D-5688
[1-6]

RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Studies on the Impact of Integrated Nutrient Management on Growth and Quality Parameters of Turmeric

R. Mondal[1], J.K. Hore[2]

10.18805/ag.D-5688

ABSTRACT

Background: The health of the soil is negatively impacted by chemical fertilizer sources and plants are less able to absorb the readily available nutrients. The current study used several nutrition sources to reduce the negative impacts of chemical fertilizers, boost nutrient availability and preserve health.

Methods: The present experiment was conducted in a field laboratory during 2017-19. 4 different manures, 3 different bio-fertilizers and graded levels of NPK were applied in the form of 13 treatments. Data on the vegetative development of turmeric plants were collected before harvesting and quality data were obtained after harvesting and some processing.

Result: Vermicompost + NPK (100%) + Biofertilizers showed the highest results by considering the leaf number (23.64), tiller number (4.25) and height of plant (191.74 cm). Higher dry recovery (23.56%), oleoresin (13.48%) and curcumin content (6.16%). Alternative sources of nutrients are reducing the dose of chemical fertilizers application as well as improving the vegetative growth and quality of turmeric rhizome. In this way, we can replace 25-50% of chemical fertilizers with organic sources and enhance the soil health for plant growth and production.

Key words: Curcumin, Dry recovery, Growth, INM, Oleoresin, Turmeric.

INTRODUCTION

Turmeric (*Curcuma longa* L.) is a perennial, tropical, monocotyledonous spice plant that has been used medicinally since antiquity and belongs to family Zingiberaceae which grows upto the height of 60-110 cm (Khawale and Chinchmalatpure, 2023). Turmeric rhizome has potential uses in food factories, textile factories, or others due to oleoresin and curcumin content causing yellow color rhizome. Rhizomes contain carbohydrates, protein, fiber, minerals, lipids, *etc*. (Ojikpong and Undie, 2019; Moulick *et al*., 2023). The most secure herb for treating blood diseases is turmeric (Sirisidthi *et al*., 2016). Rhizomes are intended to cure many ailments such as diarrhea, liver problems, fever, *etc*. (Anuradha *et al*., 2018).

Turmeric is an extremely nutrient-extensive and heavy feeder crop. Applications of organic matter have a positive impact on turmeric's growth, productivity and quality and experimental data are presented to support the impact. Organic matter can also be used in conjunction with inorganic fertilizers to improve turmeric's quality. Its capacity to produce a lot of dry matter per unit area and shallow rooting make its nutrient needs quite high. Therefore, it is crucial for optimum growth of the plant meet by plant nutrients are applied as needed with organic and inorganic manures. For the soil to remain fertile and productive, inorganic and organic manures must be used together. Studies on the effects of organic manures, biofertilizers combined with various rates of NPK fertilizers on turmeric have been documented by Sanwal *et al.* (2007); Singh (2020); Roy and Hore (2009) and Akamine *et al.* (2007). Studies examining how different nutrient management strategies affect turmeric production and quality in addition to their impact on physicochemical and biochemical variables impacting soil quality. Turmeric farmers can earn more money from their produce if they grow it organically because there is an increasing global demand for organic products. Due to improved quality, better market demands and increased environmental protection, organic farming has become more popular (Yadav *et al*., 2004). Bio-fertilizers are not just environmentally safe, sustainable and low-cost input but also given great profits under suitable condition.

The use of biofertilizers, such as *Azospirillium*, improves soil fertility and aids in the fixation of a significant amount of atmospheric nitrogen for supply to the crop. The uptake of phosphorus, which is easily fixed in the soil, is increased by applying PSB (Khan *et al*., 2022). Adopting a strategy for the perceptive amalgamation of chemical fertilizers, organic manures and bio-fertilizers is necessary to encourage, nurture and facilitate permaculture for more

[1]School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, india.
[2]Department of Plantation, Spices, Medicinal and Aromatic Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741 252, West Bengal, India.

Corresponding Author: R. Mondal, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, india.
Email: radha13192@gmail.com

How to cite this article: Mondal, R. and Hore, J.K. (2024). Studies on the Impact of Integrated Nutrient Management on Growth and Quality Parameters of Turmeric. Agricultural Science Digest. doi: 10.18805/ag.D-5688.

Submitted: 26-09-2022 **Accepted:** 22-01-2024 **Online:** 18-03-2024

profitable and healthy production. Recently, biofertilizers have become recognized as a viable nutrient supply element. Numerous researchers have demonstrated the importance of various bio fertilizers, such as *Azospirillum* and *Azotobacter* cultures, in fixing atmospheric nitrogen. The soil's microorganisms have the potential to accumulate organic matter, which increases the availability of other nutrients and secretes compounds that promote growth. In several experiments and field tests, the use of phosphate-solubilizing microorganisms has resulted in favorable results (Alori *et al*., 2017).

MATERIALS AND METHODS

The research was carried out between 2017 and 2019 at the HRS, Bidhan Chandra Krishi Viswavidyalaya, Mondouri, West Bengal. Variety is Suguna, number of treatments is 13 with 3 replications and followed RBD design. Total 13 treatments were T1: Compost + NPK (100%) + Biofertilizer, T2: Compost + NPK (75%) + Biofertilizer, T3: Compost + NPK (50%) + Biofertilizer, T4: Vermicompost + NPK (100%) + Biofertilizer, T5: Vermicompost + NPK (75%) + Biofertilizer, T6: Vermicompost + NPK (50%) + Biofertilizer, T7: Mustard Cake + NPK (100%) + Biofertilizer, T8: Mustard Cake + NPK (75%) + Biofertilizer, T9: Mustard Cake + NPK (50%) + Biofertilizer, T10: Neem Cake + NPK (100%) + Biofertilizer, T11: Neem Cake + NPK (75%) + Biofertilizer, T12: Neem Cake + NPK (50%) + Biofertilizer and T13: NPK 100%. Three biofertilizers were used: *Azotobacter chroococcum*, a bacterium that fixes nitrogen, *Bacillus polymixa*, a bacterium that dissolves phosphate and potassium mobilizer (*Fraturia aurantea*). Five randomly chosen plants were evaluated for growth factors such height, number of leaves per plant and number of tillers per plant 90, 120, 150 and 180 days after planting.

Dry recovery

Fixed quantity of fresh rhizomes from five randomly selected plants were weighed by using electric balance, then oven dried the harvested rhizome at 55°C for 3-5 days until no further change in weight. The dry recovery was expressed in percentage.

Oleoresin conten

The dried rhizomes were grinded and sieved. Turmeric powder was kept in chromatographic column with acetone for overnight (AOAC, 1975) and filtered out. Oleoresin with acetone was dried and weight was measured.

$$\text{Oleoresin \%} = \frac{\text{Weight of oleoresin}}{\text{Weight of sample}} \times 100$$

Curcumin content

Through solvent extraction of turmeric with ethanol and water, the amount of curcumin was estimated (Bagchi, 2012). 2 g of material from each treatment was collected, mixed with 30 ml each of ethanol and water and then filtered. Each filtrate's concentration is held constant and a spectrophotometer is used to detect the absorbance at 425 nm. The formula for calculating curcumin content (g/100 g) is as follows:

Curcumin content (g/100 g) =

$$\frac{0.0025 \text{ x Absorbance at 425 nm} \times \text{Volume made up} \times \text{Dilution factor} \times 100}{0.42 \times \text{weight of sample} \times 1000}$$

Since 0.42 absorbance at 425 nm = 0.0025 g of curcumin.

Statistical analysis

In accordance with Panse and Sukhatme, statistical analysis of variance was performed on the collected data (1985). To perform combined analysis, the mean data from two seasons were combined and analyzed using MSTAT-C. Fisher and Snedecor's "F" test was used to determine the significance of various sources of variation at a probability level of 0.05. Fisher and Yates (1979) tables were used to determine the critical difference (C.D.) at a 5% level of significance. The tables of results include the critical difference (C.D.) value and the standard error of the mean [S.Em. (±)] to compare the variance between means.

RESULTS AND DISCUSSION

Height of the plant

At different stages of plant growth, organic manures, biofertilizers and inorganic fertilizers had a considerable impact on plant height. 90 days after planting, based upon the data given in Table 1, the maximum height (118.26 cm) was recorded in plants grown under T10: Neem Cake + NPK (100%) + Biofertilizer (BF) and minimum plant height was recorded under T6: Vermicompost + NPK (50%) + BF (89.47 cm). The plant height with T13: NPK (100%) only was 96.24 cm. At 120 DAP, plants raised under T8: Mustard Cake + NPK (75%) + BF exhibited maximum plant height of 145.82 cm and minimum plant height of 114.86 cm was observed under T9: Mustard Cake + NPK (50%) + BF but plant height of 118.02 cm was recorded under T13: NPK (100%) only, though both of them were statistically not significant. At 150 DAP, the tallest plant (178.30 cm) was observed under T10: Neem Cake + NPK (100%) + BF as compared to shortest plant (132.65 cm) under T9: Mustard Cake + NPK (50%) + BF. The plants raised under only inorganic fertilizer *i.e*., T13: NPK (100%) exhibited plant height of 137.56 cm. The last two treatment combinations were statistically *at par*. At 180 DAP, the maximum plant height (193.20cm) was recorded under T10: Neem Cake + NPK (100%) + BF followed by T4: Vermicompost + NPK (100%) + BF (191.74 cm) and T7: Mustard Cake + NPK (100%) + BF (189.35 cm) in contrasted to the minimal plant height of T9: Mustard Cake + NPK (50%) + BF (154.76 cm). The plants raised under only recommended fertilizer (T13: NPK 100%) recorded plant height of 159.38 cm.

Number of tillers per clump

The largest number of tillers per clump (1.61) at 90 DAP was recorded in T11: Neem Cake + NPK (75%) + BF in contrasted to the minimal tiller (0.52) under T9: Mustard Cake + NPK (50%) + BF (Table 2). At 120 DAP, the plants raised under T4: Vermicompost + NPK (100%) + BF exhibited maximum tiller of 2.36 in contrasted to the minimal tiller (0.93) under T12: Neem Cake + NPK (50%) + BF. The plant grown under only inorganic treatment recorded tiller number of 1.24. At 150 DAP, maximum number of tiller (3.17) was associated with treatment combination of T10: Neem Cake + NPK (100%) + BF (3.17) as compared to minimum number of tillers (1.58) under T9: Mustard Cake + NPK (50%) + BF. At 180 DAP, as per pooled data the maximum number of tiller (4.25) was observed in treatment combination of T4: Vermicompost + NPK (100%) + BF followed by T10: Neem Cake + NPK (100%) + BF (4.16), as compared to minimum number of tiller in T12: Neem Cake + NPK (50%) + BF (2.35). Plants under T13: NPK (100%) produced tiller number of 2.64.

Number of leaves per clump

The maximum leaf number (10.80) was recorded in plants raised under T5: Vermicompost + NPK (75%) + BF as compared to minimum leaf number (8.12) under T9: Mustard Cake + NPK (50%) + BF (Table 3). At 120 DAP, the maximum number of leaf (14.31) was associated with plants grown under treatment combination of T1: Compost + NPK (100%) + BF as compared to minimum number of leaves (10.32) under T12: Neem Cake + NPK (50%) + BF. The plants raised under T13: NPK (100%) only produced leaf number of 12.25. At 150 DAP, plants raised under T4: Vermicompost + NPK (100%) + BF recorded largest leaf number (18.15) as compared to minimum leaf number (13.16) under T9: Mustard Cake + NPK (50%) + BF. At 180 DAP, like 150 DAP

Table 1: Influence of different levels of organic, inorganic and biofertilizers on plant height of turmeric (in cm).

Treatments	90 DAP	120 DAP	150 DAP	180 DAP
T1: C + NPK (100%) + BF	105.62	132.51	167.82	188.36
T2: C + NPK (75%) + BF	99.36	130.38	159.05	180.46
T3: C + NPK (50%) + BF	92.64	122.64	142.62	161.35
T4: VC + NPK (100%) + BF	102.35	134.34	169.82	191.74
T5: VC + NPK (75%) + BF	109.64	136.29	164.13	186.38
T6: VC + NPK (50%) + BF	89.47	117.05	148.05	169.45
T7: MC + NPK (100%) + BF	112.36	142.34	172.82	189.35
T8: MC + NPK (75%) + BF	115.67	145.82	170.26	182.03
T9: MC + NPK (50%) + BF	98.35	114.86	132.65	154.76
T10: NC + NPK (100%) + BF	118.26	145.65	178.30	193.20
T11: NC + NPK (75%) + BF	112.45	136.12	165.12	181.32
T12: NC + NPK (50%) + BF	106.26	128.48	149.36	168.06
T13: NPK (100%)	96.24	118.02	137.56	159.38
S.Em. (±)	1.492	1.859	2.232	2.469
C.D. (P=0.05)	4.380	5.458	6.554	7.250

DAP= Days after planting**,** C= Compost, VC= Vermicompost, MC= Mustardcake, NC= Neemcake BF= Biofertilizer

Table 2: Influence of different levels of organic, inorganic and biofertilizers on number of tillers of turmeric.

Treatments	90 DAP	120 DAP	150 DAP	180 DAP
T1: C + NPK (100%) + BF	1.14	2.02	2.94	3.76
T2: C + NPK (75%) + BF	0.96	1.89	2.68	3.49
T3: C + NPK (50%) + BF	0.65	1.15	2.05	2.86
T4: VC + NPK (100%) + BF	1.26	2.36	3.14	4.25
T5: VC + NPK (75%) + BF	1.42	2.14	2.86	3.92
T6: VC + NPK (50%) + BF	0.82	1.16	2.15	2.74
T7: MC + NPK (100%) + BF	1.18	1.96	2.38	3.87
T8: MC + NPK (75%) + BF	1.46	1.72	2.56	3.45
T9: MC + NPK (50%) + BF	0.52	0.96	1.58	2.49
T10: NC + NPK (100%) + BF	1.25	1.56	3.17	4.16
T11: NC + NPK (75%) + BF	1.61	2.23	2.86	4.02
T12: NC + NPK (50%) + BF	0.63	0.93	1.92	2.35
T13: NPK (100%)	0.72	1.24	1.65	2.64
S.Em. (±)	0.016	0.024	0.034	0.048
C.D. (P=0.05)	0.046	0.071	0.099	0.142

the same treatment combination *i.e*., T4: Vermicompost + NPK (100%) + BF recorded maximum leaf number of 23.64. The next best treatment combination in respect of leaf production was T10: Neem Cake + NPK (100%) + BF (22.13), T5: Vermicompost + NPK (75%) + BF (21.32) and T11: Neem Cake + NPK (75%) + BF (20.36) as compared to minimum leaf number (16.45) under T3: Compost + NPK (50%) + BF. The plants under only inorganic fertilizer T13: NPK (100%) recorded leaf number of 18.36. similar plant growth results were also shown by Dikey *et al.* (2019); Kumar *et al.* (2018); Lohar and Hase (2021). Diverse organic nutrient sources, such as biofertilizers and manures, are applied in stages to foster beneficial microorganisms and enhance humus content within the soil, hence increasing nutrient availability and promoting soil health by restoring soil physicochemical qualities (Amala *et al*., 2019; Lohar and Hase, 2021). The availability of nutrients in the soil promotes plant development.

Dry recovery

Dry recovery of rhizome increased from 21.62% to 24.62% (Table 4). The maximum dry recovery (24.62%) was observed in the treatment combination T10: Neem Cake + NPK (100%) + BF followed by T7: Mustard Cake + NPK (100%) + BF (23.86%) as compared to minimum dry recovery (21.62%) in T2: Compost + NPK (75%) + BF combination. The dry recovery was 22.84% under T13: NPK (100%). In the Mustard and Neem Cake combination, dry

Table 3: Influence of different levels of organic, inorganic and biofertilizers on number of leaves of turmeric.

Treatments	90 DAP	120 DAP	150 DAP	180 DAP
T1: C + NPK (100%) + BF	10.45	14.31	17.12	20.16
T2: C + NPK (75%) + BF	10.15	13.16	16.56	19.30
T3: C + NPK (50%) + BF	9.30	11.45	13.28	16.45
T4: VC + NPK (100%) + BF	10.12	13.46	18.15	23.64
T5: VC + NPK (75%) + BF	10.80	14.12	16.86	21.32
T6: VC + NPK (50%) + BF	8.32	10.85	14.12	18.35
T7: MC + NPK (100%) + BF	9.64	12.84	15.64	20.74
T8: MC + NPK (75%) + BF	10.24	13.17	16.28	19.36
T9: MC + NPK (50%) + BF	8.12	11.28	13.16	16.45
T10: NC + NPK (100%) + BF	10.56	12.56	16.84	22.13
T11: NC + NPK (75%) + BF	9.86	12.42	15.17	20.36
T12: NC + NPK (50%) + BF	8.34	10.32	14.32	19.14
T13: NPK (100%)	8.90	12.25	15.26	18.36
S.Em. (±)	0.139	0.184	0.226	0.281
C.D. (P=0.05)	0.408	0.541	0.664	0.825

Table 4: Influence of different levels of organic, inorganic and biofertilizers on quality parameters of turmeric.

Treatment	Dry recovery (%)	Oleoresin (%)	Curcumin (%)
T1: C + NPK (100%) + BF	27.84	13.28	5.76
T2: C + NPK (75%) + BF	21.62	12.62	5.32
T3: C + NPK (50%) + BF	21.76	12.24	5.06
T4: VC + NPK (100%) + BF	23.56	13.48	6.16
T5: VC + NPK (75%) + BF	22.39	12.80	5.94
T6: VC + NPK (50%) + BF	22.60	11.62	5.72
T7: MC + NPK (100%) + BF	23.86	13.06	6.28
T8: MC + NPK (75%) + BF	22.34	12.38	5.86
T9: MC + NPK (50%) + BF	21.92	12.72	6.04
T10: NC + NPK (100%) + BF	24.62	13.76	6.34
T11: NC + NPK (75%) + BF	24.28	13.34	6.18
T12: NC + NPK (50%) + BF	23.64	12.56	5.98
T13: NPK (100%)	22.84	11.84	5.82
S.Em. (±)	0.324	0.179	0.083
C.D. (P=0.05)	0.952	0.524	0.245

C= Compost, VC= Vermicompost, MC= Mustardcake, NC= Neemcake BF= Biofertilizer (*Azotobacter chroococcum, Bacillus polymyxa and Frateuria aurantia*).

recovery decreased with the decreasing level of inorganic (100 to 50%).

Oleoresin content

Oleoresin content increased from 11.62% to 13.76% (Table 4). The results showed that combining bio-inoculants and organic manure with T13: 100% NPK (inorganic) enhanced oleoresin content compared to 75% and 50% inorganic NPK. It also exhibited that the maximum oleoresin content (13.76%) was observed in the treatment combination T10: Neem Cake + NPK (100%) + BF followed by T4: Vermicompost + NPK (100%) + BF (13.48%) as compared to minimum oleoresin (11.62%) in T6: Vermicompost + NPK (50%) + BF combination. Except for the Mustard Cake combination, the decreasing trend in the oleoresin content was noticed with decreasing the quantity of inorganic NPK *i.e*., 100% to 50%. The oleoresin content is 11.84% under T13: NPK (100%) treatment.

Curcumin content

Curcumin content increased from 5.06% to 6.34% (Table 4). The results showed that the concomitant application of bio-inoculants and 100% NPK boosted the curcumin content (inorganic). The maximum curcumin content (6.34%) was observed in the treatment combination T10: Neem Cake + NPK (100%) + BF followed by T7: Mustard Cake + NPK (100%) + BF (6.28%) as compared to minimum curcumin (5.06%) in T3: Compost + NPK (50%) + BF combination. In Compost, Vermicompost and Neem Cake combination, the curcumin content decreased with decreasing levels of inorganic. Similar findings were examined and presented by (Kumar *et al*., 2018; Tripathi *et al*., 2021 and Jabborova *et al*., 2021).

By raising the biofertilizer applications enhanced the quality of the root system and the rhizome's oleoresin content. *Azotobacter*, in addition to their capacity to fix nitrogen, also create anti-fungal antibodies that prevent the growth of several harmful fungi in the root area, hence enhancing root development and crop nutrition, which in turn enhances the final product's quality (Subba Rao, 2001). Additionally, they create growth-regulating compounds like phytohormones, vitamins and other chemicals that balance the crop's nutrition and enhance the quality of the plant. Like this, *Phosphatica* enhances crop quality by increasing physiological activities through improved P nutrition and aids in the solubilization of soil-accessible and local P through the creation of organic acids. The increased availability of nutrients in the root zone due to increased microbial activity in the biofertilizer treatment's good influence on rhizome quality may improve crop nutrition (Bijaya and Ado, 2005). When compared to NPK (100%) inorganic fertilizer, it was discovered that the quality parameters-dry recovery, oleoresin and curcumin content-were raised by the all-organic and bio-fertilizer combination. These results agree with past research by Mridhula and Jayachandran (2001), as well as Velmurugan *et al.* (2008). All organic and biofertilizer combinations boost quality aspects because they include micro- and macronutrients and enhance the physical, chemical and biological characteristics of the soil, which encourage the proliferation of roots and promote nutrient uptake by the crop. In addition to increasing P availability, PSB is also known to produce vitamins, amino acids and growth-promoting compounds including IAA and GA, which aid in improved plant development. This could have caused the PSB-inoculated plots in the current investigation to expand more rapidly. Increased levels of nutrients like nitrogen, phosphorus and potassium in plants result in an increase in the production of plant metabolites that assist to construct the tissues of plants, which can be linked to an increase in growth characteristics because of increased fertilizer application (Chanchan *et al*., 2017).

CONCLUSION

Integrated nutrient management with multiple sources of nutrients amplifies plant growth. Better plant growth of turmeric produces and accumulates more amount of photosynthates in the producing parts like rhizome. These accumulated photosynthates will improve the qualitative characteristics of the rhizome. Treatments with vermicompost + NPK (100%) + Biofertilizers show the highest results based on growth and quality parameters. But we can reduce the use of chemical fertilizers by 25-30 % of organic sources, which will prevent the soil from pollution and maintain the soil health and productivity.

Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

AOAC, (1975). Association of Official Analytical Chemists, Washington, USA.

Akamine, H., Hossain, M.A., Ishimine, Y., Yogi, K., Hokama, K., Iraha, Y., Aniya, Y. (2007). Effects of application of N, P and K alone or in combination on growth, yield and curcumin content of turmeric (*Curcuma longa* L.). Plant Production Science. 10: 151-154.

Alori, E.T., Glick, B.R., Babalola, O.O. (2017). Microbial phosphorus solubilization and its potential for use in sustainable agriculture. Frontiers in Microbiology. 8: 971. doi: https://doi.org/10.3389/fmicb.2017.00971.

Amala, D., Prabhakar, B.N., Padma, M., Triveni, S. (2019). Effect of integrated nutrient management on yield, yield attributing characters and economics of turmeric (*Curcuma longa* L.) var. IISR Pragathi. The Journal of Research PJTSAU. 47(3): 51-54.

Anuradha, U.B., Patil, S.S., Kurubar, A.R., Ramesh, G., Hiregoudar, S. (2018). Effect of Integrated Nutrient Management on Growth and Yield of Turmeric (*Curcuma longa* L.) cv. Salem. International Journal of Current Microbiology and Applied Sciences. 7(1): 3196-203.

Bagchi, A. (2012). Extraction of curcumin. IOSR Journal of Environmental Science, Toxicology and Food Technology. 1(3): 1-16.

Bijaya, A. K. and Ado, L. (2005). Effect of fertilizers and biofertilizer on physiological parameters of multiplier onion (*Allium cepa* var. aggregatum). Indian J. Agril. Sci. 75: 352-54.

Chanchan, M., Ghosh, D.K., Hore, J.K. and Anitha, M. (2017). Studies on response of manures and biofertilizers on growth and yield of turmeric (*Curcuma longa* L.). J. Crop Weed. 13(2): 112-15.

Dikey, H.H., Bhale, V.M., Kale, V.S., Wankhade, R.S. (2019). Effect of land configuration, irrigation level and nutrient management on growth, yield and economics of turmeric (*Curcuma longa* L.). International Journal of Current Microbiology and Applied Sciences. 8(9): 2306-2322. doi: https://doi.org/10.20546/ijcmas.2019.809.266.

Fisher, R.A. and Yates, F. (1979). Statistical Tables for Biological Agricultural and Medical Research. Oliver and Boyd London. pp. 46-63.

Jabborova, D., Sulaymanov, K., Sayyed, R.Z., Alotaibi, S.H., Enakiev, Y., Azimov, A., Jabbarov, Z., Ansari, M.J., Fahad, S., Danish, S. (2021). Mineral fertilizers improves the quality of turmeric and soil. Sustainability. 13: 9437. https://doi.org/10.3390/su13169437.

Khan, H., Akbar, W.A., Shah, Z., Rahim, H.U., Taj, A., Alatalo, J.M. (2022). Coupling phosphate-solubilizing bacteria (PSB) with inorganic phosphorus fertilizer improves mungbean (*Vigna radiata*) phosphorus acquisition, nitrogen fixation and yield in alkaline-calcareous soil. Heliyon. 9:8(3): e09081. doi: 10.1016/j.heliyon.2022.e09081.

Khawale, V.G. and Chinchmalatpure, U.R. (2023). Adoption of turmeric cultivation practices by turmeric growers. Bhartiya Krishi Anusandhan Patrika. 38(4): 417-419. doi: 10.18805/BKAP651.

Kumar, A., Tewari, S., Singh, I., Pandey, R., Kumar, D. and Anand, R. (2018). Effect of nutrient sources on growth, yield and quality of turmeric under harad (*Terminalia chebula*) based agroforestry system. Indian Journal of Agroforestry. 20(2): 1-6.

Lohar, R.R. and Hase, C.P. (2021). Sustainable agricultural practices for improving growth, yield and quality of turmeric (*Curcuma longa* L.). Annals of Plant and Soil Research. 23(1): 48-53.

Moulick, S.P., Jahan, F., Islam, M.B., Al Bashera, M., Hasan, M.S., Islam, M.J., Bhuiyan, M.N.H. (2023). Nutritional characteristics and antiradical activity of turmeric (*Curcuma longa* L.), beetroot (*Beta vulgaris* L.) and carrot (*Daucus carota* L.) grown in Bangladesh. Heliyon. 9(11). doi: 10.1016/j.heliyon.2023.e21495.

Mridhula, K.R. and Jayachandran, B.K. (2001). Quality of mango ginger as influenced by mineral nutrition. J. Trop. Ag. 39(2): 182-83.

Ojikpong, T.O. and Undie, U.L. (2019). Growth, yield and quality of turmeric (*Curcuma longa* Linn.) As influenced by nitrogen fertilizer rates and nitrogen split application in Obubra, South-South Nigeria. European Journal of Agriculture and Forestry Research. 7(4): 1-13.

Panse, V.G. and Sukhatme, P.V. (1985). Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi.

Rao, M.R., Reddy, K.R.C., Subbarayudu, M. (1975). Promising turmeric types of Andhra Pradesh. Indian Spices. 12: 2-5.

Roy, S.S. and Hore, J.K. (2009). Biofertilizers and inorganic fertilizers on growth and yield of turmeric grown as intercrop in arecanut plantation. Indian Journal of Horticulture. 37: 56-59.

Sanwal, S.K., Laxminarayana, K., Yadav, R.K., Rai, N., Yadav, D.S., Bhuyan, M. (2007). Effect of organic manures on soil fertility, growth, physiology, yield and quality of turmeric. Indian Journal of Horticulture. 64(4): 444-449.

Singh, V. (2020). Effect of integrated nutrient management on yield and uptake of nutrients in pearl millet (*Pennisetun glaucum*)-mustard (*Brassica juncea*) crop sequence. Annals of Plant and Soil Research. 22(4): 349-353. https://doi.org/10.47815/apsr.2020.10003.

Sirisidthi, K., Kosai, P., Jiraungkoorskul, K., Jiraungkoorskul, W. (2016). Antithrombotic activity of turmeric (*Curcuma longa*): A review. Indian Journal of Agricultural Research. 50(2): 101-106.

Subba Rao, N.S. (2001). An Appraisal of Biofertilizers in India. In: The Biotechnology of Biofertilizers, [Kannaiyan, S. (Ed.)], Narosa Publishing House, New Delhi, pp: 45-105.

Tripathi, S.K., Sharma, B., Kumari, P., Deb, P., Ray, R., Denis, A.F. (2021). Evaluation of productivity, quality and economics of turmeric under different moisture regime and integrated nutrient management at eastern indo-gangetic plains, India. Agricultural Research. 10: 601-612. https://doi.org/10.1007/s40003-020-00524-w.

Velmurugan, M., Chezhiyan, N. and Jawaharlal, M. (2008). Influence of organic manures and inorganic fertilizers on cured rhizome yield and quality of turmeric (*Curcuma longa* L.) cv. BSR-2. Int. J. Agric. Sci. 4(1): 142-45.

Yadav, R.K., Yadav, D.S., Rai, N. (2004). Commercial prospects of ginger cultivation in North-Eastern region. Himalayan Eco. 12: 1-10.