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Effect of Different Combinations of Organic and Synthetic Sources of Nutrients on Growth, Yield and Quality Parameters of Turmeric Under Faisalabad Conditions

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Abstract: *Curcuma longa* L. (Turmeric) is a perennial herbaceous crop that belongs to the family Zingiberaceae. It is being used for medicinal as well as culinary purposes. Turmeric requires a substantial amount of chemical fertilizers, animal manure or farmyard manure to produce a high rhizome yield. This study was conducted at Vegetable Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, during 2019-20. Six different fertilizers treatments, viz. T_0 (control), T_1 (8 ton ha^{-1} FYM), T_2 (8 ton FYM + N:P:K 75, 25 and 50 kg ha^{-1}), T_3 (4 ton FYM + N:P:K 90, 32 and 62 kg ha^{-1}), T_4 (N:P:K 136, 100 and 125 kg ha^{-1}) and T_5 (2.5 ton FYM + N:P:K 182, 172 and 80 kg ha^{-1}) were used. The experiment was laid out in randomized complete block design with three replications and collected data were statistically analyzed using Statistix 8.1. Maximum growth, yield and quality traits, viz. plant height (87.8 cm), number of tillers per plant (3.8), number of leaves per plant (19.0), leaf length (39.8 cm), leaf width (13.3 cm), stem diameter (17.3 mm), number of primary rhizomes per plant (6.4), number of secondary rhizomes per plant (14.2), total number of rhizomes per plant (21.6), weight of primary rhizomes (115.4 g plant^{-1}), weight of secondary rhizomes (116.7 g plant^{-1}), yield (257.7 g plant^{-1}), rhizome length (53.2 mm), rhizome diameter (24.3 mm) and total dry matter (49.5 %) were recorded in treatment T_5 (2.5 ton FYM + N:P:K 182, 172 and 80 kg ha^{-1}). Moisture content was highest, i.e. 59.8% and 59.7% in treatment T_0 (control) and T_1 (8 ton ha^{-1} FYM), respectively. Total soluble solids were found highest, i.e. 11.92 and 11.48 ^{o}Brix, in T_3 (4 ton FYM + N:P:K 90, 32 and 62 kg ha^{-1}) and T_4 (N:P:K 136, 100 and 125 kg ha^{-1}), respectively. However, maximum curcumin content (0.94%) was observed in treatment T_4 (N:P:K 136:100:125 kg/ha). This study concluded that application of N:P:K 136:100:125 kg ha^{-1} was best for increasing curcumin content (curcumin yield) but further increase in applied nutrients along with FYM, i.e. 2.5 ton FYM + N:P:K 182, 172 and 80 kg ha^{-1} can produce highest rhizome yield in sandy loam soils.

Keywords: *Curcuma longa*, Spice, Curcumin, Chemical Fertilizers, Farmyard manure, Rhizomes.

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1. Introduction

Curcuma longa L. (Turmeric) is a perennial herbaceous crop that belongs to the family Zingiberaceae (Guerra et al., 2020). It is a common spice crop in Asian countries including Pakistan, India, Sri Lanka and, Bangladesh. It is native to tropical southern Asia and found in tropical and subtropical areas of Asia, South America and Australia (El-Kenawy et al., 2019; Rupani and Chavez. 2018). Turmeric contains a yellowish compound named curcumin. The curcuminoid is the active compound in turmeric rhizomes which has medicinal importance and has been used for curing hepatic disorders, skin diseases and blood purification (Kocaadam andŞanlier, 2017; Li et al., 2020; Marton et al., 2020). It also

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contains volatile compounds that have medicinal properties in them such as anti-inflammatory, anti-cancer, anti-diabetic, anti-fungal and detoxifying (Vaughn et al., 2016; Mariam et al., 2017; Kotra et al., 2019; Noureddin et al., 2019). Firstly, turmeric used in herbal medicines but at this time, it is used at large scale for different purposes such as coloring agents for food, cosmetics, dyes, even in medicines due to its antioxidant properties (Anandaraj et al., 2014; Gopinath and Karthikeyan, 2018; Kotha and Luthria, 2019; Ahmed et al., 2020; Dua and Paul, 2020).

Different plants require different quantities of nutrients which depend on plant characteristics, agro-climatic conditions, physical and chemical properties of soil, moisture availability, type and placement of fertilizer during their growth and development (Lu et al., 2019; Steusloff et al., 2019; Li et al., 2020). Turmeric is a nutrient exhaustive crop and requires ample quantity of fertilizer for high yield. One of the constraints in the popularization of turmeric production is low productivity, which can be attributed to poor nutrient management besides other factors. The crop is known to respond well to fertilizer application (Verma et al., 2019).

Incorporation of manures in nutrient management of agricultural soils is an effort to reduce the environmental impacts of excessive use of synthetic fertilizers and improve nutrient availability under various agro-climatic conditions (Wu and Ma, 2015; Bai et al., 2016; Chadwick et al., 2020; Zahid et al., 2020). The organic source helps to maintain nutrient equilibrium in soils whereas the inorganic fertilizers readily furnish nutrient, which enhanced the initial growth of the crop and finally resulted in better growth, development and yield. Composts and manures tend to have lower nitrogen and potassium, but higher phosphorus content (Almeida et al., 2019). The use of manure and compost over a period of time tends to increase tissue phosphorus as well as secondary and micronutrients levels (Anuradha et al., 2018).

Optimum yield is the main goal of farmers in crop production. Final yield of any crop is the cumulative effect of yield attributes and the factors, which directly and indirectly influence them (Nautiyal et al., 2016). The yield of turmeric is directly related to soil nutrients status, either through natural or synthetic source (Jagadeeswaran et al., 2005).

In Pakistan, turmeric's production is comparatively low as compared to other Asian countries. The main reason for this low yield of turmeric in Pakistan is the lack of modern production technology as compared to India, which is the leading producer and exporter of turmeric. Among the various factors which affect the yield of turmeric, nutrient management is the vital component that boosts the growth and production of turmeric plants. Therefore, an investigation was launched to optimize the dose of organic and inorganic fertilizers for higher yield and curcumin contents of turmeric.

2. Materials and Methods

The present study was conducted at Vegetable Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, during 2019-20. The experiment was set up in randomized complete block design with six treatments replicated thrice. Treatments consisted of T_0 (control), T_1 (8 ton ha^{-1} FYM), T_2 (8 ton FYM + N:P:K 75, 25 and 50 kg ha^{-1}), T_3 (4 ton FYM + N:P:K 90, 32 and 62 kg ha^{-1}), T_4 (N:P:K 136, 100 and 125 kg ha^{-1}) and T_5 (2.5 ton FYM + N:P:K 182, 172 and 80 kg ha^{-1}). The rhizomes were planted at 20 cm plant to plant distance in 60 cm spaced rows on 30th March. Before sowing, full dose of FYM, phosphorus and potassium along with ½ dose of nitrogen were applied in each block of treatments according to layout. Other ½ dose of nitrogen was applied into two splits at two months interval. Light irrigation was applied after sowing, subsequently, crop was irrigated throughout the growing season according to crop requirement. Weeding was done manually 2-3 times during the early growth stages to save the crop from competition for nutrients and moisture. Insect and diseases were controlled by adopting standard plant protection measures according to local recommendations. Before conducting the experiment, complete soil analysis was carried out from Soil and Water Testing Laboratory, District Kasur, Punjab, Pakistan (Table 1).

Table 1. Physico-chemical properties of soil from the experimental site

Physical Analysis	Value
Textural Class	Sandy loam
Saturation percentage (%)	34
Chemical Analysis	
Soil pH	8.7
EC (dSm^{-1})	1.1
Organic matter (percentage)	0.74
Available P (ppm)	7.4
Available K (ppm)	55

2.1. Parameters

Data were collected for plant height (cm) by using measuring tape from the ground level to the tip of the tallest leaf near crop maturity, tillers per plant by counting, no. of leaves per plant by counting, leaf width (cm) by measuring tape, leaf length (cm) by measuring tape, stem diameter (mm) by using Vernier caliper, number of rhizomes per plant (primary, secondary, total) by counting after harvesting and mean value was computed, weight of rhizomes per plant (primary, secondary) in gram by using digital balance and average value was computed, yield (g plant^{-1}) with the help of digital balance and average value was computed, rhizome length (mm) by using vernier caliper, and rhizome diameter (mm) with the help of vernier caliper. For total dry matter, rhizomes were weighed, spread in a dry place and exposed to sunlight for 15 days. After that, dry weight of rhizomes was weighed on digital weighing balance. Total dry matter percentage was determined by using following formula:

$$\text{Dry matter (\%)} = \frac{\text{Wd}}{\text{Wf}} \times 100$$

Moisture contents of rhizomes were determined by using following formula:

$$\text{Mositure (\%)} = \frac{\text{Wf} - \text{Wd}}{\text{Wf}} \times 100$$

Where, Wf, weight of fresh sample; Wd, weight of dry sample

2.2. Total soluble solids (°Brix)

Mortar and pestle were used to crush the turmeric and total soluble solids were measured by hand refractometer (ATC-1, Atago, Japan). A drop of turmeric juice was dropped on refractometer prism, lid was closed and TSS (°Brix) measured at room temperature through refractometer digital scale.

2.3. Curcumin analysis

For curcumin analysis, rhizomes were sorted, cleaned and washed with water. Then, mother and fingers were separated manually. The rhizomes were boiled for 45 minutes at 100 °C. After that, rhizomes were peeled and dried in hot air oven for 48 hours at 70 °C. Then, rhizomes were powdered by grinding machine and curcumin content was analyzed through high-performance liquid chromatography (LC 20AT HPLC SHIMADZU) by adopting the protocol briefed by Lim et al. (2011).

Analysis of variance technique (ANOVA) was used to test the overall significance of recorded data.

3. Results and Discussion

3.1. Growth Parameters

Nitrogen has a vital role in the growth and yield of turmeric among the other nutrients (Nautiyal et al., 2016). Results of this study showed that different proportions of farmyard manure and fertilizers had a significant effect on the growth parameters of turmeric (Table 2). Results revealed that the tallest plant (87.8 cm) was obtained in T_5 treatment (2.5 ton FYM + N:P:K 182, 172 and 80 kg ha^{-1}). Among the different treatments, maximum numbers of tillers per plant (3.8), number of leaves per plant (19), leaf length (39.8 cm), leaf width (13.3 cm), stem length (27.1 cm) and stem diameter (17.3 cm) were noted in the treatment T_5. These results are in line with the findings of Sadarunnisa et al. (2010), who obtained maximum plant height (99.36 cm) and number of tillers per plant (3.14) in NPK fertilizer (180:60:120 kg ha^{-1}). Similarly, beneficial effect of farmyard manure on vegetative growth was observed by Velmurugan et al. (2008). The increase in number of tillers may be due to the impact of plant capacity to absorb and utilize the optimum nitrogen amount to build up the plant tissue and vegetative growth (Leva et al., 2013). Number of leaves per plant increased with higher nutrient (nitrogen) which trigger synthesis of nucleic acid, protein and protoplasm formation and ultimately leaf formation was vigorous (Ojikpong and Undie, 2019).

Table 2. Effects of fertilizers treatments on growth parameters of turmeric

Fertilizer treatments	Plant height (cm)	No. of tillers plant^{-1}	No. of leaves plant^{-1}	Leaf length (cm)	Leaf width (cm)	Stem diameter (mm)
T_0	60.0 f	2.3 f	13.5 e	32.1 f	9.8 e	13.9 d
T_1	65.2 e	2.6 e	14.9 d	33.4 e	10.6 d	14.4 cd
T_2	72.0 d	2.9 d	15.8 cd	35.3 d	11.6 c	15.2 bcd
T_3	77.7 c	3.2 c	16.8 bc	36.4 c	12.0 bc	15.7 abc
T_4	82.4 b	3.5 b	17.7 b	37.6 b	12.4 b	16.2 ab
T_5	87.8 a	3.8 a	19.0 a	39.8 a	13.3 a	17.3 a

T_0 (control), T_1 (8 ton ha^{-1} FYM), T_2 (8 ton ha^{-1} FYM + N:P:K 75, 25 and 50 kg ha^{-1}), T_3 (4 ton ha^{-1} FYM + N:P:K 90, 32 and 62 kg ha^{-1}), T_4 (N:P:K 136, 100 and 125 kg ha^{-1}) and T_5 (2.5 ton ha^{-1} FYM + N:P:K 182, 172 and 80 kg ha^{-1})

Table 3: Effects of fertilizers treatments on yield parameters of turmeric

Fertilizer treatments	Number of rhizomes plant^{-1}			Weight of rhizomes plant $^{-1}$ (g plant^{-1})		Yield (g plant $^{-1}$)	Rhizome length (mm)	Rhizome diameter (mm)
	Primary rhizomes	Secondary rhizomes	Total rhizomes	Primary rhizomes	Secondary rhizomes			
T_0	4.1 d	4.9 f	10.1 f	47.7 f	34.9 f	103.5 f	41.7 f	15.5 f
T_1	4.6 cd	6.3 e	11.9 e	59.4 e	46.0 e	130.2 e	43.4 e	17.5 e
T_2	4.8 c	7.7 d	13.6 d	65.9 d	63.8 d	159.8 d	45.4 d	19.7 d
T_3	5.1 bc	9.1 c	15.2 c	80.4 c	78.2 c	188.0 c	48.5 c	21.6 c
T_4	5.4 b	11.3 b	17.7 b	92.6 b	88.1 b	201.1 b	51.4 b	22.8 b
T_5	6.4 a	14.2 a	21.6 a	115.4 a	116.7 a	257.7 a	53.2 a	24.3 a

T_0 (control), T_1 (8 ton ha^{-1} FYM), T_2 (8 ton FYM + N:P:K 75, 25 and 50 kg ha^{-1}), T_3 (4 ton FYM + N:P:K 90, 32 and 62 kg ha^{-1}), T_4 (N:P:K 136, 100 and 125 kg ha^{-1}) and T_5 (2.5 ton FYM + N:P:K 182, 172 and 80 kg ha^{-1}).

Leaf length increased due to nitrogen fertilizer as it improves the cell division and cell elongation which ultimately produced the longest leaf (Ferdous et al., 2018). Taller stems can be due to high nitrogen rates as reported earlier by Maqbool et al. (2016). Stem diameter increased with the increase in nitrogen rate as recorded earlier by Modupeola and Olaniyi (2015). Verma et al. (2019) also observed significant improvement in plant height, leaves per clump, tillers per clump, numbers of leaves, plant diameter, average length of leaves and average breath of leaves with an increased level of fertilizers (120:60:120 NPK Kg ha^{-1}).

3.2. Yield parameters

Results of this study showed that maximum yield parameters, number of primary rhizomes plant^{-1} (6.4), secondary rhizomes plant^{-1} (14.2), total number of rhizomes plant^{-1} (21.6), weight of primary rhizomes plant^{-1} (115.4 g), weight of secondary rhizomes plant^{-1} (116.7 g), yield per plant (257.7 g plant^{-1}), rhizome length (53.2 mm) and rhizome diameter (21.3 mm) were recorded in treatments T_5 (2.5 ton FYM + N:P:K 182, 172 and 80 kg ha^{-1}), while the lowest yield parameters were obtained in control treatment (T_0, control) (Table 3). Behura (2001) reported that the application of NPK increased yield of turmeric by 8-9 times compared to control. Attarde et al. (2003) concluded that number of fingers per plant, length of fingers per plant, girth of fingers per plant, fresh weight per plant, yield per hectare of turmeric increased with the increase in nitrogen fertilizer up to 120 kg ha^{-1}. Similarly, Medda and Hore (2003) reported that maximum weight of primary finger, yield per plot and yield per hectare obtained at highest level of nitrogen and potassium (200:200 kg/ha).

Singh et al. (2017) concluded that a higher dose of nitrogen level with bio-fertilizers produced the highest number of secondary rhizomes (8.6), total number of rhizomes (15.7), weight of rhizomes per plant (208.2 g) and fresh yield (204.4 q ha^{-1}). An increase in nitrogen fertilizer increased the number of leaves per plant which promotes the growth and development of rhizome reported by Mekonnen and Garedew (2019). Better nutrient status increased assimilation and translocation of photosynthates from source to sink (rhizomes) that lead to greater rhizome weight (Haque et al., 2007). This increase in rhizome length might be due to the higher magnitude of growth parameters, number of leaves which ultimately provided higher amount of photosynthates and its transfer to the developing rhizomes (Datta et al., 2017).

Table 4. Effects of fertilizers treatments on quality parameters of turmeric

Fertilizer treatments	Total dry matter (%)	Moisture content (%)	Total soluble solids (ºBrix)	Curcumin content (%)
T_0	40.1 d	59.8 a	10.1 b	0.50 f
T_1	40.2 d	59.7 a	10.9 ab	0.64 e
T_2	43.7 c	56.2 b	8.6 c	0.71 d
T_3	45.3 b	54.6 c	11.9 a	0.76 c
T_4	44.9 b	55.0 c	11.4 a	0.94 a
T_5	49.5 a	50.4 d	11.2 ab	0.79 b

T_0 (control), T_1 (8 ton ha^{-1} FYM), T_2 (8 ton FYM + N:P:K 75, 25 and 50 kg ha^{-1}), T_3 (4 ton FYM + N:P:K 90, 32 and 62 kg ha^{-1}), T_4 (N:P:K 136, 100 and 125 kg ha^{-1}) and T_5 (2.5 ton FYM + N:P:K 182, 172 and 80 kg ha^{-1})

3.3. Quality parameter

Turmeric quality was judged in terms of total dry matter, moisture content, total soluble solids and curcumin content. Results of this study revealed that the highest total dry matter (49.5 %) was observed in treatment T_5 (2.5 ton FYM + N:P:K 182, 172 and 80 kg ha^{-1}). While the lowest total dry matter was obtained in control treatment. Maximum moisture content (59.8 %) was recorded maximum in T_0 treatment. However, maximum total soluble solids 11.92 ^{o}Brix and 11.48 ^{o}Brix were observed in treatment T_3 (4 ton FYM + N:P:K 90, 32 and 62 kg ha^{-1}) and T_4 (N:P:K 136, 100 and 125 kg ha^{-1}), respectively. Curcumin content (0.94 %) was maximum in treatment T_4 (N:P:K 136, 100 and 125 kg ha^{-1}), while lowest in control treatment (Table 4). Dry matter yield increased with a higher dose of nitrogen, as nitrogen is important nutrient for the production of new cells and is a constituent of chlorophyll and amino acids, which might have increased photosynthesis and ultimately the dry matter content and yield (Ojikpong and Undie, 2019). Similarly, Ojikpong (2018) also observed that dry matter production increased with increase in NPK fertilizer up to 150 kg/ha. Total soluble solids decreased with the increase in nitrogen level as reported by Asma et al. (2007). However, phosphorus has been reported to influence the total soluble solids at a certain level (Li et al., 2019). While, total soluble solids increased with increase in potassium level (Asma et al., 2007). Organic manure treatment supplies the nutrient content throughout the growth period in balanced form, which increased the curcumin content of turmeric (Datta et al., 2017). Nitrogen alone did not increase curcumin content. However, curcumin formation in turmeric rhizome is promoted by potassium and phosphorus as reported earlier by Akamine et al. (2007).

4. Conclusion

Application of N:P:K @ 136:100:125 kg/ha to turmeric crop produced highest curcumin content (0.94%) in sandy loam soils under Faisalabad conditions. However, rhizome yield was increased with the application of FYM (2.5 ton/ha) in combination with N:P:K @ 182, 172 and 80 kg ha $^{-1}$ but it slightly decreased curcumin contents. Moreover, application of 2.5 ton ha^{-1} FYM + N:P:K 182, 172 and 80 kg ha^{-1} produced 28% and 37% higher rhizome yield compared to N:P:K 136, 100 and 125 kg ha^{-1} and 4 ton ha^{-1} FYM + N:P:K 90, 32 and 62 kg ha^{-1}, respectively. While, N:P:K 136, 100 and 125 kg ha^{-1} produced 6.5% higher yield than 4 ton ha^{-1} FYM + N:P:K 90, 32 and 62 kg ha^{-1}. Further, this increase yield was concomitant with the increase in rhizome size, and not only because of increased number of rhizomes.

List of Abbreviations: ANOVA: Analysis of Variance Technique, FYM: Farm Yard Manure, NPK: Nitrogen Phosphorus and Potassium, TSS: Total Soluble Solids.

Competing Interest Statement: All the authors declare that they have no competing interests

Author's Contribution: Khurram Ziaf has planned this research, Yasir Majeed and Hamza Mujahid have done the research trial, Muhammad Ameen Ahmad has performed curcumin analysis, Iftikhar Ahmad has performed statistical analysis, Khurram Ziaf and Muhammad Awais Ghani have contributed in the research paper write-up, while Karim Yar Abbasi and Kaiser Latif Cheema have reviewed the draft of the manuscript.

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