed to the balanced nutrient composition of NPK, providing essential elements crucial for robust rhizome and finger development, thereby promoting optimal growth and productivity compared to other fertilizer sources. Following closely were the numbers of fingers from goat manure at 4.28 and 4.87, respectively. Similarly, poultry manure (4.22) and vermicompost (4.15) recorded the highest number of secondary fingers among other treatments. Possible reasons behind this may include variations in nutrient availability and release rates influencing finger proliferation. Similarly, the control groups exhibited the lowest number of primary and secondary fingers, with counts of 3.12 and 3.53, respectively. This could be attributed to the lack of essential nutrients like nitrogen, phosphorus, and potassium in the control group, leading to growth retardation and ultimately resulting in a lower number of fingers.

In comparison, farmyard manures achieved the lowest number of primary and secondary fingers per clump compared to other biofertilizers used in the study. However, contrary to our findings, Ferdous et al. (2018) reported the highest reproductive traits such as primary and secondary fingers per clump, fresh rhizome yields, and dry yields with the combined application of chemical (NPK) and organic fertilizer sources. Discrepancies between their results and ours could be attributed to variations in soil composition, climate conditions, and microbial activity, which influence nutrient availability. Additionally, differences in fertilizer application rates, timing, and sources may also contribute to variations in plant growth, highlighting the impact of environmental and fertilizer management practices. Furthermore, the study by Kadam and Kamble (2020) also corroborated our results, as their findings closely matched ours.

Similarly, the application of various fertilizers on turmeric demonstrates significant results for fresh rhizome yields at a 5% significance level. The overall mean rhizome yield recorded among these treatments was 18.62 tons ha^{-1}. The maximum yield was observed in the recommended dose of NPK, totaling 21.30 tons ha^{-1}. According to Rajbanshi et al. (2023), their findings on the effects of organic sources of nutrients and biofertilizers on turmeric growth, yield, and quality indicated the highest rhizome yield with chemical fertilizer in combination with organic sources, closely mirroring our results. The superior yield achieved with the recommended dose of NPK can be attributed to several factors. NPK fertilizers offer a balanced and readily available supply of essential nutrients crucial for optimal turmeric growth and rhizome development. Unlike organic sources, NPK fertilizers ensure precise nutrient delivery, minimizing deficiencies and maximizing yield potential. Additionally, efficient nutrient uptake from NPK fertilizers may enhance photosynthesis, increase biomass accumulation, and ultimately lead to higher rhizome yield compared to other treatments. Among the biofertilizer sources used in the study, goat manure (20.35 tons ha^{-1}) and organic manure (19.59 tons ha^{-1}) recorded superior results, followed by vermicompost (18.91 tons ha^{-1}) and poultry manure (18.69 tons ha^{-1}) respectively. These findings are strongly supported by Kadam and Kamble (2020) and Chhetri et al. (2020). Additionally, a previous study by Hossain et al. (2007) also reported similar results compared to ours. Moreover, farmyard manure (16.01 tons per hectare) and the control group (15.53 tons per hectare) exhibited similar and the lowest rhizome yields. This could be attributed to inadequate nutrient supply. Both farmyard manure and control groups likely lacked sufficient essential nutrients crucial for robust rhizome development, resulting in diminished yields compared to treatments receiving synthetic or balanced nutrient supplementation. The findings reveal that the dry yield was significantly influenced by the application of various biofertilizers and chemical fertilizers at a significant level of $p<0.01$, as indicated in Table 4. The overall grand mean of dry weight across treatments was recorded at 3.98 tons ha^{-1}. The highest dry yield was observed with the recommended dose of NPK at 4.79 tons ha^{-1}, followed closely by goat manure (4.58 tons ha^{-1}) and poultry manure (4.03 tons ha^{-1}), respectively. These results are consistent with a previous study by Hossain et al. (2007), which also reported similar dry yield ranges from 4 to 5 tons ha^{-1}. The superior performance of these treatments in both studies can likely be attributed to the balanced nutrient supply provided by these fertilizers. NPK, goat manure, and poultry manure likely supplied essential nutrients in optimal ratios, facilitating vigorous growth and maximizing dry yield compared to other treatments. Similarly, the results determined 3.83 tons ha^{-1} for organic manure, 4.03 tons ha^{-1} for poultry manure, and 3.76 tons ha^{-1} for vermicompost. Chandana et al. (2022b) also reported similar findings in their study on the effect of organic manures and biofertilizers on turmeric varieties. In contrast, the control group exhibited the lowest dry yield at 3.20 tons ha^{-1}, a result supported by Kumar et al. (2023). This minimal yield in the control group can be attributed to the absence of nutrient supplementation. Without fertilizer application, plants in the control group likely experienced nutrient deficiencies, impeding their growth and resulting in diminished dry yield compared to treated groups. Furthermore, the results indicate that dry recovery was significantly affected by the application of various fertilizers at a significant level of $p<0.001$. The highest dry recovery percentage was observed with goat manure (23.57%) and the recommended dose of NPK (23.50%), followed by poultry manure (21.54%) and organic manure (21.49%), respectively. In contrast, a study by Ferdous et al. (2018) reported the highest dry recovery percentage with synthetic fertilizer along with a biofertilizer source, a finding echoed by Baka et al. (2021). The lowest dry recovery percentage was observed in the control group (19.64%) and farmyard manure (19.57%), results closely aligned with previous findings documented by Hossain et al. (2007) and Datta et al. (2017). This minimal recovery percentage in these treatments may be attributed to inadequate nutrient availability and imbalanced soil conditions.

Table 4. Effect of various sources of fertilizer on several attributing characters of turmeric

Treatments	TP	LL	LW	LA	DS	PF	SF	FR	DY	DR
NPK	3.76^{a}	35.58^{a}	14.20^{a}	326.33^{a}	27.66^{a}	4.57^{a}	5.23^{a}	21.30^{a}	4.79^{a}	23.50^{a}
Goat manure	2.80^{bc}	32.93^{b}	13.44^{ab}	285.56^{b}	27.00^{ab}	4.28^{ab}	4.87^{a}	20.35^{a}	4.58^{ab}	23.57^{a}
Organic manure	2.12^{de}	27.04^{e}	12.28^{c}	226.48^{d}	26.00^{bc}	3.76^{bc}	3.78^{bc}	19.59^{a}	3.83^{cd}	21.49^{b}
Poultry manure	3.21^{ab}	31.07^{c}	13.20^{b}	264.47^{c}	26.66^{ab}	3.59^{cd}	4.22^{b}	18.69^{abc}	4.03^{bc}	21.54^{b}
Vermicompost	2.45^{cd}	28.58^{e}	11.23^{d}	197.07^{e}	25.33^{cd}	3.42^{cd}	4.15^{b}	18.91^{ab}	3.76^{cd}	20.61^{c}
FYM	1.74^{ef}	27.15^{e}	11.23^{d}	196.25^{e}	25.33^{cd}	3.20^{cd}	3.69^{bc}	16.01^{bc}	3.71^{cd}	19.64^{d}
Control	1.36^{f}	25.45^{f}	10.84^{d}	178.23^{e}	24.33^{d}	3.12^{d}	3.53^{c}	15.53^{c}	3.20^{d}	19.57^{d}
Grand mean	2.494	29.688	12.351	239.203	26.047	3.712	4.215	18.629	3.989	21.422
SEM	0.296	0.627	0.401	8.600	0.477	0.260	0.259	1.390	0.299	0.192
CV (%)	14.528	2.585	3.978	4.402	2.242	8.574	7.522	9.136	9.166	6.096
F-value	***	***	***	***	***	***	***	*	**	***

*: Significant at 5% level of significance. **: Significant at 1% level of significance. ***: Significant at 0.1% level of significance. NS: Non-significant. TP: Tiller per plant. LL: Leaf length (cm). LW: Leaf width (cm). LA: Leaf area (cm^2). DS: Days to 50% sprouting. PF: Number of primary fingers per clump. SF: Number of secondary fingers per clump. FR: Fresh rhizome yield (t/ha). DY: Dry yield (tons ha^{-1}). DR: Dry recovery (%)

Without proper fertilization or supplementation, turmeric plants in these treatments likely struggled to absorb and utilize nutrients efficiently, resulting in reduced dry matter accumulation and lower recovery percentages compared to treatments receiving nutrient inputs.

4. Conclusion

This study emphasizes the pivotal role of organic fertilizers in promoting sustainable turmeric cultivation in Eastern Nepal. Among various fertilizer treatments, the recommended dose of synthetic fertilizer, NPK, significantly improved both vegetative and reproductive growth parameters of turmeric, including plant height, leaf number, tillers per plant, primary and secondary fingers per clump, fresh rhizome yield, dry yield, and dry recovery percentage. Additionally, organic sources like goat manure and poultry manure showed promising results in enhancing turmeric yield and quality. These organic fertilizers deliver essential nutrients sustainably, promoting vigorous plant growth and contributing to soil health and biodiversity conservation. The findings underscore the potential of organic farming practices to mitigate soil degradation and ensure the resilience of Nepal's turmeric industry, offering viable alternatives to chemical fertilizers. Further research is needed to optimize nutrient management strategies tailored to diverse agro-climatic conditions, ultimately enhancing turmeric cultivation practices and securing farmers' livelihoods nationwide.

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no conflict of interest. All authors have read and agreed to the published version of the manuscript

Authors' Contributions

Chandani SUNUWAR: Data curation, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. **Soniya KOIRALA:** Conceptualization, Data curation, Methodology, Software, Visualization, Writing – original draft. **Ravi ACHARYA:** Investigation, Supervision, Validation, Writing – review & editing. **Nisha CHAUDHARY:** Data curation, Writing – original draft. **Uma Devi BHANDARI:** Data curation, Methodology, Writing – original draft. **Melina RAI:** Data curation, Writing – original draft. **Supriya NIRAULA:** Data curation, Resources, Writing – original draft. **Rupesh Kumar MEHTA:** Conceptualization, Software, Visualization.

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References

Bairagi, S. K. (2022). Effect of micronutrients on growth, yield and economics of turmeric (*Curcuma longa* L.). *Annals of Plant and Soil Research, 24*(2), 272–277. https://doi.org/10.47815/apsr.2022.10160

Baka, A., Poonpakdee, C., Khawmee, K., & Onthong, J. (2021). Effects of fertilizers on growth, yield and curcuminoid content of turmeric (*Cuma longa* l.) cultivated in red clay loam and sandy loam soil. *Burapha Science Journal, 26*(December), 1611–1626.

Baral, S., Luitel, G., Shrestha, A., & Basnet, B. (2021). Production and marketing of turmeric (*Curcuma longa*) in Sunsari District, Nepal. *Archives of Agriculture and Environmental Science, 6*(4), 556–562. https://doi.org/10.26832/24566632.2021.0604019

Chandana, M., Padma, M., & Prabhakar, B. N. (2024a). Studies on effect of organic manures and biofertilizers on antioxidant activity of turmeric (*Curcuma longa* L .) varieties. *The Pharma Innovation Journal, 55*(02), 17121–17133.

Chandana, M., Padma, M., Prabhakar, B. N., Joshi, V., Mahender, B., Gouthami, P., & Sathish, G. (2022b). Studies on effect of organic manures and biofertilizers on growth, yield and economics of turmeric (*Curcuma longa* L.) varieties. *International Journal of Agricultural Sciences, 11*(11), 824–832. https://doi.org/10.15740/has/ijas/18.1/160-162

Chapagain, T. R., Timilsina, A. P., Sharma, S., Dahal, K. M., & Ahamad, S. (2021). Evaluation of turmeric (*Curcuma longa* L.) genotypes for growth and yield attributes in plains of Eastern Nepal. *Asian Journal of Agricultural and Horticultural Research, 8*(4), 57–64. https://doi.org/10.9734/ajahr/2021/v8i430126

Chávez-Mejía, A. C., Magaña-lópez, R., Durán-álvarez, J. C., & Jiménez-cisneros, B. E. (2021). Factors affecting turmeric production in Sunsari District, Nepal. *International Journal of Environment, Agriculture and Biotechnology, 6*(6), 53–57. https://doi.org/10.22161/ijeab

Chhetri, G., Devkota, D., & Sharma, B. (2020). Value Chain Analysis of Turmeric Subsector In. Chronic Complement Altern Integra Med, 02(01), 1–8.

Datta, S., Jana, J. C., Bhaisare, P. T., & Nimbalkar, K. H. (2017). Effect of organic source of nutrients and biofertilizers on growth, yield and quality of turmeric (*Curcuma longa* L.). *Journal of Applied and Natural Science, 9*(4), 1981–1986. https://doi.org/10.31018/jans.v9i4.1477

Ferdous, M., Kabirul Islam, M., Monirul Islam, M., Isfatuzzaman Bhuyan, M., Sazedul Islam, M., & Sarkar, P. (2018). Effect of green manure along with nitrogenous fertilizer on the growth and yield of turmeric (*Curcuma longa* l.) of Bangladesh. *International Journal of Advanced Geosciences, 6*(1), 140–144. https://doi.org/10.14419/ijag.v6i1.11713

Hossain, M. A., Akamine, H., Ishimine, Y., Teruya, R., Aniya, Y., & Yamawaki, K. (2007). Effects of relative light intensity on the growth, yield and curcumin content of turmeric (*Curcuma longa* L.) in Okinawa, Japan. *Plant Production Science, 10*(1), 151–154. https://doi.org/10.1626/pps.12.29

Ishwar, R., Mehata, D. K., Sah, B. K., Chaudhary, A., Subedi, A., Magar, S. P., ... & Acharya, R. (2024). Evaluating the response of different synthetic and organic fertilizers on carrot vegetative and reproductive characteristics in Gothgaun, Nepal. *Turkish Journal of Food and Agriculture Sciences, 6*(1), 72-82. https://doi.org/10.53663/turjfas.1427662

Kadam, J. H., & Kamble, B. M. (2020). Effect of organic manures on growth, yield and quality of turmeric (*Curcuma longa* L.). *Journal of Applied and Natural Science, 12*(2), 91–97. https://doi.org/10.31018/jans.vi.2249

Khan, M. A. H., Rahman, M. M., Tasmima, T., & Sultana, N. (2023). Effect of fertilizer doses on turmeric at madhupur tract under AEZ-28. *Asian Journal of Agricultural and Horticultural Research, 10*(4), 507–515. https://doi.org/10.9734/ajahr/2023/v10i4290

Kumar, S., Vipin, Singh, N. K., & Kumar, S. (2023). Role of biofertilizers in turmeric production. *Just Agriculture, 4*(1), 434-440.

Majhi, S., Mehata, D., Shah, D., Yadav, N., Chaudhary, P., Shah, S., ... & Rijal, P. (2024). Impact of organic and inorganic fertilizers on the growth and yield of Beetroot (*Beta vulgaris* L.) in the hilly region of Nepal. *International Journal of Agriculture Environment and Food Sciences, 8*(2), 242-250. https://doi.org/10.31015/jaefs.2024.2.1

Mehata, D. K., Kattel, I., Sapkota, P., Ghimire, N. P., & Mehta, R. K. (2023a). Biofertilizers: A sustainable strategy for organic farming that would increase crop production and soil health. *Plant Physiology and Soil Chemistry, 3*(2), 49–53. https://doi.org/10.26480/ppsc.02.2023.49.53

Mehata, D. K., Kattel, I., Yadav, S. P. S., Bhujel, S., Bhattarai, S., Yadav, P., Sapkota, P., Timsina, S., Lahutiya, V., & Prasad, G. (2022b). Varietal trial of okra (*Abelmoschus esculentus* L.) for evaluation of yield and yield parameters. *Genomics & Plant Breeding, 6*(4), 111–116.

Mehata, D. K ., Yadav, S. P. S ., Ghimire, N. P ., Oli, B ., Mehta, R. K ., & Acharya, R . (2023c). Evaluating the impact of various biofertilizer sources on growth and yield attributes of spring rice (*Oryza sativa* L.) in Eastern Terai of Nepal. *Peruvian Journal of Agronomy, 7*(3), 200-2019. https://doi.org/10.21704/pja.v7i3.1977

Mekonnen, B., & Garedew, W. (2019). Growth, yield, and quality responses of turmeric (*Curcuma longa* L.) to nitrogen fertilizer rate and timing of its application. *Acta Agrobotanica, 72*(3), 1–11. https://doi.org/10.5586/aa.1781

Ojikpong, T. O. (2018). Effect of Planting Dates and NPK (15:15:15) Fertilizer on the growth and yield of turmeric (*Curcuma longa* Linn). *International Journal of Agriculture & Environmental Science, 5*(4), 42–46. https://doi.org/10.14445/23942568/ijaes-v5i4p108

Rajbanshi, S., Sapkota, S., Neupane, R., Dhungel, S., & Poudel, S. (2023). Economics of Production of Turmeric in Surkhet District of Nepal. *Food and Agri Economics Review, 3*(1), 14–18. https://doi.org/10.26480/faer.01.2023.14.18

Sah, D. K., Mehata, D. K., Yadav, B., Majhi, S. K., Kafle, P., & Oli, B. (2024). Effect of organic and inorganic fertilizers on morphological and yield characteristics of carrot (*Daucus carota*) cv. new Kuroda in Khotang district, Nepal. *Russian Journal of Agricultural and Socio-Economic Sciences, 3*(147), 76-84.

Timsina, K. P., Shrestha, K. P., Chapagain, T. R., & Pandey, S. (2011). Value chain analysis of turmeric (*Curcuma longa*) in Eastern Nepal. *Nepal Agricultural Research Journal, 11*, 70–79.

Yadav, B., Pandit, D. L., Banjade, D., & Mehata, D. K. (2024a). Insights into the germplasm conservation and utilization : Implications for sustainable agriculture and future crop improvement Insights into the germplasm conservation and utilization : Implications for sustainable agriculture and future crop improvement. *Archives of Agriculture and Environmental Science, 9*(1), 180–193. https://doi.org/10.26832/24566632.2024.09

Yadav, B., Mehata, D. K., Bhandari, S., Shrestha, S., & Sangroula, G. (2024b). Evaluation of different okra (Abelmoschus esculentus L.) cultivars for yield and biomass production. *Asian Journal of Research in Agriculture and Forestry, 10*(1), 99-105. https://doi.org/10.9734/ajraf/2024/v10i1273