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Effect of organic and inorganic nitrogen management on quality attributes of turmeric (*Curcuma longa* L.)

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Abstract

A field experiment was conducted during the kharif seasons of 2021-22 and 2022-23 at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, to evaluate the effect of integrated nitrogen management and split application of nitrogen with different timings on the growth, yield and quality of turmeric (*Curcuma longa* L.) Cv. PDKV Waigaon. The experiment was laid out in a Factorial Randomized Block Design with seven nitrogen management treatments and three nitrogen application timings, replicated three times. The nitrogen management treatments comprised different proportions of nitrogen supplied through vermicompost, neem cake and inorganic fertilizer. Among the nitrogen management treatments, application of 90% recommended dose of nitrogen (RDN) through neem cake + 10% RDN through inorganic fertilizer (N₂) recorded superior performance and was statistically at par with 90% RDN through vermicompost + 10% RDN through inorganic fertilizer (N₁). Among the application timings, four equal splits of nitrogen at 30, 60, 90 and 120 days after planting (DAP) (D₁) resulted in significantly higher quality attributes compared with delayed application schedules. The N₂ treatment recorded the maximum dry recovery (19.46%), curcumin content (5.76%), oleoresin content (7.91%) and essential oil content in leaves (7.29%). Similarly, D₁ recorded the maximum dry recovery (18.31%), curcumin content (5.17%), oleoresin content (6.79%) and essential oil content in leaves (6.43%). The interaction effect of nitrogen management and application timing was significant only for essential oil content, with the maximum value (7.38%) recorded under N₂D₁, i.e., 90% RDN through neem cake + 10% RDN through inorganic fertilizer applied in four equal splits at 30, 60, 90 and 120 DAP. The findings demonstrate that neem cake-based integrated nitrogen management combined with timely split application of nitrogen can effectively improve the quality attributes of turmeric and enhance nitrogen-use efficiency under the experimental conditions.

Keywords: Neem cake, vermicompost, time of application

Introduction

India is the major producer, consumer, and exporter of turmeric in the world. It is found throughout south and south-east Asia with a few species extending to Australia, China, and South-Pacific. The highest diversity is concentrated in India and Thailand, with at least 40 species in each area, followed by Burma, Bangladesh, Indonesia, and Vietnam. Indian turmeric is the best in the world market because of its high curcumin content. India accounts for about 80 percent of world turmeric production and 60 percent of world exports. Other major producers are Pakistan, China, Haiti, Jamaica, Peru, Taiwan, and Thailand. Asian countries consume much of their turmeric production.

Turmeric (*Curcuma longa* L.) is an important spice crop in India and plays vital role in national economy. *Curcuma longa* L. Syn. *C. domestica*, commonly known as turmeric, in Sanskrit 'Haridra' in Hindi 'Haldi' is one of the most important spices crops. The genus *Curcuma* is a triploid with a somatic chromosome number of 63 (2n = 3x = 63) belonging to the family Zingiberaceae considered to have originated in the Indo-Malyan region (Purseglove, 1968) [18] which comprises 40 genera and 400 tropical spices in the old world. Out of these three genera viz., *Curcuma* (Turmeric), have commercial importance as spices. It is a perennial herbaceous plant with tall leafy branches bearing up to twelve (12) leaves that can grow up to two meters in height. The leaves are oblong or lanceolate, up to 1 m long, and dark green from above and pale green from below.

The sheath and petiole are about the same length as the blade. *Curcuma longa* has a sterile, pale yellow and reddish bloom, with a green and purplish flowering bract. (Fuloria and Mehta 2022, Jyotirmayee Mahalik 2022) [7, 9]. *Curcuma longa* has a rhizome that grows underground. The plant is mostly grown for its rhizome, which has tough segmented skins. (Prasad and Aggarwal 2011) [16]. The rhizome can grow to be 2.5-7.0 cm long and 2.5 cm in diameter. The rhizome has a pleasant aroma and a bitter taste. *Curcuma longa* plants are grown in the tropics and subtropics at temperatures between 20 and 30 degrees Celsius, with adequate rainfall. (Karłowicz and Bodalska 2017) [12].

In India during 2023-24, about 3.50 lakh ha⁻¹ was cultivated area under turmeric Maharashtra occupies 89273 thousand ha⁻¹ area was covered under turmeric. (Anonymous 2024) [1]. Turmeric is a tropical crop and needs a warm and humid climate with an optimum temperature of 20 °C to 30 °C for normal growth and satisfactory production. It thrives best on sandy, loamy, and alluvial, loose, friable, and fertile soil rich in organic matter status and having a pH ranged between 5 to 7.5. Alkaline soil is not suitable for its cultivation. The crop cannot withstand water logging. It grows at all places ranging from sea level to an attitude at 1200 meter above the mean sea level. As a rainfed crop, turmeric needs a well distributed annual rainfall of 250 to 400 mm for successful production.

Turmeric (*Curcuma longa* L.) rhizomes contain 6.3% protein, 5.1% fat, 3.5% minerals, 69.4% carbohydrates and 13.1% moisture. The rhizomes are also rich in volatile oils, mainly zingiberene and sesquiterpenes, which contribute to their characteristic aroma (Kapoor, 1990) [11]. Curcumin (diferuloylmethane), present at about 3-4%, is the principal pigment responsible for the characteristic yellow colour of turmeric. The curcuminoid fraction mainly comprises curcumin I (94%), curcumin II (6%) and curcumin III (0.3%) (Ruby *et al.*, 1995) [20].

Although curcumin has many health-promoting effects but still hard to find a place in mainstream drug application due to its poor bioavailability (Prasad *et al.*, 2014) [17]; therefore, to get the health-promoting effect one must need to have a high dose of curcumin to exert the positive and health-promoting effects (Vareed *et al.*, 2008) [25]. Curcumin is an oil-soluble pigment, sparingly soluble in water at acidic and neutral pH, and soluble in alkali condition.

Integrated Nitrogen Management (INM) represents a scientifically sound and sustainable approach to nutrient management, aimed at optimizing nitrogen-use efficiency, enhancing crop productivity and maintaining long-term soil health while minimizing adverse environmental impacts. Nitrogen is a key macronutrient that regulates several fundamental physiological and biochemical processes in plants, including cell division and elongation, chlorophyll synthesis, photosynthetic activity, protein and enzyme synthesis, and assimilate partitioning, thereby exerting a direct influence on vegetative growth, biomass accumulation, yield and quality.

However, excessive and indiscriminate dependence on synthetic nitrogen fertilizers can result in substantial nitrogen losses through volatilization, leaching and denitrification, leading to declining nutrient-use efficiency, soil nutrient imbalance, deterioration of soil biological activity, groundwater contamination and increased emissions of environmentally important greenhouse gases. These concerns highlight the need for nutrient management

strategies that synchronize nitrogen availability with crop demand throughout the growing season.

Integrated Nitrogen Management addresses these challenges through the judicious integration of inorganic nitrogen fertilizers with organic nutrient sources such as neem cake and vermicompost. Organic amendments provide nutrients through gradual mineralization while improving soil organic matter, nutrient retention, microbial activity, soil structure and water-holding capacity. Neem cake, in particular, can contribute to a more sustained nitrogen supply, whereas vermicompost enhances the biological and physical environment of the rhizosphere. The complementary use of organic and inorganic nitrogen sources therefore facilitates a more continuous and balanced nutrient supply, improves nitrogen-use efficiency and promotes efficient nutrient uptake by the crop.

In long-duration crops such as turmeric, where nutrient requirements extend over an extended period and substantial biomass and rhizome development occur progressively, synchronization of nitrogen supply with critical crop growth stages is particularly important. Appropriate split application of nitrogen can reduce nutrient losses and ensure adequate nitrogen availability during periods of active vegetative growth and rhizome development. Consequently, INM serves not only as a strategy for enhancing crop growth, yield and quality but also as an important component of climate-resilient and resource-efficient agriculture. The integration of organic and inorganic nutrient sources, together with appropriate timing of fertilizer application, offers considerable potential for achieving higher productivity, improved quality, enhanced soil fertility and greater environmental sustainability in turmeric production.

Materials and Methods

The experiment was conducted during the *Kharif* seasons of 2021-22 and 2022-23 at the Chili and Vegetable Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. The experimental site is located in the subtropical region at 22.42° N latitude and 77.02° E longitude, with an altitude of 307.42 m above mean sea level. The experimental soil was very loose, uniform in texture and structure, and well drained. The soil was slightly alkaline in reaction, with a pH of 8.23, and contained 191.37 kg ha⁻¹ available nitrogen, 10.56 kg ha⁻¹ available phosphorus, and 371.43 kg ha⁻¹ available potassium. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising seven nitrogen management treatments and three nitrogen application timings, resulting in 21 treatment combinations. Neem cake and vermicompost were applied at the time of planting, while phosphorus (P₂O₅) and potassium (K₂O) were applied uniformly to all treatments. The crop was planted during the Kharif season on ridges and furrows at a spacing of 60 × 30 cm. The recommended package of practices was followed throughout the crop period. The high-curcumin turmeric cultivar 'PDKV Waigaon', developed by Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, was used for the experiment. Soil pH was determined using a glass electrode pH meter as described by Jackson (1973) [8]. The data recorded for various growth, yield, and quality parameters were statistically analysed according to the procedure suggested by Panse and Sukhatme (1985) [15].

Results and Discussion

Quality parameters (dry recovery (%), curcumin content, oleoresin percentage and essential oil content in leaves)

Effect of nitrogen management on dry recovery (%), curcumin content, oleoresin percentage and essential oil content in leaves (N)

The data presented table 1 (a) revealed that, significantly the maximum (19.46, 5.76, 7.91 and 7.29%, respectively) dry recovery, curcumin content, oleoresin percentage and essential oil content in leaves were recorded in turmeric crop due to the application of 90% RDN through neem cake along with 10% RDN (N_2) it was statically at par in the treatment (N_1). Whereas, the significantly the minimum (16.11, 4.14, 5.38 and 4.80%, respectively) dry recovery, curcumin content, oleoresin percentage and essential oil content in leaves were recorded in turmeric with the application of 100% RDN through inorganic source (N_7). Among the nitrogen management treatments, the recommended dose of nitrogen (RDN) remained comparable. The higher dry recovery, curcumin, oleoresin and essential oil contents may be attributed to the application of organic manures, particularly neem cake and vermicompost, which provide a sustained supply of nutrients and improve overall plant growth and physiological activity. The humic substances and phenolic compounds present in these organic manures may enhance hormonal activity, particularly by prolonging IAA activity, thereby promoting cell division, assimilate accumulation and dry matter production. Since turmeric rhizomes are modified underground stems and the major storage sites for curcumin, oleoresin and essential oils, improved assimilate accumulation and metabolic activity may ultimately enhance these quality attributes. The results are in conformity with Sanwal *et al.* (2007) ^[21], Chamory *et al.* (2015) ^[5] Bondre *et al.*, (2019) ^[3], Kadam and Kamble (2020) ^[10], Darekar (2022) ^[6] Bondre (2019) ^[4], Anuradha *et al.* (2022) ^[2], in turmeric and Sarkar *et al.*, (2022) ^[22].in ginger.

Effect of days to split application of nitrogen on dry recovery (%), curcumin content, oleoresin percentage and essential oil content in leaves (D)

The growth parameters were significantly influenced by the different days to split application of nitrogen. significantly the maximum (18.31, 5.17, 6.79 and 6.43%, respectively) dry recovery (%), curcumin content, oleoresin percentage and essential oil content of leaves in turmeric were obtained when nitrogen applied earlier than rest of the treatment with four equal splits at interval of 30, 60, 90 and 120 (D_1) days after planting (DAP). Whereas, significantly the minimum (17.59, 4.98, 6.63 and 6.09%, respectively) dry recovery (%), curcumin content, oleoresin percentage and essential oil content of leaves in turmeric were produced, when nitrogen was applied 20 days than rest of the treatment with four equal splits at interval of 50, 80, 110 and 140 (D_3) days after planting (DAP) in turmeric crop. Adequate and timely nitrogen application at 30, 60, 90 and 120 DAP may enhance nutrient uptake, vegetative growth, chlorophyll formation and photosynthetic efficiency. This improved physiological activity increases the availability of carbon skeletons and energy for dry matter accumulation, thereby resulting in greater dry recovery of processed turmeric. Higher nitrogen availability may also stimulate hormonal activity and promote the synthesis and accumulation of curcumin in turmeric rhizomes. Furthermore, enhanced photosynthetic activity provides substrates required for the synthesis of secondary metabolites, including terpenoids, which are major constituents of essential oils. Thus, adequate and timely nitrogen supply may contribute to higher dry recovery, curcumin and essential oil contents in turmeric rhizomes. The present findings are in agreement with the results reported by Singh *et al.*, (1992) ^[24], Padmapriya (2004) ^[14] and Rao *et al.* (2005) ^[19] Sanwal *et al.*, (2007) ^[21], Ojikpong and Undie (2019) ^[13] in turmeric and Shadap *et al.*, (2018) ^[23] in ginger.

Table 1: (a) Effect of nitrogen management and days to split application of nitrogen on quality parameters in turmeric (pooled mean)

Treatments	Dry recovery (%)	Curcumin content (%)	Oleoresin content (%)	Essential oil content in leaves (%)
	Pooled	Pooled	Pooled	Pooled
Nitrogen management (N)				
N ₁ -90% RDN through VC + 10% RDN	19.13	5.52	7.32	7.10
N ₂ -90% RDN through NC + 10% RDN	19.46	5.76	7.91	7.29
N ₃ -75%RDN through VC + 25% RDN	17.49	5.16	6.79	6.58
N ₄ -75%RDN through NC + 25% RDN	18.31	5.36	6.93	6.91
N ₅ -50%RDN through VC + 50% RDN	17.22	4.62	6.16	5.22
N ₆ -50%RDN through NC + 50% RDN	18.08	4.94	6.51	5.93
N ₇ -100% RDF through inorganic source	16.11	4.14	5.38	4.80
'F' test	Sig.	Sig.	Sig.	Sig.
SE(m)±	0.08	0.05	0.09	0.04
CD at 5%	0.23	0.14	0.25	0.11
Days to split application of nitrogen (D)				
D ₁ (at 30, 60, 90 and 120 DAP)	18.31	5.17	6.79	6.43
D ₂ (at 40,70,100 and 130 DAP)	18.02	5.06	6.71	6.27
D ₃ (at 50, 80, 110 and 140 DAP)	17.59	4.98	6.63	6.09
'F' test	Sig.	Sig.	Sig.	Sig.
SE(m)±	0.05	0.03	0.06	0.03
CD at 5%	0.14	0.08	0.18	0.09
Interaction (N X D)				
'F' test	NS	NS	NS	Sig.
SE(m)±	0.13	0.08	0.16	0.08
CD at 5%	-	-	-	0.23

Table 1: (b) Interaction effect of nitrogen management and days to application of nitrogen on qualitative characters in turmeric (pooled mean)

Treatments	Dry recovery (%)	Curcumin content (%)	Oleoresin content (%)	Essential oil content in leaves (%)
	pooled	pooled	pooled	pooled
N ₁ D ₁	19.97	5.63	7.39	7.15
N ₁ D ₂	19.32	5.51	7.31	7.10
N ₁ D ₃	18.12	5.43	7.27	7.05
N ₂ D ₁	20.04	5.87	8.02	7.38
N ₂ D ₂	19.44	5.77	7.90	7.27
N ₂ D ₃	18.90	5.64	7.80	7.22
N ₃ D ₁	17.87	5.27	6.86	6.68
N ₃ D ₂	17.53	5.14	6.78	6.58
N ₃ D ₃	17.07	5.06	6.73	6.49
N ₄ D ₁	18.53	5.44	6.97	7.49
N ₄ D ₂	18.40	5.37	6.93	6.96
N ₄ D ₃	18.02	5.29	6.91	6.30
N ₅ D ₁	17.31	4.71	6.22	5.32
N ₅ D ₂	17.20	4.63	6.16	5.26
N ₅ D ₃	17.15	4.51	6.10	5.09
N ₆ D ₁	18.25	5.03	6.58	6.10
N ₆ D ₂	18.13	4.91	6.53	5.93
N ₆ D ₃	17.88	4.87	6.44	5.78
N ₇ D ₁	16.23	4.24	5.55	4.91
N ₇ D ₂	16.12	4.12	5.37	4.79
N ₇ D ₃	16.00	4.05	5.22	4.73
'F' test	NS	NS	NS	Sig.
SE (m)	0.13	0.08	0.16	0.08
CD at 5%	-	-	-	0.23

Interaction effect of nitrogen management and days to application of nitrogen on qualitative characters in turmeric (N_xD)

The data presented in Table 1b revealed that the growth parameters of turmeric were significantly influenced by different levels of nitrogen management and days to split application of nitrogen. The interaction effect between nitrogen management and days to split application of nitrogen on dry recovery (%), curcumin content, oleoresin percentage were found to be non-significant in turmeric crop. Whereas, significantly the maximum (7.38%, respectively) essential oil content in leaves was recorded by the treatment combination N₂D₁ i.e. 90% RDN through neem cake along with 10% RDN and nitrogen was applied earlier than rest of the treatments with four equal split at an interval of 30, 60, 90 and 120 days after planting. However, significantly the minimum (4.73%) essential oil content in leaves was observed with the treatment combination N₇D₃ i.e. 100% RDN through inorganic source and when nitrogen was applied 20 days late than rest of the treatments with four equal split at 50, 80, 110 and 140 days after planting. The treatment combination N₂D₁ recorded the maximum essential oil content, clearly indicating that the application of the recommended dose of nitrogen through organic sources, particularly neem cake or vermicompost, coupled with timely split application of nitrogen at 30, 60, 90 and 120 DAP, provided a continuous and adequate supply of nitrogen throughout the crop growth period. This improved nitrogen availability may have stimulated hormonal activities, enhanced vegetative growth and physiological processes, and consequently promoted the synthesis and accumulation of essential oils in turmeric rhizomes. These findings are in conformity with results of Sanwal *et al.*, (2007) ^[21] in turmeric.

Conclusion

The present investigation clearly demonstrated that integrated nitrogen management and timely split application of nitrogen play a significant role in improving the growth, yield-contributing characters and quality attributes of turmeric cv. PDKV Waigaon. Among the nitrogen management treatments, application of 90% recommended dose of nitrogen (RDN) through neem cake along with 10% RDN through inorganic fertilizer (N₂) consistently recorded superior performance for dry recovery, curcumin content, oleoresin content and essential oil content, and was statistically comparable with 90% RDN through vermicompost + 10% RDN through inorganic fertilizer (N₁). Among the nitrogen application schedules, four equal splits at 30, 60, 90 and 120 days after planting (D₁) proved most effective, resulting in higher dry recovery, curcumin content, oleoresin content and essential oil content compared with the delayed application schedules. The interaction of nitrogen management and application timing further indicated the superiority of N₂D₁, comprising 90% RDN through neem cake + 10% RDN through inorganic fertilizer with nitrogen application at 30, 60, 90 and 120 DAP. This treatment recorded the highest essential oil content (7.38%) and also exhibited superior values for dry recovery (20.04%), curcumin content (5.87%) and oleoresin content (8.02%), although the interaction effect for these three parameters was statistically non-significant.

Overall, the findings indicate that integrated use of neem cake with a small proportion of inorganic nitrogen, combined with timely split application at 30, 60, 90 and 120 DAP, is an effective nutrient management strategy for improving the quality of turmeric cv. PDKV Waigaon. This approach can provide a sustained nitrogen supply during critical crop growth stages and enhance nutrient availability,

physiological activity and assimilate accumulation, thereby contributing to improved turmeric quality and more sustainable nitrogen management.

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