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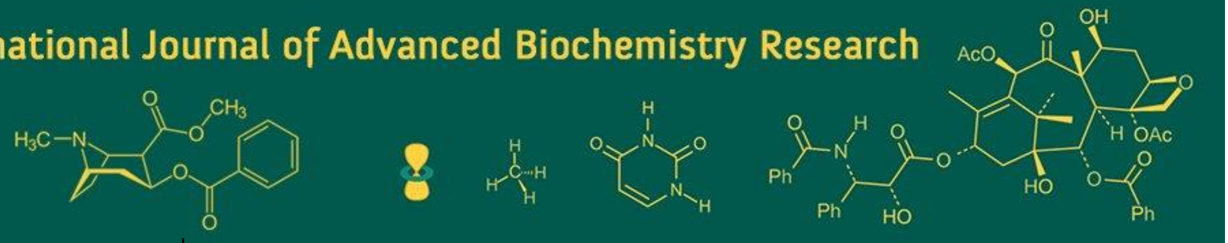

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Shailendra Kumar
Department of Horticulture, Central Agricultural University, Lamphelpat, Imphal West, Manipur, India

Meinam Chanchan
Department of Horticulture, Central Agricultural University, Lamphelpat, Imphal West, Manipur, India

Vipin
Punjab Agricultural University, Ludhiana, Punjab, India

Marifa Gulzar
Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir Shalimar campus, Srinagar, Jammu and Kashmir, India

Senjam Romen Singh
Department of Horticulture, Central Agricultural University, Lamphelpat, Imphal West, Manipur, India

KH Stina
Department of Horticulture, Central Agricultural University, Lamphelpat, Imphal West, Manipur, India

Ram Preet Singh
Department of Horticulture, Central Agricultural University, Lamphelpat, Imphal West, Manipur, India

Shubham Kumar
Anand Agricultural University, Anand, Gujarat, India

Corresponding Author:
Shailendra Kumar
Department of Horticulture, Central Agricultural University, Lamphelpat, Imphal West, Manipur, India

Influence of graded levels of inorganic with organics and biofertilizers on yield, quality and economics of turmeric (*Curcuma longa* L.)

Shailendra Kumar, Meinam Chanchan, Vipin, Marifa Gulzar, Senjam Romen Singh, KH Stina, Ram Preet Singh and Shubham Kumar

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Abstract
The study was carried out at horticulture experimental field of Central Agricultural University, Iroisemba, Imphal West, Manipur, during 2021-2022. Thirteen treatments and three replications were included in the RBD design of the experiment. Biofertilizers and organic manures are two more sustainable and alternative sources of nutrients. When biofertilizers and organic manure are mixed, the growth is affected by increased root biomass; total root surface increases nutrient absorption and yield by using less natural energy sources. The combination of organic manures *viz*., compost, vermicompost, mustard cake and neem cake and BF (biofertilizers) *viz.*, nitrogenous (*Azotobacter chroococcum*), phosphate solubilizing bacteria (*Bacillus polymixa*) and potassic mobilizing (*Fraturia aurantea*) and three levels (100%, 75% and 50%) of NPK were included in this experiment along with recommended dose of NPK (150:60:150 kg/ha). Result of the present experimentation disclosed that the application of Vermicompost + NPK 100% + BF recorded significant value for yield per plot (15.40 kg 3.0 m^{-2}), yield (38.50 t ha^{-1}), curcumin content (6.32%) and oleoresin content (13.74%). The application of Vermicompost + NPK 100% + BF recorded maximum gross return (Rs. 1155000/ha), net return (Rs. 792252.04/ha) and highest B:C ratio (2.24) followed by Compost + NPK 100% + BF (2.11).

Keywords: Biofertilizers, curcumin, oleoresin, organics, quality

Introduction
It belongs to the Zingiberaceae family and has its origins in South-East Asia (Roy *et al.* 2014, Sotiboldieva and Mahkamov 2020) [21, 27]. For centuries, it has been a staple in traditional medicine and culinary practices (Jyotirmayee *et al.* 2023) [12]. Turmeric is renowned for its brilliant golden-yellow hue and unique flavour, which imparts richness and warmth to a wide range of dishes (Ahmed *et al*. 2021) [1]. The active compound responsible for both the colour and various health benefits of turmeric is known as curcumin (Chattopadhyay *et al.* 2004) [7]. In traditional Ayurvedic and Chinese medicine, turmeric has been employed to aid digestion, alleviate joint pain, and treat various ailments (Akaberi *et al.* 2021) [2]. Additionally, it holds great significance in religious ceremonies and cultural customs in many Asian nations.

Turmeric is primarily cultivated for its rhizomes, which are bulbous, subterranean stems (Aryal 2022) [3]. After harvesting, these rhizomes are dried and ground into a fine powder, commonly referred to as turmeric powder. It finds extensive use in spice blends and holds significance in religious rituals in India (Sasikumar 2005) [24]. A crucial ingredient in dishes like curries, stews, and rice preparations, turmeric imparts both its distinctive flavour and vibrant colour to the food. Research has indicated that curcumin may possess antioxidant, anti-inflammatory, antimicrobial, and anticancer properties. Its potential in managing conditions such as arthritis, heart disease, diabetes, and certain types of cancer has been subject to numerous studies (Fuloria *et al*. 2022) [9].

Organic fertilizers, such as farmyard manure, vermicompost, neem cake and decomposed green leaf manure, play a vital role in enhancing soil health and sustaining crop yields (Indoria *et al.* 2018) [11].

Improve the soil properties (physical, chemical and biological) by essential use of organic fertilizers. By increasing soil fertility, productivity, and water-holding capacity, they contribute to superior plant growth (Verma *et al.* 2020) [31]. Indian turmeric is renowned for its high curcumin content, making it synonymous with top-notch quality. In the 2021-22 facial year, India exported 1.37 lakh tonnes of turmeric, a decrease from the previous year's 1.83 lakh tonnes. The key turmeric-producing states in India include Telangana, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Madhya Pradesh and West Bengal. In Telangana, prominent turmeric-growing districts encompass Jagtial, Nizamabad, Nirmal, Warangal and Mahabubabad. According to the Telangana State Government's 2nd advance estimates for 2022-23, turmeric production is projected to reach 1.56 lakh tonnes from 0.23 lakh hectares (0.57 lakh acres), with productivity rate of 6783 kg/ha (2745 kg/acre) (Turmeric Outlook 2023) [28].

Materials and Methods

The experiment was conducted in 2021–2022 in the experimental field of Department of Horticulture, CAU, Imphal, Manipur, India. The university is geographically situated at an altitude of 850 m above (MSL) mean sea level at 24˚45" N latitude and 93˚56" longitude. The soil in the experimental plots was clayey, with an acidic pH of 5.24, and contained 1.18% organic carbon. N, P_2O_5 and K_2O availability in soil were 238.33, 31.79 and 196.50 kg/ha, respectively. Four types of organic manures *viz*., compost, vermicompost, mustard cake and neem cake and three types of biofertilizers *viz*., *Azotobacter*, PSB and KMB were used as nutrient sources in different combinations. Thirteen treatments were included in the investigation *viz*, T_1: Compost + NPK 100% + BF, T_2: Compost + NPK 75% + BF, T_3: Compost + NPK 50% + BF, T_4: Vermicompost + NPK 100% + BF, T_5: Vermicompost + NPK 75% + BF, T_6: Vermicompost + NPK 50% + BF, T_7: Mustard Cake + NPK 100% + BF, T_8: Mustard Cake + NPK 75% + BF, T_9: Mustard Cake + NPK 50% + BF, T_{10}: Neem Cake + NPK 100% + BF, T_{11}: Neem Cake + NPK 75% + BF, T_{12}: Neem Cake + NPK 50% + BF, T_{13}: Recommended NPK 100% (150:60:150 kg/ha).

Randomised Block Design (RBD) was used to arrange the three replications of the experiment. Each block accommodated 13 treatments and the treatments were randomized in 3 replications. Raised beds of 3.0×1.0 m^2 and 15 cm high were prepared. The turmeric rhizome was transplanted by hand at a recommended spacing of 25 cm x 25 cm.

The organic inputs namely compost, vermicompost, mustard cake and neem cake were applied basally during final land preparation @ 10t, 5t, 3t and 3t per hectare respectively. Recommended dose of inorganic fertilizers was 150:60:150 kg NPK per hectare (Medda 2000) [17]. The total fertilizers were applied in three split doses. 1/3rd of N and full dose of P was applied after 15 days of planting whereas each split of 1/3rd N and 1/2nd K were applied after 45 and 90 days after the first application. Urea, SSP and MOP were used as inorganic source of Nitrogen, Phosphorus and Potassium, respectively. Straw was used as mulching material. Biofertilizers (*Azotobacter*, phosphorus solubilizing bacteria and potassic mobilizer) was applied @ 20 kg/ha directly to the soil along with the organic manures. Healthy seed rhizome (30-35 g) along with *Trichoderma viride* @ 5 g/kg and Acacia gum used as a sticker were taken in water in a plastic tray and mixed thoroughly. After soaking the rhizomes bits were dried under shade in airy place. Treated rhizomes of turmeric were planted to a depth of 4-5 cm, in the last week of May, 2021. Plots were mulched immediately with straw of paddy after planting. 3-4 hand weeding were done. Irrigation was given as per requirement. The crop was harvested 8 months after planting, observations on yield, quality and economic parameters were recorded after harvest. Rhizome yield was taken on net plot basis at harvest and yield/ha were calculated on the basis of yield/plot, considering the 75% area occupied by the crop (Chanchan *et al.* 2018) [5].

Curcumin content

The curcumin content was estimated by using the procedure given by (Sadasivam and Manickam 2008) [23]. 0.2g of moisture-free turmeric powder was dissolved in 150 ml of ethanol in a 250 ml flask. The contents in the flask were refluxed (heated with an air condenser) over a heating mantle for 6 hours. After refluxing, the content was allowed to cool. The extract was decanted into a 100 ml volumetric flask. The volume was made up to 100 ml by adding more ethanol to achieve a 20 times dilution (0.5 ml to 10 ml with ethanol). The intensity of the yellow colour in the extract was measured at a wavelength of 425 nm using a spectrophotometer.

$$\text{Curcumin \% (g/100 g)} = \frac{0.0025 \times {}^{A}425 \times \text{volume made up} \times \text{dilution factor} \times 100}{0.42 \times \text{weight of sample (g)} \times 1000}$$

Here, 0.42 absorbance at 425 nm =0.0025 gm curcumin

Oleoresin content

The oleoresin content was estimated by using the procedure given by (Sadasivam and Manickam 2008) [23]. The weight of the empty extractor flask (W1) was recorded. 3g of moisture-free turmeric powder was placed in a Soxhlet thimble. The powder in the thimble was extracted with diethyl ether through reflux for 6 hours at a temperature of 60-80 °C. The flow of diethyl ether was regulated using a stopper. The extraction process was continued until all of the diethyl ether had evaporated (a vacuum pump was used to aid in the evaporation). After the extraction, a dark-coloured sticky oleoresin was collected in the beaker. The weight of the extractor flask with the collected oleoresin (W2) was recorded. The following formula was used to determine the oleoresin content:

$$\text{Oleoresin \% (g/100 g)} = \frac{\text{Weight of beaker after extraction (W2) - Weight of beaker before extraction (W1)} \times 100}{\text{Weight of sample taken (g)}}$$

Economic analysis

The variable costs of turmeric cultivation included expenses of land preparation, seed rhizome costs, treatment of seed rhizome by fungicides and transplanting, mulch materials, plant protection measures, weeding, organic manures and biofertilizers and its application, irrigation water and the harvesting. The gross return was derived by considering the existing mean market price of the turmeric during the experiment. To calculate the net return, total cultivation cost (fixed cost + variable cost) were subtracted from the gross return. The benefit: cost ratio (BCR) for each treatments were calculated by evaluating the net return in relation to the cultivation cost, with all values expressed in Rs/ha.

Statistical analysis

Fisher's methodology of analysis of variance was used to statistically analyse the gathered experimental data. When the findings were significant, the "F" test was used to determine the significance of the difference in the treatment effect at the 5% level of significance. CD or the crucial difference, was then computed. The standard error of mean [S.Em (±)] and the value of critical difference (CD) to compare the difference between means are provided in the tables of the results.

Results and Discussion

Yield Parameters

Results showed that the application of inorganic with organic manures and biofertilizers had a significant effect on yield, quality attributes and economics of turmeric (Table 1). The maximum yield per plot (15.40 kg 3.0 m-2) and yield per hectare (38.50 t ha^{-1}) were recorded in vermicompost + NPK 100% + BF followed by compost + NPK 100% + BF (14.63 kg 3.0 m-2). While, the minimum yield per plot (9.82 kg 3.0 m-2) and yield per hectare (24.55 t ha^{-1}) were recorded in compost + NPK 50% + BF. The application of vermicompost increases the activity of helpful microbes such as N_2 fixers and mycorrhizal fungi, which plays a significant role in N_2 fixation and phosphate mobilisation, leading to better uptake by the plant and better growth and yield (Kale *et al.* 1992) [13]. The utilization of organic manures has demonstrated a significant enhancement in soil productivity and fertility, consequently leading to improved yield and quality of long-duration crops like turmeric. In this particular study, the application of higher quantities of FYM and vermicompost resulted in notable improvements in turmeric growth, dry matter accumulation, yield, and quality. Similar results were observed and reported by Hossain and Ishimine (2007) [10], Mohapatra and Das (2009) [18], Manhass and Gill (2010) [16], Datta *et al.* (2017) [8] and Chandana *et al.* (2022) [6]. Furthermore, the combined application of FYM, vermicompost, leaf manure, along with *Azospirillum* and PSB (Phosphate Solubilizing Bacteria) showcased superior effects on the yield-related attributes of turmeric in the present experiment. This discovery is consistent with the findings published by Velmurugan *et al*. (2007) [29]. Similar yield responses to organic manures with biofertilizer as observed as previous investigation studies on response of various manure and biofertilizer on growth and yield of turmeric have been reported by Chanchan *et al*. (2017) [4].

Table 1: Influence of graded levels of inorganic with organics and biofertilizers on yield of turmeric

Treatment combination	Yield	
	Per plot (kg $3m^{-2}$)	(t ha^{-1})
Compost + NPK 100% + BF	14.63	36.57
Compost + NPK 75% + BF	12.28	30.70
Compost + NPK 50% + BF	9.82	24.55
Vermicompost + NPK 100% + BF	15.40	38.50
Vermicompost + NPK 75% + BF	13.36	33.40
Vermicompost + NPK 50% + BF	11.72	29.30
Mustard Cake + NPK 100% + BF	12.93	32.32
Mustard Cake + NPK 75% + BF	11.32	28.30
Mustard Cake + NPK 50% + BF	9.90	24.77
Neem Cake + NPK 100% + BF	14.02	35.05
Neem Cake + NPK 75% + BF	12.70	31.76
Neem Cake + NPK 50% + BF	10.62	26.55
Recommended NPK 100% (150:60:150 kg/ha)	9.99	24.98
S.Em (±)	0.89	2.22
CD 5%	2.59	6.47

Quality parameters

The data revealed that (table 2) curcumin and oleoresin content (%) significantly with different treatments.

The highest curcumin content (6.32%) was noted in a combination of vermicompost + NPK 100% + BF, followed by mustard cake + NPK 100% + BF (6.26%). Meanwhile, the lowest curcumin content (5.03%) was found in a combination of compost + NPK 50% + BF, followed by compost + NPK 75% + BF (5.30%). The highest oleoresin content (13.74%) was noted in a combination of vermicompost + NPK 100% + BF, followed by neem cake + NPK 100% + BF (13.46%). While the lowest oleoresin content (11.60%) was obtained in a combination of vermicompost + NPK 50% + BF, followed by the recommended NPK 100% (11.82%). Quality parameters, such as curcumin and oleoresin content were found to increases in all the organic and biofertilizer combinations compared to inorganic NPK (100%). These findings are in consonance with prior findings of Mridula and Jayachandran (2001) [19] and Velmurugan *et al*. (2008) [30]. According to Kumar *et al*. (2016) [15], the higher curcumin content is caused by an increase in the availability of micronutrients from various organic sources that are supplied as FYM, vermicompost, and neem cake. The treatments organic manure provided a balanced nutrient supply throughout the growth period, consequently enhancing the curcumin content in turmeric. This effect aligns with the findings reported by Velmurugan *et al.* (2007) [29]. A similar experiment was also carried out by Singh *et al.* (2015) [26] and Datta *et al*. (2017) [8] to evaluate the effects of organic manures and biofertilizers on the quality measurements of turmeric. Their study revealed that the application of organic manures significantly increased both yield and quality in comparison to using inorganic fertilizers alone, mirroring the results recorded in the present experiment.

Table 2: Influence of graded levels of inorganic with organics and biofertilizers on quality characters

Treatment combination	Quality characters	
	Curcumin (%)	Oleoresin (%)
Compost + NPK 100% + BF	5.76	13.26
Compost + NPK 75% + BF	5.30	12.68
Compost + NPK 50% + BF	5.03	12.22
Vermicompost + NPK 100% + BF	6.32	13.74
Vermicompost + NPK 75% + BF	5.92	12.78
Vermicompost + NPK 50% + BF	5.70	11.60
Mustard Cake + NPK 100% + BF	6.26	13.04
Mustard Cake + NPK 75% + BF	5.84	12.36
Mustard Cake + NPK 50% + BF	6.02	12.70
Neem Cake + NPK 100% + BF	6.14	13.46
Neem Cake + NPK 75% + BF	6.16	13.32
Neem Cake + NPK 50% + BF	5.97	12.54
Recommended NPK 100% (150:60:150 kg/ha)	5.80	11.82
S.Em (±)	0.16	0.11
CD 5%	0.47	0.33

Economics analysis

The information disclosed that Table 3. The highest net return (Rs. 792252.04/ha) was recorded in vermicompost + NPK 100% + BF, followed by compost + NPK 100% + BF (Rs. 744352.04/ha). While, the lowest net return (Rs. 271646.02/ha) was recorded in neem cake + NPK 100% + BF, followed by mustard cake + NPK 50% + BF (Rs. 374246.02/ha). The maximum B: C ratio (2.24) was recorded in vermicompost + NPK 100% + BF. While, the minimum B: C ratio (0.51) was observed in neem cake + NPK 100% + BF. Earlier several workers reported increase in yield and net return in organics over inorganic fertilizers (Roy and Hore 2011, Nanda *et al*. 2012) [22, 20]. To maximize profits, it is desirable to focus on features that possess a higher monetary value while incurring lower cultivation costs. As a result, an assessment was conducted on the economic dimensions of the treatments. Singh (2013) [25] noted that the turmeric variety Guntur Local yielded a maximum of 194.50 quintals per hectare of rhizome production. A similar experiment was carried out by Khedkar *et al*. (2023) [14] to evaluate the impact of organic manures and bio-fertilizers on the growth and production of turmeric. The economic analysis of the yield data revealed that O_2B_4 i.e., vermicompost 7.5 t ha^{-1} and PSB 5 kg ha^{-1} recorded the highest gross return and B: C ratio. If we consider the yield, curcumin content, oleoresin content, gross return and net return, then the best treatments were application of vermicompost + NPK 100% + BF, followed by compost + NPK 100% + BF.

Table 3: Influence of graded levels of inorganic with organics and biofertilizers on Benefit: cost ratio of turmeric cultivation under different treatments

Treatments	Total cost (Rs./ha)	Yield (t/ha)	Gross return (Rs./ha)	Net return (Rs./ha)	Benefit: Cost ratio
T1	352747.96	36.57	1097100	744352.04	2.11
T2	348800.97	30.70	921000	572199.03	1.64
T3	344853.98	24.55	736500	391646.02	1.14
T4	362747.96	38.50	1155000	792252.04	2.24
T5	358800.97	33.40	1002000	643199.03	1.79
T6	354853.98	29.30	879000	524146.02	1.47
T7	376747.96	32.32	969600	592852.04	1.57
T8	372800.97	28.30	849000	476199.03	1.27
T9	368853.98	24.77	743100	374246.02	1.01
T10	532747.96	35.05	1051500	518752.04	0.97
T11	528800.97	31.76	952800	423999.03	0.80
T12	524853.98	26.55	796500	271646.02	0.51
T13	246747.96	24.98	749400	502652.04	2.03

Conclusion

The best treatment for turmeric yield, quality and cost-benefit analysis were found to be vermicompost + NPK 100% + Biofertilizer (T_4). The most efficient integrated nutrient management method, when considering yield, gross return and the Benefit-to-Cost (B: C) ratio, is vermicompost + NPK 100% + biofertilizer. It may be concluded that applying organic manures and biofertilizers has the ability to substitute 25% of inorganic fertilizers by comparing the yield/hectare at 75% NPK level with four various organic manures and 100% NPK alone.

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