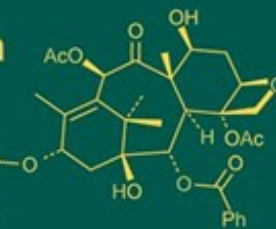
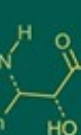
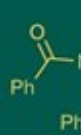


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
Indexing: Embase
IJABR 2026; 10(9S): 1851-1862
www.biochemjournal.com
Received: 06-07-2026
Accepted: 08-08-2026
Published: 21-09-2026

Chaitra Lamani

PG Scholar, Department of
Floriculture and Landscaping,
College of Horticulture, Bidar,
University of Horticultural
Sciences, Bagalkot, Karnataka,
India.

Anand G Patil

Professor and ICAR Nodal
Officer, University of
Horticultural Sciences, Bagalkot,
Karnataka, India

Spoorti Tirki

PhD Scholar, Department of
Floriculture and Landscaping,
College of Horticulture,
Bagalkot, University of
Horticultural Sciences, Bagalkot,
Karnataka, India.

Harshad Padasalagi

PG Scholar, Department of
Floriculture and Landscaping,
College of Horticulture,
Bagalkot, University of
Horticultural Sciences, Bagalkot,
Karnataka, India.

Aishwarya S Jeevanagi

PG Scholar, Department of
Floriculture and Landscaping,
College of Horticulture,
Bagalkot, University of
Horticultural Sciences, Bagalkot,
Karnataka, India.

Rushikesh Bharsakale

Young Professional-I, ICAR-
CCRI, Amravati Road, Nagpur,
Maharashtra, India-400330.

Corresponding Author:**Anand G Patil**

Professor and ICAR Nodal
Officer, University of
Horticultural Sciences,
Bagalkot, Karnataka, India

Site-specific nutrient management based on target yield improves productivity and economic returns of African marigold (*Tagetes erecta* L.)

Chaitra Lamani¹, Anand G Patil², Spoorti Tirki³, Harshad Padasalagi⁴, Aishwarya S Jeevanagi⁵, Rushikesh Bharsakale⁶

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i9S.w.10091>

ABSTRACT

A field experiment was conducted at the College of Horticulture, Bidar, Karnataka, during 2022 to evaluate soil test- and target yield-based nutrient management in African marigold (*Tagetes erecta* L.) cv. Tall Yellow. The experiment was laid out in a randomized complete block design with seven treatments and three replications, comprising target flower yields of 15, 20, 25, 30 and 35 t ha⁻¹, recommended dose of fertilizers (RDF), and farmer practice. The target-yield treatments were formulated based on soil-test values and crop nutrient requirement, enabling nutrient application according to the desired yield level. Significant differences were observed among treatments for vegetative growth, flowering, flower yield, quality attributes, leaf nutrient concentration and economic returns. The 35 t ha⁻¹ target treatment (*T*₅) recorded the highest plant height (67.12 cm), stem girth (3.71 cm), plant spread (42.98 × 40.29 cm), primary branches (21.33 plant⁻¹), secondary branches (32.33 plant⁻¹), leaf area (43.53 cm²) and leaf area index (2.70). It also recorded the highest chlorophyll content at 60 days after transplanting (3.02 mg g⁻¹), dry matter production (283.33 g plant⁻¹), flower number (88.14 plant⁻¹), flower weight (2.28 kg plant⁻¹), flower diameter (6.65 cm), individual flower weight (25.89 g) and shelf life (4.27 days). The maximum flower yield of 35.21 t ha⁻¹ was obtained under *T*₅, closely achieving the targeted yield with only 0.60% deviation. The 15, 20, 25 and 30 t ha⁻¹ target treatments similarly achieved 15.12, 20.27, 25.30 and 30.27 t ha⁻¹, respectively, demonstrating close correspondence between targeted and actual yields. *T*₅ also recorded the highest gross return (₹7,04,200 ha⁻¹) and net return (₹4,91,542 ha⁻¹). Overall, the study demonstrated that soil test and target yield-based nutrient management can effectively synchronize nutrient application with crop requirements and desired productivity, thereby improving growth, yield, flower quality and profitability of African marigold under the experimental conditions. The findings support further multi-season and multi-location validation of the target-yield approach for site-specific nutrient management in marigold. The targeted-yield concept is consistent with earlier marigold research demonstrating the usefulness of soil-test-based fertilizer prescriptions for achieving specified yields.

Keywords: African marigold, *Tagetes erecta* L., Soil test-based nutrient management, Target yield, Site-specific nutrient management, Flower yield, Nutrient management, Fertilizer prescription, Profitability

1. Introduction

Floriculture has emerged as an important component of diversified horticultural production, contributing to farm income, employment generation and value addition through the production of loose flowers, cut flowers, planting material and floral products. Among the commercially cultivated loose flowers, marigold (*Tagetes* spp.) occupies a prominent position because of its wide adaptability, relatively short crop duration, attractive flower colour, ease of cultivation and sustained market demand. African marigold (*Tagetes erecta* L.), in particular, is extensively cultivated for loose flowers used in garlands, religious ceremonies, social functions, decoration and other value-added applications. The crop is also recognized as an important source of natural carotenoids, particularly xanthophylls, which have applications beyond ornamental use. Its broad adaptation and responsiveness to crop management have made nutrient management an important determinant of productivity and flower quality (Ahmad *et al.*, 2011) [3].

Productivity and quality of marigold are strongly influenced by the availability and balance of essential plant nutrients. Nitrogen (N), phosphorus (P) and potassium (K) are particularly important because they regulate vegetative development, root growth, photosynthetic activity, assimilate production, flowering and flower development. Adequate nitrogen promotes canopy development and photosynthetic capacity, phosphorus contributes to root development and reproductive growth, while potassium plays an important role in physio

logical regulation, assimilate transport and maintenance of plant quality. Experimental evidence has demonstrated that NPK fertilization can substantially influence plant height, number of branches, leaf area, chlorophyll content, number of flowers, flower diameter, flower weight, flowering duration and total flower yield in marigold (Ahmad *et al.*, 2011) [3]. However, the response to fertilization is not simply a function of increasing nutrient application; rather, it depends on the interaction between crop nutrient demand, native soil fertility, nutrient recovery and the prevailing environmental conditions.

Conventional fertilizer recommendations are generally developed from multilocation experiments and are often expressed as a common recommended dose for a crop over a relatively broad geographical region. Although such recommendations provide a practical basis for fertilizer application, they may not adequately account for differences in initial soil fertility, nutrient-supplying capacity, crop yield potential and management conditions among individual fields. Consequently, application of a uniform fertilizer dose may result in nutrient under-application in nutrient-deficient soils or unnecessary application in soils with substantial indigenous nutrient supply. Contemporary nutrient-management research therefore increasingly emphasizes the need to integrate soil fertility information with crop nutrient requirements and realistic yield objectives. Recent STCR research has reiterated that blanket recommendations may overlook spatial variability in soil fertility and consequently reduce the efficiency and economic precision of fertilizer use (Krishna Murthy *et al.*, 2024).

The Soil Test Crop Response (STCR) approach provides a quantitative framework for addressing this limitation by establishing relationships among soil-test nutrient status, crop nutrient requirement, fertilizer contribution and targeted crop yield. The targeted-yield concept, originally developed through the work of Truog and subsequently formalized for fertilizer prescription by Ramamoorthy *et al.* (1967), is based on the premise that fertilizer requirements can be calculated according to the nutrient requirement of a crop for a specified yield target while accounting for the contribution of nutrients already available in the soil. Thus, instead of prescribing a single fertilizer dose irrespective of soil fertility, the approach enables fertilizer application to be adjusted according to both the initial soil nutrient status and the desired yield level. The basic fertilizer-prescription framework uses parameters such as nutrient requirement per unit of produce and the relative contributions of soil and applied fertilizer nutrients to crop uptake.

The principal advantage of the targeted-yield approach is therefore its ability to link soil fertility, crop nutrient demand and yield expectation within a single fertilizer-management framework. This is particularly relevant to intensive horticultural crops, where excessive nutrient application may increase production costs without producing a proportional increase in yield, whereas inadequate nutrient supply can restrict vegetative growth and reproductive development. The approach also provides a scientific basis for estimating the amount of fertilizer required to achieve a predetermined yield rather than simply maximizing fertilizer input. Recent long-term investigations in southern India have demonstrated that STCR-based nutrient prescriptions, particularly when integrated with farmyard manure, can improve crop productivity, nutrient uptake, nutrient-use efficiency and soil fertility compared with conventional fertilizer recommendations (Krishna Murthy *et al.*, 2024).

The importance of this approach is especially evident in the context of sustainable nutrient management. Excessive or imbalanced fertilizer use can contribute to declining nutrient-use efficiency, nutrient accumulation or depletion, soil degradation and increased risk of nutrient losses to the environment. Conversely, insufficient nutrient application can limit crop productivity and reduce the economic return from land and other production inputs. The objective of site-specific nutrient management is therefore not necessarily to reduce fertilizer use in absolute terms, but to improve the synchronization between nutrient supply and crop demand. Recent research on STCR-based nutrient management has emphasized that targeted-yield prescriptions can simultaneously improve productivity and nutrient-use efficiency by

considering indigenous soil nutrient supply, crop nutrient removal and the contribution of applied fertilizers and organic nutrient sources (Krishna Murthy *et al.*, 2024).

Evidence supporting the applicability of soil-test-based targeted nutrient management is available for several field and horticultural crops. For example, long-term STCR experiments conducted in southern India across soybean, sunflower, dry chilli, aerobic rice, foxtail millet, okra and kodo millet demonstrated that STCR-based NPK integrated with farmyard manure consistently improved crop productivity relative to conventional recommendations in several cropping situations. The authors attributed these responses to balanced nutrient application based on soil-test values, crop nutrient removal and targeted yield requirements (Krishna Murthy *et al.*, 2024). Similarly, recent work on beetroot demonstrated the development and validation of STCR-integrated plant nutrition models for establishing fertilizer prescriptions under specific soil conditions, further demonstrating the applicability of the targeted-yield concept to horticultural crops.

Marigold provides a particularly suitable crop for evaluating such an approach because of its substantial nutrient requirement and strong response to nutrient availability. Earlier studies have clearly demonstrated that balanced NPK fertilization can modify both vegetative and reproductive performance. Ahmad *et al.* (2011) [3], for instance, reported significant responses of African and French marigold to different NPK combinations, with improvements in plant height, branching, leaf area, chlorophyll concentration, flower number, flower diameter, flower weight and overall flower production under suitable nutrient combinations. Such findings establish the importance of nutrient management but also demonstrate that the optimum nutrient combination for one parameter may not necessarily be identical to that required for another parameter.

More specifically, soil-test-based targeted-yield research has already demonstrated the potential of this methodology in marigold. Durga *et al.* (2017) [18] quantified the nutrient requirement of marigold under Inceptisol conditions at New Delhi and estimated that approximately 0.46 kg N, 0.07 kg P and 0.49 kg K were required to produce one quintal of flowers. The study also developed fertilizer-prescription equations and demonstrated that the inclusion of farmyard manure with NPK could reduce the quantity of fertilizer required for attaining a specified yield target. For a target yield of 30 t ha⁻¹, the integrated approach saved 9.3 kg N, 10.17 kg P₂O₅ and 3.09 kg K₂O ha⁻¹ compared with NPK alone at specified soil-test values, illustrating the potential of targeted nutrient management to improve fertilizer-use efficiency.

Similarly, Tripathi and Srivastava (2019) developed and evaluated STCR-based fertilizer prescriptions for marigold grown on Mollisols of Uttarakhand. Their study demonstrated that fertilizer recommendations based on targeted yield could outperform general recommended doses, and fertilizer-adjustment equations were developed using soil-test values and crop-response data. These findings are particularly important because they establish that the nutrient requirement and fertilizer response of marigold can vary with soil type and production environment, thereby reinforcing the need for location-specific nutrient prescriptions rather than indiscriminate extrapolation of fertilizer recommendations from one agro-ecological region to another.

Recent research continues to support the importance of precision nutrient management in African marigold, although much of the recent literature has focused on integrated nutrient management rather than soil-test-based targeted yield. Studies published during 2025 reported that combinations of mineral fertilizers with organic manures and biofertilizers improved vegetative growth, flowering and flower yield in African marigold. Dhaker *et al.* (2025), for example, reported enhanced growth, flowering and flower yield under integrated nutrient management involving reduced mineral fertilizer rates combined with vermicompost and biofertilizer. Similarly, Sharma *et al.* (2025) observed improvements in nutrient availability, flowering characteristics, flower number, flower size and flower weight under integrated nutrient management involving nitrogen and biofertilizers. These recent findings reinforce the broader principle that nutrient management

should focus on synchronizing nutrient availability with crop demand rather than relying exclusively on high rates of mineral fertilizers. Further, recent studies have expanded the sustainability perspective by examining nutrient management together with other resource-use strategies. For example, research conducted during 2023-2025 evaluated the interaction between deficit irrigation and biologically based nutrient management in African marigold and emphasized the importance of integrating nutrient and water management for sustainable floriculture under resource-limited conditions. Such developments indicate that nutrient-management research in marigold is increasingly moving from simple fertilizer-response experiments towards approaches that consider productivity, resource-use efficiency, soil biological processes and economic viability together.

Despite these advances, important gaps remain in the application of the targeted-yield approach to African marigold under specific soil and agro-climatic conditions. Fertilizer prescriptions developed for *Tagetes patula* or for African marigold under Inceptisols or Mollisols cannot automatically be assumed to be appropriate for *T. erecta* grown under lateritic red soils. Indeed, a recent 2026 study from Odisha further highlighted the need to develop location-specific targeted-yield equations for African marigold and estimated nutrient requirements of approximately 0.55 kg N, 0.09 kg P and 0.56 kg K per quintal of flowers under its experimental conditions. The variation among these estimates and earlier studies illustrates the influence of soil type, cultivar, environment and experimental conditions on crop nutrient requirements.

The present investigation was therefore undertaken to evaluate soil-test- and target-yield-based nutrient management in African marigold (*Tagetes erecta* L.) cv. Tall Yellow under the North Eastern Transitional Zone of Karnataka. The experiment evaluated progressively increasing target-yield levels of 15, 20, 25, 30 and 35 t ha⁻¹ in comparison with the recommended dose of fertilizers and farmers' fertilizer practice. The study was conducted on lateritic red soil at Bidar, and the farmers' practice treatment was established from a survey of 30 marigold-growing farmers in the surrounding area, thereby providing a locally relevant benchmark for comparison. The experimental framework was designed to determine whether nutrient application calculated according to soil fertility and target yield could improve vegetative growth, flowering, flower yield, quality, nutrient uptake and economic returns relative to conventional fertilizer-management practices.

Accordingly, the study was aimed at establishing a practical relationship between soil-test status, target yield and fertilizer requirement for African marigold under the experimental conditions. Particular emphasis was placed on identifying the target yield that could be realistically achieved without disproportionate fertilizer expenditure and on determining whether soil-test-based nutrient management could provide economic advantages over conventional fertilizer recommendations and prevailing farmers' practice. The resulting information is expected to contribute to the development of more precise nutrient-management strategies for African marigold and provide a basis for improving fertilizer-use efficiency, productivity and profitability in commercial loose-flower production.

2. Materials and Methods

2.1 Experimental site and climatic conditions

The field experiment was conducted during 2022 at the College of Horticulture, Floriculture and Landscape Architecture, Bidar, Karnataka, India. The experimental site falls within the North Eastern Transitional Zone of Karnataka (Agro-Climatic Zone I) and is situated at an altitude of approximately 615 m above mean sea level at 17.91° N latitude and 77.51° E longitude. The experimental field was characterized by naturally occurring lateritic red soil.

Meteorological observations were recorded during the crop period from January to July 2022. The maximum temperature ranged from

27.7 to 38.5 °C, while the minimum temperature ranged from 14.3 to 24.1 °C. Relative humidity varied from 33 to 93% during the experimental period.

2.2 Experimental material and design

African marigold (*Tagetes erecta* L.) cv. Tall Yellow was used as the test crop. Seeds of the cultivar were obtained from HyVeg Pvt. Ltd. The experiment was laid out in a randomized complete block design (RCBD) comprising seven nutrient-management treatments with three replications. Each net plot measured 1.8 × 1.8 m, and plants were maintained at a spacing of 40 × 40 cm.

The treatments consisted of five target-yield levels, one recommended dose of fertilizer (RDF), and one farmer-practice treatment:

Treatment	Nutrient-management strategy
T ₁	Soil-test-based nutrient management for a target yield of 15 t ha ⁻¹
T ₂	Soil-test-based nutrient management for a target yield of 20 t ha ⁻¹
T ₃	Soil-test-based nutrient management for a target yield of 25 t ha ⁻¹
T ₄	Soil-test-based nutrient management for a target yield of 30 t ha ⁻¹
T ₅	Soil-test-based nutrient management for a target yield of 35 t ha ⁻¹
T ₆	Recommended dose of fertilizer (RDF)
T ₇	Farmer's practice

2.3 Survey of farmers and estimation of farmer-practice nutrient application

A preliminary survey was conducted among 30 marigold-growing farmers in villages surrounding the experimental site. Information on fertilizer-use practices was collected, and the average fertilizer quantities used by the surveyed farmers were used to formulate the farmer-practice treatment (T₇).

2.4 Soil sampling and characterization

Before establishment of the experiment, soil samples were collected from the experimental plots and characterized for physical and chemical properties. The soil was classified as lateritic red soil. The physical composition comprised 36.03% sand, 39.32% silt and 30.13% clay.

For chemical analysis, composite soil samples were air-dried, gently ground and passed through a 2-mm sieve. A finer fraction was prepared by passing soil through a 0.2-mm sieve for organic carbon determination. Soil pH was measured potentiometrically, while electrical conductivity (EC) was determined using a conductivity meter. Organic carbon was estimated by the Walkley and Black method.

Available nitrogen was estimated by the alkaline permanganate method of Subbiah and Asija (1956), available phosphorus by the colorimetric method of Olsen *et al.* (1954/1957) and available potassium using the flame-photometric procedure described by Stanford and English (1963). The available nutrient concentrations were expressed in kg ha⁻¹.

The soil-test classification used for fertilizer adjustment was:

Nutrient	Low	Medium	High
Available N (kg ha ⁻¹)	< 280	280–560	> 560
Available P ₂ O ₅ (kg ha ⁻¹)	< 10	10–25	> 25
Available K ₂ O (kg ha ⁻¹)	< 120	120–280	> 280

According to the experimental records, the soil was categorized as low in available N, high in available P₂O₅ and medium in available K₂O.

2.5 Calculation of nutrient requirements and fertilizer doses

Target-yield nutrient management was based on the nutrient requirement of marigold and the initial soil-test status. The nutrient requirement adopted for production of one tonne of marigold flowers was 4.60 kg N, 0.70 kg P₂O₅ and 4.90 kg K₂O. This value was derived from the targeted-yield work of Durga *et al.* (2017) [18], who quantified nutrient requirement and developed soil-test-based fertilizer prescriptions for marigold.

For each target yield, the total nutrient requirement was first calculated from the target yield and the corresponding nutrient requirement per tonne. For example, a target yield of 15 t ha⁻¹ required 69.0 kg N, 10.5 kg P₂O₅ and 73.5 kg K₂O before adjustment for soil-test status.

The soil-test categories were subsequently used to adjust the nutrient requirement. For nutrients classified as low, 30% more than the calculated nutrient removal was applied; for nutrients classified as medium, the calculated removal quantity was applied; and for nutrients classified as high, 30% less than the calculated removal quantity was applied. Thus, the low-N status resulted in a 30% upward adjustment of N, high P₂O₅ resulted in a 30% downward adjustment of P₂O₅, and medium K₂O resulted in application equivalent to the calculated K₂O removal.

This approach follows the general principle of soil-test- and target-yield-based nutrient management, in which fertilizer requirements are adjusted according to crop nutrient requirement and the nutrient-supplying capacity of the soil. Similar targeted-yield approaches have been successfully evaluated in marigold under Inceptisols and Mollisols.

Important manuscript note: because the present experiment used predetermined nutrient-requirement values and soil-test rating adjustments, it should be described as a soil-test and target-yield based nutrient-management approach, rather than stating that new fertilizer prescription equations were developed from the present experiment.

2.6 Nursery raising and transplanting

Marigold seedlings were raised in protrays filled with cocopeat, with one seed sown per cell. The trays were initially stacked and covered with polyethylene to facilitate germination. After six days, the trays were transferred to a shade-net environment and irrigated daily using a rose can. A 19:19:19 water-soluble fertilizer solution at 5 g L⁻¹ was applied as a drench at 20 days after sowing.

The experimental field was ploughed and harrowed to a depth of approximately 30 cm two to three times, followed by fine leveling. Stones, weeds and other debris were removed, beds were prepared, and farmyard manure was incorporated according to the respective treatment requirements. Irrigation channels were provided around the beds.

Healthy, approximately one-month-old seedlings were transplanted at a spacing of 40 × 40 cm. Light irrigation was provided immediately after transplanting.

2.7 Irrigation and crop management

Following establishment, irrigation was provided through furrows in the morning at intervals of approximately 3-4 days, depending on soil moisture and prevailing weather conditions.

The required quantities of N, P and K were supplied through urea, single superphosphate (SSP) and muriate of potash (MOP), respectively. Fertilizers were manually applied according to the respective treatment. One week after transplanting, a circular fertilizer band approximately 10 cm in diameter and 3-4 cm deep was prepared around each plant. Half of the N dose and the full doses of P and K were applied at this stage, while the remaining half of the N dose was applied as top dressing 30 days after transplanting.

Gap filling was carried out at 7 and 10 days after transplanting to maintain uniform plant population. Manual weeding was performed periodically. Shoot tips of approximately 2.5 cm were removed at 30 days after transplanting to suppress apical dominance and promote lateral branching, followed by earthing-up to maintain plant stability. Plant protection measures were adopted whenever required. Acephate at 1.5 mL L⁻¹ was used for management of insect pests such as leaf miner, while wettable sulphur at 1 g L⁻¹ was used for powdery mildew management.

2.8 Recording of growth, flowering and yield attributes

Five plants were randomly selected and tagged in each experimental plot. Observations on growth, flowering, yield and quality characteristics were recorded on these plants, and treatment means were calculated from the tagged plants.

Growth observations were recorded at 30, 60 and 90 days after transplanting (DAT). The parameters included plant height, stem girth, plant spread and number of branches. Leaf area and leaf area index were also recorded, while chlorophyll content was estimated at 30 and 60 DAT. Total dry matter was determined at harvest.

Plant height was measured from ground level to the growing tip of the main stem. Stem girth was measured using a Vernier caliper at three positions near the base of the stem. Plant spread was measured in the north-south and east-west directions. Primary and secondary branches were counted at 30, 60 and 90 DAT.

Leaf area was determined from 25 representative leaves collected from the lower, middle and upper portions of the plant. Leaf area index (LAI) was calculated as:

$$LAI = \frac{A}{P}$$

where *A* represents leaf area and *P* represents the ground area occupied by the plant.

Flowering observations included days to first flower-bud initiation, days to first flower opening, days to 50% flowering and flowering duration. Days to first bud initiation and first flower opening were calculated from the date of transplanting, while 50% flowering was recorded when 50% of the plants had initiated flowers. Flowering duration was calculated from flower-bud initiation until completion of flowering.

Fully opened flowers were harvested at weekly intervals throughout the flowering period. Number of flowers per plant, flower yield per plant, flower yield per plot and flower yield per hectare were recorded. Total flower yield per hectare was calculated from the cumulative yield obtained from successive harvests and expressed in tonnes ha⁻¹.

2.9 Flower quality and physiological parameters

Individual flower weight was determined by weighing fully opened flowers from tagged plants using an electronic balance. Flower diameter was measured at full bloom using a Vernier caliper. Shelf life was assessed by maintaining freshly harvested flowers at room temperature on paper plates and recording the number of days until loss of marketable appearance.

Total chlorophyll content was determined from fully expanded mature leaves using the DMSO extraction procedure described by Shoaf and Lium (1976). Approximately 100 mg fresh leaf tissue was incubated in 7 mL DMSO for 24 h, after which the extract was brought to 10 mL with DMSO. Absorbance was recorded at 645 and 652 nm, and total chlorophyll was calculated as:

$$\text{Total chlorophyll (mg g}^{-1}\text{)} = \frac{[20.2(A_{645}) + 8.02(A_{652})] \times V}{1000W}$$

where *A* represents absorbance, *V* is the final extract volume (10 mL), and *W* is the fresh weight of the sample (100 mg).

For determination of total dry matter, five plants were randomly selected from each plot, washed with distilled water and dried in a hot-air oven at 60 °C for two days. The mean dry matter production was expressed on a per-plant basis.

2.10 Plant nutrient analysis

Plant samples were collected at harvest, oven-dried at 60 °C, ground using stainless-steel blades and stored in polythene bags until analysis. Total N, P and K concentrations were determined following standard procedures.

For nitrogen estimation, 0.5 g of powdered plant material was digested using concentrated H₂SO₄ in the presence of K₂SO₄:CuSO₄·5H₂O:Se digestion mixture in a 100:20:1 ratio. Following digestion, the released ammonia was distilled under alkaline conditions, trapped in boric acid-containing mixed indicator solution and titrated against standard H₂SO₄.

$$\text{Net returns (₹ ha}^{-1}\text{)} = \text{Gross returns} - \text{Cost of cultivation}$$

The benefit:cost ratio was calculated as:

$$\text{B:C ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

as specified in the original experimental methodology.

2.12 Statistical analysis

The experimental data were subjected to statistical analysis appropriate for an RCBD following the procedures described by Panse and Sukhatme (1969). Treatment effects were evaluated using the analysis of variance, and statistical significance was interpreted at the 1 and 5% probability levels.

Results

3.1 Effect of soil-test and target-yield based nutrient management on vegetative growth

Soil-test- and target-yield-based nutrient management significantly influenced the vegetative growth of African marigold cv. Tall Yellow. In general, plant growth increased progressively with increasing target yield from 15 to 35 t ha⁻¹, with the 35 t ha⁻¹ treatment (T₅) recording the highest values for most growth attributes. The farmer-practice treatment (T₇) consistently recorded the lowest growth, while the rec-

ommended fertilizer dose (T₆) generally performed below the target-yield treatments.

2.11 Economic analysis

Economic analysis was performed using prevailing input and labour costs during 2022. Treatment-wise costs included the expenditure on fertilizers, organic inputs, planting material, labour and other production inputs. Gross returns were calculated from flower yield and the prevailing market price of marigold flowers.

Net returns were calculated as:

ommended fertilizer dose (T₆) generally performed below the target-yield treatments.

3.1.1 Plant height and stem girth

Plant height increased significantly with increasing target yield at 30, 60 and 90 days after transplanting (DAT) (Table 1). At 30 DAT, plant height ranged from 28.73 cm under farmer's practice (T₇) to 33.86 cm under the 35 t ha⁻¹ target-yield treatment (T₅). At 60 DAT, T₅ recorded the maximum plant height (62.25 cm), followed by T₄ (60.42 cm), whereas T₇ recorded the minimum (53.14 cm). At 90 DAT, plants under T₅ attained a maximum height of 67.12 cm, followed by T₄ (65.17 cm), while the shortest plants were recorded under T₇ (57.21 cm). The critical difference (CD) at 5% was 0.65 cm at 90 DAT, indicating significant treatment differences.

Stem girth showed a similar treatment response. At 30 DAT, stem girth increased from 0.96 cm under farmer's practice to 2.01 cm under T₅. At 60 DAT, the corresponding values were 2.24 and 3.13 cm, respectively, while at 90 DAT T₅ recorded the maximum stem girth of 3.71 cm compared with 2.47 cm under T₇. The CD at 5% at 90 DAT was 0.17 cm, confirming significant differences among treatments.

At 90 DAT, the 35 t ha⁻¹ target-yield treatment therefore increased plant height by approximately 17.3% and stem girth by 50.2% relative to farmer's practice. Compared with RDF, the corresponding increases were approximately 13.2 and 39.0%, respectively.

Table 1. Effect of target-yield-based nutrient management on plant height and stem girth of African marigold

Treatment	Plant height (cm) 30 DAT	60 DAT	90 DAT	Stem girth (cm) 30 DAT	60 DAT	90 DAT
T ₁ – 15 t ha ⁻¹	30.40	56.60	60.76	1.20	2.51	3.01
T ₂ – 20 t ha ⁻¹	31.20	57.98	62.10	1.34	2.62	3.16
T ₃ – 25 t ha ⁻¹	31.46	59.14	63.43	1.60	2.80	3.32
T ₄ – 30 t ha ⁻¹	32.26	60.42	65.17	1.78	2.97	3.56
T ₅ – 35 t ha ⁻¹	33.86	62.25	67.12	2.01	3.13	3.71
T ₆ – RDF	29.73	54.96	59.28	1.12	2.40	2.67
T ₇ – Farmer's practice	28.73	53.14	57.21	0.96	2.24	2.47
SEm ±	0.24	0.57	0.21	0.13	0.02	0.05
CD (5%)	0.77	1.78	0.65	0.40	0.08	0.17

3.1.2 Plant spread

Target-yield-based nutrient management significantly affected plant spread in both east–west and north–south directions at 30, 60 and 90 DAT (Table 2). At 30 DAT, the maximum east–west and north–south spread was recorded in T₅ (22.06 and 24.66 cm, respectively), whereas T₇ recorded the minimum values (15.40 and 15.68 cm).

The same trend continued at 60 DAT. T₅ recorded 41.22 cm east–west and 38.71 cm north–south spread, compared with 34.02 and

31.38 cm, respectively, under farmer's practice. At 90 DAT, T₅ maintained the highest canopy development, with east–west and north–south spread of 42.98 and 40.29 cm, respectively. The corresponding values in T₇ were only 33.86 and 31.67 cm.

Thus, at 90 DAT, T₅ increased east–west plant spread by approximately 26.9% and north–south spread by 27.2% over farmer's practice. The 30 t ha⁻¹ target (T₄) was the next highest treatment, recording 41.42 and 38.67 cm in the two directions.

Table 2. Effect of target-yield-based nutrient management on plant spread

Treatment	E-W 30 DAT	N-S 30 DAT	E-W 60 DAT	N-S 60 DAT	E-W 90 DAT	N-S 90 DAT
T_1 - 15 t ha ⁻¹	17.00	17.73	35.73	33.54	36.84	34.18
T_2 - 20 t ha ⁻¹	17.86	18.56	37.12	34.53	38.71	35.46
T_3 - 25 t ha ⁻¹	19.00	19.11	38.18	36.78	39.86	37.50
T_4 - 30 t ha ⁻¹	20.06	21.12	39.54	37.38	41.42	38.67
T_5 - 35 t ha ⁻¹	22.06	24.66	41.22	38.71	42.98	40.29
T_6 - RDF	16.33	16.66	34.86	32.62	35.12	32.83
T_7 - Farmer's practice	15.40	15.68	34.02	31.38	33.86	31.67
SEm ±	0.46	0.73	0.37	0.63	0.15	0.52
CD (5%)	1.46	2.29	1.18	1.99	0.49	1.63

3.1.3 Number of primary and secondary branches

The number of primary and secondary branches increased significantly with increasing target yield at all three observation stages (Table 3). At 30 DAT, T_5 produced the maximum number of primary branches (11.53 plant⁻¹), followed by T_4 (10.33), whereas T_7 recorded only 6.40 branches plant⁻¹. At 60 DAT, T_5 produced 16.73 primary branches plant⁻¹ compared with 11.00 under farmer's practice. By 90

DAT, T_5 reached 21.33 primary branches plant⁻¹, while T_7 recorded 12.53.

Secondary branching followed the same pattern. At 30 DAT, T_5 recorded 23.06 secondary branches plant⁻¹ compared with 12.40 under T_7 . At 60 DAT, the corresponding values were 29.66 and 19.53, while at 90 DAT T_5 recorded 32.33 secondary branches plant⁻¹ compared with 20.26 under farmer's practice.

At 90 DAT, T_5 therefore produced approximately 70.2% more primary branches and 59.6% more secondary branches than T_7 .

Table 3. Effect of target-yield-based nutrient management on branch production

Treatment	Primary branches 30 DAT	Secondary branches 30 DAT	Primary branches 60 DAT	Secondary branches 60 DAT	Primary branches 90 DAT	Secondary branches 90 DAT
T_1 - 15 t ha ⁻¹	7.66	15.53	12.80	24.26	15.33	25.80
T_2 - 20 t ha ⁻¹	8.06	17.46	13.60	25.73	16.13	26.86
T_3 - 25 t ha ⁻¹	9.26	19.20	14.40	27.06	17.93	28.46
T_4 - 30 t ha ⁻¹	10.33	21.13	15.20	28.00	19.80	29.80
T_5 - 35 t ha ⁻¹	11.53	23.06	16.73	29.66	21.33	32.33
T_6 - RDF	7.13	14.20	12.07	22.20	13.73	23.40
T_7 - Farmer's practice	6.40	12.40	11.00	19.53	12.53	20.26
SEm ±	0.16	0.44	0.30	0.42	0.20	0.40
CD (5%)	0.52	1.39	0.91	1.33	0.62	1.24

3.1.4 Leaf area and leaf area index

Leaf area and leaf area index (LAI) measured at 60 DAT were significantly influenced by nutrient-management treatments (Table 4). The maximum leaf area (43.53 cm²) and LAI (2.70) were recorded in T_5 , followed by T_4 with 41.04 cm² and 2.55, respectively. Farmer's practice recorded the lowest leaf area (37.20 cm²) and LAI (2.32). The CD at 5% was 1.14 cm² for leaf area and 0.07 for LAI.

Relative to farmer's practice, the 35 t ha⁻¹ target increased leaf area and LAI by approximately 17.0 and 16.4%, respectively.

Table 4. Effect of target-yield-based nutrient management on leaf area and LAI

Treatment	Leaf area (cm ²)	LAI
T_1 - 15 t ha ⁻¹	39.07	2.43
T_2 - 20 t ha ⁻¹	39.43	2.45
T_3 - 25 t ha ⁻¹	39.89	2.48
T_4 - 30 t ha ⁻¹	41.04	2.55
T_5 - 35 t ha ⁻¹	43.53	2.70
T_6 - RDF	37.86	2.35
T_7 - Farmer's practice	37.20	2.32
SEm ±	0.36	0.02
CD (5%)	1.14	0.07

3.2 Effect on flowering behaviour

Nutrient management significantly altered the flowering behaviour of marigold (Table 5). The response, however, was not strictly linear for all flowering parameters. The lower target treatments promoted relatively early bud initiation, whereas the 30 and 35 t ha⁻¹ treatments resulted in earlier attainment of 50% flowering and a substantially longer flowering period.

3.2.1 Days to flower-bud initiation

The earliest flower-bud initiation was observed in T_1 (41.25 days), closely followed by T_2 (41.50 days). T_5 recorded bud initiation at 43.50 days, while T_7 required the longest period (46.50 days). The CD at 5% was 0.48 days, indicating significant treatment differences.

3.2.2 Days to first flowering

T_2 recorded the earliest first flower opening at 43 days after transplanting, followed by T_5 at 44 days and T_4 at 45 days. The farmer-practice treatment required 51 days, representing the latest flowering response.

3.2.3 Days to 50% flowering

The 35 t ha⁻¹ target treatment reached 50% flowering earliest, at 49 days, followed by T_4 at 50 days. In contrast, T_7 required 59 days to reach 50% flowering. Thus, T_5 reached the 50% flowering stage 10 days earlier than farmer's practice.

3.2.4 Flowering duration

Flowering duration increased progressively with the higher target-yield treatments. T_5 recorded the longest flowering duration (50 days), followed by T_4 (48 days), whereas farmer's practice had the

shortest flowering duration (39 days). The CD at 5% was 0.88 days.

Table 5. Effect of target-yield-based nutrient management on flowering behaviour

Treatment	Days to bud initiation	Days to first flowering	Days to 50% flowering	Flowering duration (days)
T_1 - 15 t ha ⁻¹	41.25	46	55	44
T_2 - 20 t ha ⁻¹	41.50	43	56	45
T_3 - 25 t ha ⁻¹	45.00	47	53	46
T_4 - 30 t ha ⁻¹	44.65	45	50	48
T_5 - 35 t ha ⁻¹	43.50	44	49	50
T_6 - RDF	42.75	47	57	42
T_7 - Farmer's practice	46.50	51	59	39
SEm ±	0.16	0.20	0.29	0.29
CD (5%)	0.48	0.62	0.88	0.88

3.3 Effect on flower production and yield

Flower production showed the clearest response to increasing target yield. Number of flowers plant⁻¹, flower yield plant⁻¹, plot yield and extrapolated hectare yield increased progressively from the 15 t ha⁻¹ to the 35 t ha⁻¹ target (Table 6).

The number of flowers plant⁻¹ increased from 43.71 in T_1 to 88.14 in T_5 . T_4 produced 78.92 flowers plant⁻¹, whereas RDF and farmer's practice produced only 43.29 and 39.36 flowers plant⁻¹, respectively. T_5 therefore produced approximately 124% more flowers plant⁻¹ than farmer's practice and more than twice the number recorded under RDF.

Flower yield plant⁻¹ followed the same pattern. T_5 produced 2.28 kg plant⁻¹, compared with 1.96 kg under T_4 , 0.91 kg under RDF and only 0.76 kg under farmer's practice. The difference between T_5 and T_7 represented a 200% increase in flower yield plant⁻¹.

At plot level, T_5 produced 11.41 kg plot⁻¹, followed by T_4 with 9.81 kg plot⁻¹. The lowest plot yield was recorded in T_7 (3.83 kg).

The cumulative flower yield reached 35.21 t ha⁻¹ under T_5 , compared with 30.27 t ha⁻¹ under T_4 , 25.30 t ha⁻¹ under T_3 , 20.27 t ha⁻¹ under T_2 and 15.12 t ha⁻¹ under T_1 . RDF produced 14.10 t ha⁻¹, while farmer's practice yielded only 11.82 t ha⁻¹. T_5 consequently produced approximately 197.9% higher flower yield than farmer's practice and 149.7% higher yield than RDF.

Table 6. Effect of target-yield-based nutrient management on flower production and yield

Treatment	Flowers plant ⁻¹	Flower yield plant ⁻¹ (kg)	Flower yield plot ⁻¹ (kg)	Flower yield (t ha ⁻¹)
T_1 - 15 t ha ⁻¹	43.71	0.98	4.90	15.12
T_2 - 20 t ha ⁻¹	56.56	1.31	6.57	20.27
T_3 - 25 t ha ⁻¹	67.65	1.64	8.20	25.30
T_4 - 30 t ha ⁻¹	78.92	1.96	9.81	30.27
T_5 - 35 t ha ⁻¹	88.14	2.28	11.41	35.21
T_6 - RDF	43.29	0.91	4.57	14.10
T_7 - Farmer's practice	39.36	0.76	3.83	11.82
SEm ±	1.48	0.04	0.22	0.69
CD (5%)	4.57	0.14	0.69	2.12

The measured yield response is particularly important because the target-yield treatments closely tracked their nominal yield targets: 15.12, 20.27, 25.30, 30.27 and 35.21 t ha⁻¹ were obtained against target levels of 15, 20, 25, 30 and 35 t ha⁻¹, respectively. The deviations from the respective targets were only 0.8, 1.35, 1.2, 0.9 and 0.6%, respectively. This is one of the strongest outcomes of the experiment and should be emphasized in the manuscript.

3.4 Effect on flower quality

Target-yield-based nutrient management significantly affected all three measured flower-quality parameters: flower diameter, individual flower weight and shelf life (Table 7).

Flower diameter increased from 5.72 cm under farmer's practice to 6.65 cm under T_5 . T_4 recorded 6.44 cm. The CD at 5% was 0.22 cm,

confirming significant differences. Thus, the 35 t ha⁻¹ treatment increased flower diameter by approximately 16.3% compared with farmer's practice.

Individual flower weight also increased progressively with target yield. T_5 produced the heaviest flowers (25.89 g), followed by T_4 (24.86 g), whereas T_7 produced the lightest flowers (19.40 g). The increase in individual flower weight under T_5 relative to farmer's practice was approximately 33.5%.

Shelf life showed a similar response. T_5 recorded the longest shelf life (4.27 days), followed by T_4 (3.97 days), whereas T_7 recorded the shortest shelf life (2.97 days). The difference between T_5 and T_7 represented an increase of approximately 43.8%.

Table 7. Effect of target-yield-based nutrient management on flower quality

Treatment	Flower diameter (cm)	Individual flower weight (g)	Shelf life (days)
T ₁ - 15 t ha ⁻¹	6.10	22.42	3.37
T ₂ - 20 t ha ⁻¹	6.20	23.23	3.57
T ₃ - 25 t ha ⁻¹	6.28	24.24	3.63
T ₄ - 30 t ha ⁻¹	6.44	24.86	3.97
T ₅ - 35 t ha ⁻¹	6.65	25.89	4.27
T ₆ - RDF	5.90	21.11	3.13
T ₇ - Farmer's practice	5.72	19.40	2.97
SEm ±	0.07	0.35	0.03
CD (5%)	0.22	1.10	0.11

3.5 Chlorophyll content and dry matter production

Chlorophyll concentration was significantly influenced by nutrient-management treatments at both 30 and 60 DAT (Table 8). At 30 DAT, T₅ recorded the highest chlorophyll concentration (3.42 mg g⁻¹), followed by T₄ (3.22 mg g⁻¹), while T₇ recorded the lowest value (2.27 mg g⁻¹). At 60 DAT, T₅ again recorded the highest chlorophyll concentration (3.02 mg g⁻¹), whereas T₇ recorded the minimum (1.57 mg g⁻¹).

The difference was particularly pronounced at 60 DAT, where T₅ showed approximately 92.4% higher chlorophyll concentration than farmer's practice and 77.6% higher than RDF.

Total dry matter production at harvest also increased significantly with increasing target yield. T₅ produced the maximum dry matter (283.33 g plant⁻¹), followed by T₄ (266.66 g plant⁻¹), while T₇ recorded only 120.00 g plant⁻¹.

Thus, dry matter production under T₅ was approximately 136.1% higher than farmer's practice and 107.3% higher than RDF.

Table 8. Effect of target-yield-based nutrient management on chlorophyll concentration and dry matter

Treatment	Chlorophyll 30 DAT (mg g ⁻¹)	Chlorophyll 60 DAT (mg g ⁻¹)	Dry matter (g plant ⁻¹)
T ₁ - 15 t ha ⁻¹	2.72	1.89	173.33
T ₂ - 20 t ha ⁻¹	2.87	1.95	200.00
T ₃ - 25 t ha ⁻¹	3.01	2.06	256.66
T ₄ - 30 t ha ⁻¹	3.22	2.46	266.66
T ₅ - 35 t ha ⁻¹	3.42	3.02	283.33
T ₆ - RDF	2.58	1.70	136.66
T ₇ - Farmer's practice	2.27	1.57	120.00
SEm ±	0.08	0.11	14.06
CD (5%)	0.27	0.34	43.82

3.6 Leaf nutrient concentration

Nutrient-management treatments significantly affected the N, P and K concentrations of marigold leaves (Table 9). The highest N concentration was recorded in T₅ (3.98%), followed by T₄ (3.90%), whereas the lowest concentration was recorded in farmer's practice (3.50%).

Phosphorus concentration showed a similar pattern, increasing from 0.13% in T₇ to 0.24% in T₅. T₄ recorded 0.20%. Potassium concentration increased from 0.92% under farmer's practice to 1.11% under T₅, with T₄ recording 1.08%.

Relative to farmer's practice, T₅ increased leaf N, P and K concentrations by approximately 13.7, 84.6 and 20.7%, respectively.

Table 9. Effect of target-yield-based nutrient management on leaf nutrient concentration

Treatment	N (%)	P (%)	K (%)
T ₁ - 15 t ha ⁻¹	3.68	0.15	1.00
T ₂ - 20 t ha ⁻¹	3.76	0.16	1.01
T ₃ - 25 t ha ⁻¹	3.88	0.18	1.05
T ₄ - 30 t ha ⁻¹	3.90	0.20	1.08
T ₅ - 35 t ha ⁻¹	3.98	0.24	1.11
T ₆ - RDF	3.63	0.15	0.97
T ₇ - Farmer's practice	3.50	0.13	0.92
SEm ±	0.03	0.01	0.02
CD (5%)	0.09	0.02	0.07

Note: These values represent nutrient concentration (%) rather than nutrient uptake. The terminology should be corrected in the manuscript unless actual uptake (e.g., kg ha⁻¹) has been calculated from nutrient concentration and biomass.

3.7 Economic performance

Nutrient management had a pronounced effect on the economics of marigold production (Table 10). The cost of cultivation increased gradually with increasing target yield because of the additional nutrient inputs. The lowest cost of cultivation was recorded under farmer's practice (₹207,299 ha⁻¹), whereas T₅ required the highest cost (₹212,658 ha⁻¹).

Despite the slightly higher production cost, the higher flower yield obtained under T₅ resulted in a substantial increase in gross and net

returns. T_5 generated the highest gross return of ₹704,200 ha⁻¹, followed by T_4 with ₹605,400 ha⁻¹. Farmer's practice produced only ₹236,400 ha⁻¹.

Net return was also highest under T_5 at ₹491,542 ha⁻¹, followed by T_4 at ₹393,895 ha⁻¹. The corresponding net returns under RDF and farmer's practice were ₹69,567 and ₹29,101 ha⁻¹, respectively. Thus,

T_5 generated approximately 16.9-fold higher net returns than farmer's practice and approximately 7.1-fold higher net returns than RDF.

The reported B:C ratio increased from 0.5 under T_1 to 2.3 under T_5 . T_4 recorded a B:C ratio of 1.9, whereas RDF and farmer's practice recorded 0.3 and 0.1, respectively.

Table 10. Economic performance of African marigold under target-yield-based nutrient management

Treatment	Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B:C ratio*
T_1 - 15 t ha ⁻¹	2,08,044	3,02,400	94,356	0.5
T_2 - 20 t ha ⁻¹	2,09,198	4,05,400	1,96,202	0.9
T_3 - 25 t ha ⁻¹	2,10,351	5,06,000	2,95,649	1.4
T_4 - 30 t ha ⁻¹	2,11,505	6,05,400	3,93,895	1.9
T_5 - 35 t ha ⁻¹	2,12,658	7,04,200	4,91,542	2.3
T_6 - RDF	2,12,433	2,82,000	69,567	0.3
T_7 - Farmer's practice	2,07,299	2,36,400	29,101	0.1

3.8 Overall treatment response and achievement of target yields

A clear relationship was observed between the imposed yield targets and the actual flower yield obtained. Increasing the target from 15 to 35 t ha⁻¹ resulted in a corresponding increase in observed yield from 15.12 to 35.21 t ha⁻¹. Importantly, the observed yields under T_1 – T_5 were very close to their respective target yields:

Target yield (t ha ⁻¹)	Observed yield (t ha ⁻¹)	Deviation from target
15	15.12	+0.12 t ha ⁻¹
20	20.27	+0.27 t ha ⁻¹
25	25.30	+0.30 t ha ⁻¹
30	30.27	+0.27 t ha ⁻¹
35	35.21	+0.21 t ha ⁻¹

The deviations correspond to approximately 0.6–1.4% above the specified targets, indicating a close correspondence between the target-yield nutrient-management levels and the yields obtained under the experimental conditions.

The response was also consistent across the major growth, yield and quality variables. T_5 recorded the highest plant height, stem girth, plant spread, branching, leaf area, LAI, chlorophyll concentration, dry matter, number of flowers, flower yield, flower diameter, individual flower weight and shelf life. T_4 generally ranked next, while farmer's practice generally produced the lowest values.

3.9 Principal outcome of the experiment

Taken together, the results demonstrate a strong yield-response gradient across the target-yield treatments. Increasing the target yield from 15 to 35 t ha⁻¹ was accompanied by progressively greater vegetative development and reproductive productivity. The 35 t ha⁻¹ target treatment (T_5) produced 35.21 t ha⁻¹ of flowers, which was only 0.21 t ha⁻¹ above the nominal target and approximately 198% greater than farmer's practice (11.82 t ha⁻¹). The treatment also produced 88.14 flowers plant⁻¹ and 2.28 kg flowers plant⁻¹, together with superior flower size (6.65 cm), individual flower weight (25.89 g) and shelf life (4.27 days).

Economically, the increase in nutrient input associated with higher target yields was accompanied by a much larger increase in flower returns. T_5 generated ₹4.92 lakh ha⁻¹ net return compared with ₹0.29 lakh ha⁻¹ under farmer's practice, with the reported B:C ratio increasing from 0.1 to 2.3.

Recent African marigold studies also report substantial responses to nutrient-management strategies, including integrated inorganic and organic nutrient management, although those experiments used differ-

ent cultivars, environments and treatment structures and therefore are not directly comparable with the present target-yield experiment. For example, recent 2026 experiments reported improvements in flower yield and economic returns under integrated nutrient management in *T. erecta*.

Discussion

The present study demonstrated that soil-test- and target-yield-based nutrient management substantially modified the growth, flowering, yield, flower quality, nutrient concentration and economic performance of African marigold (*Tagetes erecta* L.) cv. Tall Yellow. Across most measured parameters, the response increased with increasing yield target from 15 to 35 t ha⁻¹, with the 35 t ha⁻¹ treatment (T_5) consistently recording the highest values. This response indicates that nutrient supply adjusted according to the soil fertility status and desired yield level was more closely aligned with crop demand than the RDF and farmer-practice treatments. The principle is consistent with the STCR concept, in which fertilizer requirements are derived from soil nutrient-supplying capacity, crop nutrient requirement and the desired yield target rather than from a uniform recommendation. Recent long-term work in southern India has similarly demonstrated that STCR-based nutrient management can improve crop productivity, nutrient uptake and soil quality relative to generalized fertilizer recommendations.

The improvement in vegetative growth under increasing target yields was particularly evident in plant height, stem girth, plant spread and branching. At 90 DAT, T_5 produced the maximum plant height (67.12 cm), stem girth (3.71 cm), east-west spread (42.98 cm), north-south spread (40.29 cm), primary branches (21.33 plant⁻¹) and secondary branches (32.33 plant⁻¹), whereas farmer's practice consistently produced the lowest values. This response is physiologically plausible because adequate and balanced availability of N, P and K supports cell division and expansion, photosynthetic development and formation of vegetative sinks, ultimately increasing plant architecture and assimilatory surface. The greater leaf area (43.53 cm²) and LAI (2.70) under T_5 compared with 37.20 cm² and 2.32 under farmer's practice further indicate improved canopy development under targeted nutrient management. Similar positive effects of mineral nutrition on growth and yield attributes of marigold have been reported previously, including improvements in plant growth, flowering and yield following NPK fertilization.

The progressive improvement in vegetative growth was accompanied by greater chlorophyll concentration and dry matter accumulation. Treatment T_5 recorded 3.42 and 3.02 mg g⁻¹ chlorophyll at 30 and 60 DAT, respectively, compared with only 2.27 and 1.57 mg g⁻¹ under farmer's practice. Dry matter production was also highest under T_5 (283.33 g plant⁻¹), compared with 120.00 g plant⁻¹ under T_7 . The greater chlorophyll concentration suggests improved nutritional status

and maintenance of photosynthetically active foliage, while the greater dry matter indicates that the additional assimilates were translated into overall biomass production. Importantly, the response was not simply a consequence of greater vegetative growth; it was ultimately reflected in reproductive productivity.

Flowering behaviour showed a somewhat different response from vegetative growth. The earliest bud initiation occurred under the 15 t ha⁻¹ target (41.25 days), while the earliest first flower opening was observed under the 20 t ha⁻¹ target (43 days). In contrast, T_5 reached 50% flowering earliest (49 days) and maintained the longest flowering duration (50 days), whereas farmer's practice required 59 days to reach 50% flowering and had only 39 days of flowering duration. These findings indicate that higher nutrient availability did not necessarily accelerate every stage of flowering, but it substantially improved the duration and intensity of reproductive development. Thus, the effect of nutrient management should be interpreted in terms of the entire flowering period rather than only the date of first flowering. The strongest response was observed in flower production and yield. Number of flowers increased from 39.36 plant⁻¹ under farmer's practice to 88.14 plant⁻¹ under T_5 , while flower yield increased from 0.76 to 2.28 kg plant⁻¹. At the hectare scale, yield increased from 11.82 t ha⁻¹ under farmer's practice to 35.21 t ha⁻¹ under T_5 . This approximately three-fold difference in yield is consistent with the improvement in branching, leaf area, chlorophyll concentration and dry matter production observed under T_5 . Greater branching provided more potential sites for flower formation, while the larger assimilatory canopy likely supported greater assimilate production and partitioning towards reproductive sinks.

A particularly important finding was the close agreement between the specified yield targets and the yields actually obtained. The 15, 20, 25, 30 and 35 t ha⁻¹ treatments produced 15.12, 20.27, 25.30, 30.27 and 35.21 t ha⁻¹, respectively. Thus, all five target treatments achieved yields very close to their respective targets. This finding provides direct experimental support for the applicability of the targeted-yield approach under the soil and environmental conditions of the study. Earlier STCR research in marigold has also demonstrated the utility of soil-test-based fertilizer prescription. Durga *et al.* (2017) [18], working with marigold in an Inceptisol of New Delhi, developed fertilizer prescriptions based on nutrient requirement and soil contribution and reported that targeted-yield recommendations could reduce fertilizer inputs under integrated NPK + FYM management. Similarly, Tripathi and Srivastava (2019) reported that targeted-yield-based fertilizer prescriptions for marigold grown on Mollisols were superior to general recommended fertilization in verification trials. The present study therefore extends this evidence to *T. erecta* cv. Tall Yellow under the agroecological and soil conditions of Karnataka.

The improvement in yield was accompanied by better flower quality. T_5 produced the largest flowers (6.65 cm diameter), greatest individual flower weight (25.89 g) and longest shelf life (4.27 days), whereas farmer's practice produced 5.72 cm flowers weighing 19.40 g with a shelf life of 2.97 days. Adequate nutrient availability during flower development may have supported greater assimilate accumulation and flower expansion, resulting in larger and heavier capitula. The concurrent increase in flower number and individual flower weight is particularly important because it indicates that the higher yield under T_5 was not achieved at the expense of flower size.

The higher target-yield treatments also resulted in greater leaf N, P and K concentrations. T_5 recorded 3.98% N, 0.24% P and 1.11% K, compared with 3.50, 0.13 and 0.92%, respectively, under farmer's practice. These results suggest that targeted nutrient application im-

proved plant nutritional status and helped maintain adequate nutrient availability during active vegetative and reproductive growth. However, these data represent nutrient concentrations rather than nutrient uptake; therefore, the manuscript should avoid interpreting them as total nutrient uptake unless biomass-based uptake calculations are available. Modern STCR studies similarly emphasize the importance of balancing fertilizer application with crop nutrient demand and soil nutrient-supplying capacity.

The economic results further strengthened the agronomic response. Although T_5 incurred the highest cultivation cost (₹2,12,658 ha⁻¹), its substantially greater yield resulted in the highest gross return (₹7,04,200 ha⁻¹) and net return (₹4,91,542 ha⁻¹), with a reported B:C ratio of 2.3. Farmer's practice generated only ₹29,101 ha⁻¹ net return and a reported B:C ratio of 0.1. Similar economic advantages from soil-test-based targeted nutrient management have been documented in other crops, where balanced nutrient application improved productivity and returns compared with generalized fertilizer recommendations.

Overall, the results indicate that the 35 t ha⁻¹ target-yield treatment provided the highest agronomic and economic performance under the conditions of the experiment, while the lower target treatments produced progressively lower yields corresponding closely to their specified targets. The findings support the use of soil-test-based targeted nutrient management as a more site-specific approach for marigold than generalized fertilization. Nevertheless, the present conclusion is specific to the cultivar, soil, location and experimental season; validation across additional seasons, soil fertility classes and production environments would be necessary before recommending the 35 t ha⁻¹ prescription broadly. This is particularly important because STCR prescriptions are inherently site-specific and their performance depends on soil nutrient status and the nutrient contribution of soil, fertilizer and organic inputs. Recent validation studies in horticultural crops likewise demonstrate that targeted-yield models can be highly effective but require crop- and soil-specific calibration.

Conclusion

The present study demonstrated that soil test- and target yield-based nutrient management was effective in improving the growth, flowering, yield and quality of African marigold (*Tagetes erecta* L.) cv. Tall Yellow under the red lateritic soils of Bidar, Karnataka. Among the nutrient management treatments, the 35 t ha⁻¹ target-yield treatment (T_5) consistently produced superior vegetative growth, greater leaf area and chlorophyll content, prolonged flowering duration, higher flower number and flower yield, and improved flower quality compared with RDF and farmer practice. Most importantly, the targeted-yield approach achieved the prescribed yield levels with close agreement between target and actual yields, with deviations of only 0.6–1.35% for the 15–35 t ha⁻¹ targets. The highest actual flower yield of 35.21 t ha⁻¹ was obtained under T_5 , while farmer practice produced only 11.82 t ha⁻¹. The improvement in yield was accompanied by higher leaf N, P and K concentrations and greater economic returns. These findings support the use of soil test-based target yield nutrient management as a site-specific approach for optimizing nutrient application and improving productivity of African marigold. However, the results represent a single-season, location-specific evaluation and should be further validated across seasons, soil types and production environments before wider recommendation. The targeted-yield concept is consistent with earlier marigold STCR research demonstrating the potential of soil-test-based fertilizer prescriptions to achieve specified yields while improving nutrient-use efficiency.

Figures



Figure 1. Experimental layout and treatment structure for soil test- and target yield-based nutrient management in African marigold (*Tagetes erecta* L.) cv. Tall Yellow.



References

1. Abdulrahman S, Gines HC, Nagaraj R, Satawathananont S, Son TT, Tan PS, Wang GH. Variation in the performance of site specific nutrient management among different environments with irrigated rice in Asia. *Better Crops International*. 2002;16(20):18-23.
2. Adhikari P, Mishra K, Marasini S, Neupane RC, Shrestha AK, Shrestha J, Subedi S. Effect of nitrogen doses on growth and yield of marigold (*Tagetes erecta* L.) in subtropical climate of Nepal. *Fundamental and Applied Agriculture*. 2020;5(3):414-420.
3. Ahmad I, Asif M, Amjad A, Ahmad S. Fertilization enhances growth, yield, and xanthophyll contents of marigold. *Turkish Journal of Agriculture and Forestry*. 2011;35:641-648.
4. Airadevi PA. Integrated nutrient management studies on growth, yield and quality of garland chrysanthemum (*Chrysanthemum coronarium* L.) [M.Sc. (Agri.) thesis]. University of Agricultural Sciences, Dharwad; 2010.
5. Ahammed RS, Chandrasekhar RK, Shaik M. Soil test yield goal approach as an aid to balanced fertilization to rice in intensive cropping system. *Oryza*. 1999;36(3):223-227.
6. Baboo R, Singh MK. Response of graded levels of nitrogen and phosphorus on growth and flowering in African marigold. *Journal of Ornamental Horticulture*. 2003;6(4):400-402.
7. Baboo R, Ahmad N, Singh D. Growth and flowering of African marigold (*Tagetes erecta* L.) as affected by nitrogen and phosphorus under varying intra-row spacing. *Journal of Ornamental Horticulture*. 2005;8(4):312-313.
8. Berra R, Seal A, Bhattacharyya P, Das TH, Sarkar D, Kangjoo K. Targeted yield concept and framework of fertilizer recommendation in irrigated rice domains of subtropical India. *Journal of Zhejiang University Science*. 2006;7(12):963-968.
9. Bhat DJ, Dogra S, Pandey RK, Sharma JP, Jamwal S. Influence of integrated nutrient management on growth, flowering and yield of African marigold cv. *Pusa Narangi*. *Environment and Ecology*. 2010;28(1):466-468.
10. Bhat ZA, Shepherd H. Effect of source and level of nitrogen on growth, flowering and yield in African marigold (*Tagetes erecta* L.). *Journal of Ornamental Horticulture*. 2006;9(3):218-220.
11. Chandrikapure KR, Sadawarte DM, Panchabhi, Shelke BD. Effect of bioinoculants and graded dose of nitrogen on growth and flower yield of marigold (*Tagetes erecta* L.). *Orissa Journal of Horticulture*. 1999;27(2):31-34.

12. Choudhary M, Beniwal BS, Kumari A. Evaluation of marigold genotypes under semi-arid conditions of Haryana. *Annals of Horticulture*. 2014;7(1):30-35.
13. Dahiya SS, Bhatia BK. Effect of iron and nitrogen levels on dry matter yield and nutrients uptake by maize. *Agricultural University Journal of Research*. 1982;12(2):254-258.
14. Dahiya SS, Beniwal BS. Variability studies in marigold (*Tagetes* sp.). In *National Seminar on Sustainable Agriculture and Food Security: Challenges in Changing Climate*. CCS Haryana Agricultural University, Hisar, India; 2012:298.
15. Deepa VP, Patil VS, Venugopal CK, Biradar MS, Sridhar K. Study on the growth and yield attributes of marigold (*Tagetes* sp.) hybrids under Dharwad condition. *HortFlora Research Spectrum*. 2016;5(1):43-47.
16. Dhillon NS, Brar BS, Benipal DS, Mavi MS. Economics of various soil test based fertilization approaches for different crops. *Crop Research*. 2006;32(3):377-381.
17. Dobermann A, Witt C, Robert PC, Larson WE. SSNM concept for irrigated rice systems. *Proceedings of the 5th International Conference on Precision Agriculture*. 2000;25:1-7.
18. Durga ML, Raju DVS, Pandey RN, Singh KP, Kumar P, Pandey R, Gopalakrishnan S, Chandra S. Soil test and targeted yield based primary nutrient management of marigold (*Tagetes patula*) in an Inceptisol. *The Indian Journal of Agricultural Sciences*. 2017;87(4):500-504.
19. Ferguson RB, Hergert GW, Schepers JS, Gotway CA, Cahoon JE, Peterson TA. Site-specific nitrogen management of irrigated rice: Yield and soil residual nitrate effects. *Soil Science Society of America Journal*. 2002;66:544-553.
20. Gotmare PT, Damke MM, Gonge VS, Deshmukh S. Influence of integrated nutrient management on vegetative growth parameters of marigold (*Tagetes erecta* L.). *Asian Journal of Horticulture*. 2007;2(2):33-36.
21. Haque MA, Miah MM, Hossain S, Alam M. Economics of marigold cultivation in some selected areas of Bangladesh. *Bangladesh Journal of Agricultural Research*. 2012;37(4):711-720.
22. Jadhav PB, Singh A, Mangave BD, Patil NB, Patel DJ, Dekhane SS, Kireeti A. Effect of organic and inorganic fertilizers on growth and yield of African marigold (*Tagetes erecta* L.) cv. *Pusa Basanti* Gaiinda. *Annals of Biological Research*. 2015;5(9):10-14.
23. Pandey RN, Janakiram T, Raju DVS, Lakshmi DM, Pradip D. Soil test based integrated nutrient management in flower crops. *Indian Horticulture*. 2015;60(12):42-45.
24. Pooja G, Sunila K, Dikshit SN. Response of African marigold (*Tagetes erecta* L.) to integrated nutrient management. *Annals of Biology*. 2012;28(1):66-67.
25. Rao CC, Goud PV, Reddy KM, Padmaja G. Screening of African marigold (*Tagetes erecta* L.) cultivars for flower yield and carotenoid pigments. *Indian Journal of Horticulture*. 2005;62(3):276-279.
26. Rolaniya MK, Khandelwal SK, Choudhary A, Jat PK. Response of African marigold to NPK, biofertilizers and spacings. *Journal of Applied and Natural Science*. 2017;9(1):593-597.
27. Sachin K, Singh JP, Braj Mohan, Nathiram, Rajbeer. Influence of integrated nutrient management on growth, flowering and yield parameters of marigold (*Tagetes erecta* L.) cv. *Pusa Basanti* Gaiinda. *Asian Journal of Horticulture*. 2013;8(1):118-121.
28. Singh CV, Vidhya Shankar M, Kasana BS, Bobede A. Effect of integrated nutrient management on flowering characters of African marigold (*Tagetes erecta* L.). *International Journal of Agricultural Sciences*. 2016;8(4):1000-1002.
29. Singh KP, Raju DVS, Namita N, Janakiram T. Determination of genetic variation for vegetative and floral traits in African marigold (*Tagetes erecta*). *The Indian Journal of Agricultural Sciences*. 2014;84(9):1057-1062.

How to cite this article: Lamani C, Patil AG, Tirki S, Padasalagi H, Jeevanagi AS, Bharsakale R. Site-specific nutrient management based on target yield improves productivity and economic returns of African marigold (*Tagetes erecta* L.). *International Journal of Advanced Biochemistry Research*. 2026;10(9S):1851-1862. doi: <https://www.doi.org/10.33545/26174693.2026.v10.i9S.w.10091>