

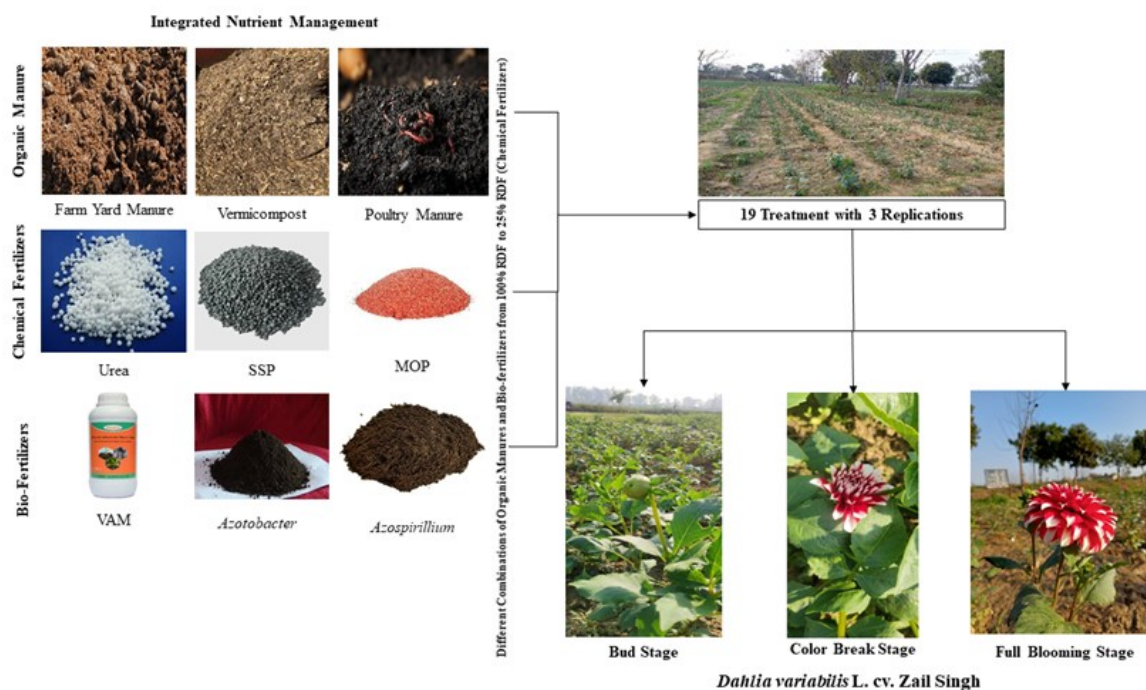
Integrated Nutrient Management's Impact on Dahlia Cultivation (*Dahlia variabilis* L.) cv. Zail Singh

Krishna Kaushik,^{a,*} Mukesh Kumar^a, Ravi Kumar^a,
Kedar Mahadev Gheware^b, Devanshu Shukla^a, Rohan Tomar,^a Abhay Vedwan^a,
Vishal Srivastava,^a Mahima Sharma,^a and Shivani Chahar^a

* Corresponding author: kaushikkaali007@gmail.com

DOI: 10.15376/biores.20.4.10028-10050

GRAPHICAL ABSTRACT



Integrated Nutrient Management's Impact on Dahlia Cultivation (*Dahlia variabilis* L.) cv. Zail Singh

Krishna Kaushik,^{a,*} Mukesh Kumar^a, Ravi Kumar^a,
Kedar Mahadev Gheware^b, Devanshu Shukla^a, Rohan Tomar,^a Abhay Vedwan^a,
Vishal Srivastava,^a Mahima Sharma,^a and Shivani Chahar^a

The experiment was conducted during the winter season of 2022–2023 at the Horticultural Research Centre, SVPUA&T, Meerut, to evaluate the impact of Integrated Nutrient Management (INM) on *Dahlia variabilis* L. cv. Zail Singh using a Randomized Complete Block Design (RCBD) with 19 treatments and three replications. Significant differences ($P < 0.05$) were observed among treatments for vegetative growth, flowering, and soil parameters. Treatment T₁₂ (50% RDF + poultry manure + *Azotobacter* + VAM) recorded the maximum number of primary branches (9.75), leaf area (97.75 cm²), leaf area index (0.048), chlorophyll index 55.45 mg/m², and nitrogen index (26.62 mg/m²), showing approximately 81% improvement over the control (100% RDF). T₁₇ (25% RDF + vermicompost + *Azospirillum* + VAM) produced the largest stem diameter (14.30 mm), stalk diameter (10.30 mm), and flower diameter (18.00 cm). T₅ enabled early color break (6.58 days), T₁₀ extended vase life (7.10 days), while T₆ and T₇ significantly enhanced soil nutrient availability, and T₁₄–T₁₅ improved soil organic carbon, EC, and pH. In contrast, the control (T₁) consistently recorded the lowest values across traits. These findings demonstrated that integrating organic manures and bio-inoculants with reduced levels of chemical fertilizers significantly enhanced crop performance and soil health, offering a sustainable strategy for ornamental horticulture.

DOI: 10.15376/biores.20.4.10028-10050

Keywords: Integrated nutrient management (INM); Vermicompost (VC); Poultry manure (PM); Farm yard manure (FYM); Recommended dose of fertilizer (RDF)

Contact Information: a: Department of Floriculture and Landscaping Architecture, College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, 250110, India; b: Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu; *Corresponding author: kaushikkaali007@gmail.com

INTRODUCTION

Dahlias, one of the most popular half-hardy tuberous rooted perennials, are valued for their beautiful blooms and landscaping value. Mexico's national flower is native to the Asteraceae family. According to Darlington (1973), the wild species from which the octoploid (8X) *Dahlia variabilis* ($n = 64$) is believed to have arisen are tetraploids with 32 chromosomes. The main producer of tuberous-rooted dahlias is the Netherlands (Bhattacharjee *et al.* 2019). It is noteworthy that Holland annually exports 50 million dahlia tubers to international markets and the Netherlands floriculture market size is estimated at \$4.89 billion US in 2024, growing at a compound annual growth rate (CAGR) of 4.70% during the forecast period 2024 to 2029 (Dutch flower Industry Report 2023, 2024).

Dahlias are used as both cut flowers and loose flowers. The trade appreciation of the dahlia crop has been exploited only in certain countries (Milian 2024). The Netherlands is a major producer of tuberous-rooted Dahlias, supplying 50 million tubers annually to international markets (Singh *et al.* 2023; Kumar *et al.* 2024). Dahlias are grown for ornamental purposes due to their aesthetic characteristics, which are crucial for the ornamental industry. Improved quality in these aspects requires proper rooting and vegetative growth, ensuring water, gas exchange, nutrient supply, and plant support (Shukla *et al.* 2023).

Successful cultivation and production of quality dahlia flowers are influenced by various factors, such as rooting media, nutrient management during crop cultivation, and environmental factors. Nutrient management is a major factor, and it plays a vital role in producing quality yield while improving soil health (Wararkar *et al.* 2020). In modern horticulture, integrated nutrient management (INM) is a comprehensive and advanced approach intended to meet the complex nutritional requirements of crops (Kushwah *et al.* 2024). INM entails the strategic integration of several nutrition sources, such as crop residues, organic manures, inorganic or chemical fertilizers, and bio-fertilizers. The aim of INM is clear to develop a sustainable and optimal nutrient supply that meets the various needs of crops at their crucial stages of growth and improving soil health (Wu and Ma 2015). Organic manures, such as farm yard manure (FYM), poultry manure (PM), and vermicompost (VC) have been widely known to restore soil health and improve soil structure (Tripathi *et al.* 2020; Sharma *et al.* 2024). Inorganic fertilizers can reduce costs for farmers and provide nutrients instantly to the plants in their initial stage (Tiemann and Douchamps 2023). However, in the comparison of organic fertilizers, which have a longer-lasting effect on soil and plant health, inorganic fertilizers can leach into groundwater, and nutrient runoff can pass into waterways (Tiwari and Pal 2022; Kumar *et al.* 2024a). Bio-fertilizers, encompassing symbiotic nitrogen-fixing bacteria, phosphorous-solubilizing bacteria, as well as potassium solubilizing bacteria, offer a promising avenue for sustainable nutrient management (Samad *et al.* 2024).

Application of INM was also reported to be associated with improvement in plant growth (Sudhagar *et al.* 2019), flowering (Kaushik and Singh 2020), tubers growth (Singh *et al.* 2024), chlorophyll content (Tian *et al.* 2024), and photosynthetic rate of plant, as well as nutrient uptake, nutrient availability, and soil structure (Drózdź *et al.* 2023). Rajaselvam *et al.* (2024) showed that the INM is effective when applied in the right combination of organic, inorganic, and bio-fertilizers. They noticed an improvement in the growth, flowering, and photosynthetic rate of tuberose (*Polianthes tuberosa* L.) cv. Prajwal through applying INM treatments.

Previous researchers have reported positive effects of INM on floricultural crops viz., gladiolus (Maniram *et al.* 2012; Kumar *et al.* 2014; Singh *et al.* 2014; Motla *et al.* 2022; Kaur *et al.* 2023), chrysanthemum (Kumar *et al.* 2015; Aashutosh *et al.* 2019), marigold (Singh *et al.* 2015; Garge *et al.* 2020), and tuberose (Tomar *et al.* 2024). Unlike previous studies that have mainly focused on cereals, vegetables, and a few ornamentals, research on INM in Dahlia remains very limited. To the best of the authors' knowledge, this is the first systematic evaluation of combined organic manures, inorganic fertilizers, and bio-inoculants on the growth, flowering, and soil health of *Dahlia variabilis* L. cv. Zail Singh under subtropical conditions. Building on these findings, the present study was undertaken to assess whether integrating organic manures and bio-inoculants with reduced levels of chemical fertilizers could enhance vegetative growth, floral quality and soil fertility in dahlia.

EXPERIMENTAL

Materials

The present experiment was executed in the HRC, Sardar Vallabhbhai Patel University of Agriculture and Technology (SVPUA&T), Meerut during 2022-2023. *D. variabilis* L. cv. Zail Singh cuttings were purchased from a local plant nursery in Kolkata in November. Source of macro and micronutrients, such as FYM, VC, PM, *Azotobacter*, *Azospirillum*, Vesicular Arbuscular Mycorrhizae (VAM), urea (46% N), Single Super Phosphate (SSP) (18% P), and Muriate of Potash (MOP) (46% K), were used. These prepared inputs were collected from the store of the College of Horticulture, SVPUA&T, Meerut.

Treatment Details

The different combinations of various concentrations of inorganic fertilizers were calculated and applied to dahlia plants at distinct intervals.

Sl.No.	Treatment Details	Notations
1.	100% Recommended dose of fertilizer (RDF) + blank organic/bio-fertilizer (Control)	T ₁
2.	75% RDF + 2.5ton/ha FYM + 2Kg/ha <i>Azotobacter</i> + 4.50 L/ha VAM	T ₂
3.	75% RDF + 2.5ton/ha FYM + 2Kg/ha <i>Azospirillum</i> + 4.50 L/ha VAM	T ₃
4.	75% RDF + 0.83ton/ha Vermicompost + 2Kg/ha <i>Azotobacter</i> + 4.50 L/ha VAM	T ₄
5.	75% RDF + 0.83ton/ha Vermicompost + 2Kg/ha <i>Azospirillum</i> + 4.50 L/ha VAM	T ₅
6.	75% RDF + 0.41ton/ha Poultry manure + 2Kg/ha <i>Azotobacter</i> + 4.50 L/ha VAM	T ₆
7.	75% RDF + 0.41ton/ha Poultry manure + 2Kg/ha <i>Azospirillum</i> + 4.50 L/ha VAM	T ₇
8.	50% RDF + 5ton/ha FYM + 4Kg/ha <i>Azotobacter</i> + 4.50 L/ha VAM	T ₈
9.	50% RDF + 5ton/ha FYM + 4Kg/ha <i>Azospirillum</i> + 4.50 L/ha VAM	T ₉
10.	50% RDF + 1.6ton/ha Vermicompost + 4Kg/ha <i>Azotobacter</i> + 4.50 L/ha VAM	T ₁₀
11.	50% RDF + 1.6ton/ha Vermicompost + 4Kg/ha <i>Azospirillum</i> + 4.50 L/ha VAM	T ₁₁
12.	50% RDF + 0.82ton/ha Poultry manure + 4Kg/ha <i>Azotobacter</i> + 4.50 L/ha VAM	T ₁₂
13.	50% RDF + 0.82ton/ha Poultry manure + 4Kg/ha <i>Azospirillum</i> + 4.50 L/ha VAM	T ₁₃
14.	25% RDF + 7.5ton/ha FYM + 6Kg/ha <i>Azotobacter</i> + 4.50 L/ha VAM	T ₁₄
15.	25% RDF + 7.5ton/ha FYM + 6Kg/ha <i>Azospirillum</i> + 4.50 L/ha VAM	T ₁₅
16.	25% RDF + 2.5ton/ha Vermicompost + 6Kg/ha <i>Azotobacter</i> + 4.50 L/ha VAM	T ₁₆
17.	25% RDF + 2.5ton/ha Vermicompost + 6Kg/ha <i>Azospirillum</i> + 4.50 L/ha VAM	T ₁₇
18.	25% RDF + 1.23ton/ha Poultry manure + 6Kg/ha <i>Azotobacter</i> + 4.50 L/ha VAM	T ₁₈
19.	25% RDF + 1.23ton/ha Poultry manure + 6Kg/ha <i>Azospirillum</i> + 4.50 L/ha VAM	T ₁₉

Methods

The experiment was laid out within three replications of 19 treatments and a total of 57 plots. Each replication had 19 plots. There were 12 plants in each plot, out of which 5 healthy plants had been selected for measuring qualitative characteristics. There were 6 vegetative parameters, 10 flowering parameters, and 12 soil parameters that were measured from each treatment. In vegetative parameters, the stem diameter (SD) was measured through calculating the average (avg) of three values from each plant by vernier caliper in millimeters (mm); number of primary branches (No. PB) were observed by counting of primary branches present on the plant. Leaf area (LA) was calculated with a leaf area meter

in unit mm²; chlorophyll index per leaves (Ch/L) was measured by using a soil plant analysis development (SPAD) meter by measuring five leaves from each plant, in which three readings were taken from each leaf, and the mean value was calculated which represent the chlorophyll content of the plant. Nitrogen content in leaves (N/L) were calculated by chlorophyll content in leaves (SPAD value) multiplied by constant value and expressed in mg/m².

$$\text{Nitrogen content in leaves } \left(\frac{\text{mg}}{\text{m}^2} \right) = \text{SPAD value} \times 0.48 \quad (1)$$

The total leaf area index (LAI) was calculated through dividing leaf area by the respective ground area from each treatment in cm.

$$LAI = \frac{\text{Leaf Area (cm}^2\text{)}}{\text{Ground Area Occupied by the Plant (cm}^2\text{)}} \quad (2)$$

In the flowering parameter, the number of days taken for the appearance of the first flower bud (DAFFB) was recorded. The days were counted from the date of planting until the first floral bud appeared. For each treatment, the values were then averaged across the selected plants. Days taken to color break (DTCB) were recorded from each plant of all treatments from the appearance of floral buds to color break and then the average was calculated. Days taken to first flower opening (DAFFO) were counted from the planting date of selected plants in each treatment to first flower opening in each treatment. Days taken to flower opening (DAFO) were counted from color break stage to full opening of flower and then the mean value was calculated. Duration of flowering (DOF) values were recorded from the time of the first flower opening until the last flower opening in each treatment and the mean value was calculated. Stalk diameter (StD) values were measured by calculating the average (avg) of three values from each plant by vernier caliper in millimeters (mm); fresh weight of flower (FWF) were taken from each plant by randomly selecting five flowers and the avg weight of the flower was calculated in gram (gm) by digital balancer; dry weight of flower (DWF) were measured in gram through weighing balance machine in gram after full drying of selected flowers for fresh weight at room temperature; flower diameter (FD) values were taken by scale in cm² using the method of the avg of the east to west and north to south length of the selected flowers; vase life (VL) values of selected flowers were counted in days from placing the fully open flower into the vase to the stage when the flowers started to lose their aesthetic value.

Each of the soil parameters was estimated from soil samples collected from a soil depth of 0 to 15 cm prior to the start of the experiment and after the termination of the experiment. Soil samples from furrow slices were collected to evaluate the effect of organic and inorganic inputs on pH, electrical conductivity, organic carbon, and the availability of nitrogen, phosphorus, and potassium. Collected soil samples were air-dried in the shade and ground using a pestle and mortar, passed through a 2-mm sieve, and stored in polythene bags for further analysis as per the method given below.

The pH of soil at planting time (pHP) and pH of soil after harvesting (pHH) were estimated by the 1:2 (soil water suspension) method given by Jackson (1973). The procedure was to measure 20 g of soil in a 50-mL beaker, add 40 mL of distilled water, and stir the mixture at least four times within a period of half an hour. This is required for the soil and water to reach an equilibrium state. After half an hour again, the soil suspension was stirred and the pH was measured with a pH meter.

The EC of soil was estimated by taking a soil sample of 20 g and pouring it into a 50-mL beaker. Then 40 mL of distilled water was added to the beaker followed by stirring four times within a period of half an hour. Again, stirring of soil suspension was done after half an hour. Then electric conductivity was measured on an electric conductivity meter (dS/m).

The available nitrogen in soil was estimated by taken 5 gm soil sample for micro-Kjeldahl's method given by Subbiah and Asija (1956) and calculated in ppm through given formula. The volume of acid used is equivalent to the amount of ammonia and also amount of nitrogen present in soil sample,

$$\text{Available Nitrogen Percentage (\%N)} = \frac{(V_1 - V_2) \times N \times 14 \times 100}{\text{Weight of soil} \times 1000} \quad (3)$$

where V_1 is the volume of acid used for the sample (mL), V_2 is the volume of acid for blank (mL), N is the normality of acid, 14 is the atomic weight of nitrogen, and W is the weight of soil sample (gm).

Then the ppm value of available nitrogen from the sample was converted into kilogram/hectare (Kg/ha) through the following conversion formula:

$$\text{Available Nitrogen} \left(\frac{\text{Kg}}{\text{ha}} \right) = \%N \times \frac{\text{Soil mass (kg/ha)}}{100} \quad (4)$$

Available phosphorus was determined using Olsen's method (Olsen *et al.* 1954). The intensity of the color was determined by a visible spectrophotometer at a wavelength of 660 nm using a red filter. The readings were then located in the standard curve and calculated in ppm through the given formula,

$$\text{Available Phosphorus (P ppm)} = \frac{C \times V_e}{W} \quad (5)$$

where C is the concentration of P from colorimeter reading (mg/L), V_e is the volume of extractant (mL), and W is the weight of soil (gm). The ppm value of available phosphorus from sample is converting into kg/ha through the conversion formula:

$$P \left(\frac{\text{kg}}{\text{ha}} \right) = P (\text{ppm}) \times 2.4 \quad (6)$$

Available potassium was extracted with neutral normal ammonium acetate as per the procedure given by Merwin and Peech (1951). The sample solution to the atomizer of the flame photometer, and the reading was indicated by the galvanometer needle. Then, with the help of the standard curve, the amount of available potassium in the soil under test was calculated,

$$\text{Available K (K ppm)} = \frac{C \times V_e}{W} \quad (7)$$

where C is the concentration of K from flame photometer, V_e is the volume of extractant (mL), and W is the weight of soil (gm). The ppm value of available K from sample is then converted into kg/ha through the conversion formula:

$$K \left(\frac{\text{kg}}{\text{ha}} \right) = K (\text{ppm}) \times 2.4 \quad (8)$$

The organic carbon percent was estimated by following the rapid titration method given by Walkely and Black (1934).

Statistical Analysis

The experiment was laid out according to a randomized complete block design (RCBD) with three replications and 19 treatments, making a total population of 285 plants in the experiment. The replications served as the blocking factor, which were arranged to minimize the influence of field heterogeneity, particularly soil fertility gradients across the experimental site. This ensured that treatment effects could be evaluated more accurately and with improved reliability. Collected data for growth, flowering, and soil health traits were taken from five selected plants from each treatment and analyzed using analysis of variance (ANOVA) to check any differences between the means (Gomez and Gomez 1984). Significant means were compared by using Tukey's honestly significant difference (HSD) test at a 5% probability level (Nanda *et al.* 2021) using Statistical Package for the Social Sciences (SPSS) software. As the study was not structured as a factorial design but rather as fixed INM treatment packages, main and interaction effects (organic source $\times$ fertilizer level) could not be separated; therefore, single-factor ANOVA was used.

RESULTS AND DISCUSSION

Effect of Integrated Nutrient Management on Vegetative Growth Characteristics of Dahlia

Significant variation ($P < 0.05$) was observed among the treatments for all vegetative growth parameters of dahlia (Table 1).

Stem Diameter (SD) mm

The plants treated with treatment T₁₇ (25% RDF + 2.5 ton/ha VC + 6 Kg/ha *Azospirillum* + 4.50 L/ha VAM) showed the best performance in terms of stem diameter (14.30 mm), followed by T₁₆ > T₄ > T₂, respectively. However, treatment T₇ (75% RDF + 0.41 tons/ha PM + 2 Kg/ha *Azospirillum* + 4.50 L/ha VAM) showed the lowest stem diameter (5.87 mm). Treatment T₁₇ achieved 25% RDF with the combination of VC, *Azospirillum*, and VAM, which increased microbial activity in the soil and enhanced macro and micro nutrients in the soil. These nutrients are crucial for overall growth and development, VC and *Azospirillum* produces many useful substances such as macro and micro nutrients, PGRs, and enzymes like lipases, chitinases, *etc.* (Arancon *et al.* 2020). The VAM enhances the ability of plants to absorb phosphorus from soil, also increases phyto-availability of micronutrients, and enhances absorption of trace elements (boron and molybdenum); the VAM is able to mobilize organically bound nitrogen (Abbasi *et al.* 2015), which enlarged the stem diameter. Similar results were also recorded by Verma *et al.* (2017), whereas chemical fertilizer with organic manure increases stem diameter in cape gooseberry.

Number of Primary Branches per Plant (No. PB)

The maximum number of primary branches (9.75) was observed in T₁₂ (50% RDF + 0.82 ton/ha PM + 4 Kg/ha *Azotobacter* + 4.50 L/ha VAM), which was statically superior to most treatments, followed by T₁₃ > T₁₆ > T₁₇. The lowest number of primary branches (2.42) was recorded in the control treatment (T₁). In this study, the number of primary braches per plant were significantly increased with the combination of 50% inorganic fertilizer, 0.82 ton/ha PM, 4 Kg/ha *Azotobacter*, and 4.50 L/ha VAM, thereby promoting macro, micro nutrients availability (Sumita *et al.* 2017), which is essential for protein and protoplasm synthesis in the plant (Rajaselvam *et al.* 2024). Additionally, microbial

inoculants such as VAM and *Azotobacter* enhance cytokinin synthesis, further boosting plant growth (Gangwar *et al.* 2017; Shaifali *et al.* 2024). The use of reduced inorganic fertilizers supports cell division and carbohydrate accumulation, improving vegetative growth (Singh 2018). Similar findings have been also reported in other crops by Verma *et al.* 2017 whereas 50% NPK with 50% organic manure increase the number of branches per plant in cape gooseberry. Chirukuri *et al.* (2023) also observed similar results in marigold flower.

Leaf area (LA) and Leaf area index (LAI) (mm²)

Treatment T₁₂ with the combination of 50% RDF, 0.82 ton/ha PM, 4 Kg/ha *Azotobacter*, and 4.50 L/ha VAM was recorded to outperform other treatments in terms of LA (97.75 mm²) and LAI (0.048 mm²), followed by T₁₃ > T₁₈ > T₁₉, respectively. In contrast, the control (T₁) showed poor performance in LA and LAI (75.32 mm² and 0.037mm², respectively).

The combination of T₁₂ had 50% RDF, PM, *Azotobacter*, and VAM, which has high microbial activity due to presence of fungi, bacteria. These microbes are reported to produce plant growth regulators (PGRs) (Mattos Abreu *et al.* 2021; Kaur *et al.* 2023a) and abscisic acid, which affects LA and LAI, which may be due to the cell division caused by cytokinins (Gangwar *et al.* 2017; Shaifali *et al.* 2024). Similarly, Verma *et al.* (2017) also observed optimum leaf width and length in cape gooseberry due to the application of 50% NPK with 50% organic manure. In spinach, Adison *et al.* (2024) also recorded the best results in leaf area per plant due to the effect of *Azotobacter* with organic manure.

Chlorophyll index (Ch/L) and Nitrogen Index (N/L) per Leaf (mg/m²)

The plants treated with treatment T₁₂ (50% RDF + 0.82 ton/ha PM + 4 Kg/ha *Azotobacter* + 4.50 L/ha VAM) showed the best performance in terms of chlorophyll index (55.45 mg/m²) and nitrogen index (26.62 mg/m²) per leaf, followed by T₁₃ > T₉ > T₁₇, respectively. However, treatment T₁ with 100% RDF was found to have the lowest chlorophyll index and nitrogen index in the leaf (45.00 mg/ha and 21.60 mg/ha, respectively).

Treatment T₁₂ reached 50% RDF with the combination of PM, *Azotobacter*, and VAM, which increases microbial activity in the soil and enhances macro and micro nutrients in the soil. Nitrogen (N) is a constituent of protein (Sumita *et al.* 2017), while phosphorus is known to promote cell division as well as photosynthetic activity (Rajaselvam *et al.* 2024), which plays a vital role in enhancing chlorophyll in leaves and as well as nitrogen in leaves. Similar results were also recorded by Iqbal *et al.* (2021), whereas chemical fertilizer with PM increased chlorophyll content in the leaves of the paddy crop.

Effect of Integrated Nutrient Management on Flowering Characteristics of Dahlia

The application of different combinations of organic, inorganic, and bio-fertilizers significantly ($P < 0.05$) influenced all flowering parameters of dahlia (*D. variabilis* L.) examined in the present study (Table 2).

Days Taken to Appearance of First Flower Bud (DAFFB)

The earliest bud initiation (52.00 days) was recorded in T₁₂ (50% RDF + 0.82 ton/ha PM + 4 kg/ha *Azotobacter* + 4.50 L/ha VAM), followed closely by T₁₃ > T₈ > T₄, all of

which were significantly earlier than the control (T_1). In contrast, treatments, T_{18} recorded the longest time to bud appearance (82.00 days).

Table 1. Effect of Integrated Nutrient Management on Vegetative Growth of Dahlia

Treatments	SD (mm)	No. PB	LA (mm ²)	LAI (mm ²)	Ch/L (mg/m ²)	N/L (mg/m ²)
T_1	7.47 ± 0.05 jk	2.42 ± 0.52	75.32 ± 8.87 c	0.037 ± 0.0046 c	45.00 ± 1.22 g	21.60 ± 0.59 g
T_2	11.21 ± 0.23 cd	4.92 ± 0.14 ghi	84.61 ± 0.89 abc	0.042 ± 0.0006 abc	45.60 ± 0.53 fg	21.89 ± 0.25 fg
T_3	6.83 ± 0.05 kl	4.00 ± 0.00 i	84.60 ± 2.43 abc	0.042 ± 0.0012 abc	49.32 ± 0.08 cdef	23.67 ± 0.04 cdef
T_4	11.59 ± 0.46 c	7.00 ± 0.00 cd	83.70 ± 8.64 abc	0.042 ± 0.0042 abc	46.96 ± 0.55 efg	22.54 ± 0.26 efg
T_5	10.74 ± 0.46 de	5.25 ± 0.43 fgh	77.90 ± 8.61 bc	0.039 ± 0.0042 bc	52.36 ± 2.22 abcd	25.13 ± 1.06 abcd
T_6	9.00 ± 0.21 fgh	5.92 ± 0.14 efg	85.80 ± 6.82 abc	0.042 ± 0.0031 abc	51.20 ± 2.16 bcd	24.58 ± 1.04 bcd
T_7	5.87 ± 0.11 m	4.00 ± 0.00 i	88.60 ± 2.14 abc	0.044 ± 0.0010 abc	48.35 ± 0.91 defg	23.21 ± 0.44 defg
T_8	8.34 ± 0.06 i	4.08 ± 0.14 i	89.31 ± 0.79 abc	0.044 ± 0.0006 abc	49.65 ± 0.26 cdef	23.83 ± 0.12 cdef
T_9	10.31 ± 0.11 e	5.00 ± 0.00 ghi	84.54 ± 2.15 abc	0.042 ± 0.0010 abc	53.20 ± 2.25 abc	25.54 ± 1.08 abc
T_{10}	9.44 ± 0.35 fg	5.92 ± 0.14 efg	85.48 ± 2.62 abc	0.042 ± 0.0015 abc	50.30 ± 0.99 cde	24.14 ± 0.47 cde
T_{11}	7.63 ± 0.46 j	4.92 ± 0.14 ghi	88.62 ± 1.64 abc	0.044 ± 0.0012 abc	52.90 ± 2.00 abc	25.39 ± 0.96 abc
T_{12}	9.53 ± 0.03 f	9.75 ± 0.43 a	97.75 ± 7.69 a	0.048 ± 0.0040 a	55.45 ± 0.69 a	26.62 ± 0.33 a
T_{13}	8.85 ± 0.31 ghi	8.67 ± 0.57 b	95.36 ± 2.02 a	0.047 ± 0.0010 a	54.80 ± 1.03 ab	26.30 ± 0.49 ab
T_{14}	6.84 ± 0.14 kl	4.00 ± 0.00 i	89.82 ± 2.43 abc	0.044 ± 0.0015 abc	49.20 ± 1.61 cdef	23.62 ± 0.77 cdef
T_{15}	6.51 ± 0.26 lm	4.25 ± 0.43 hi	90.47 ± 1.77 abc	0.045 ± 0.0012 abc	48.66 ± 0.39 defg	23.36 ± 0.18 defg
T_{16}	12.74 ± 0.07 b	7.67 ± 0.38 bc	93.23 ± 7.07 ab	0.046 ± 0.0036 ab	51.77 ± 1.86 abcd	24.85 ± 0.89 abcd
T_{17}	14.30 ± 0.10 a	7.33 ± 0.57 c	92.70 ± 4.82 ab	0.046 ± 0.0023 ab	53.10 ± 1.67 abc	25.49 ± 0.80 abc
T_{18}	8.33 ± 0.03 i	6.17 ± 0.14 def	94.25 ± 1.67 a	0.046 ± 0.0006 a	47.00 ± 1.22 efg	22.56 ± 0.58 efg
T_{19}	8.65 ± 0.09 hi	6.67 ± 0.57 cde	94.45 ± 4.61 a	0.047 ± 0.0025 a	50.18 ± 0.72 cde	24.09 ± 0.34 cde
CD (P <0.05)	0.34	0.53	8.33	0.0042	2.23	1.07
SE(m)	0.12	0.19	2.90	0.0015	0.77	0.37
CV (%)	2.29	5.89	5.70	5.81	2.68	2.68

SD, Stem Diameter; No.PB, Number of Primary Branches; LA, Leaf Area; LAI, Leaf Area Index; Ch/L, Chlorophyll Index per leaves; N/L, Nitrogen per Leaves

Note: Different letters in each column indicate significant differences, according to ANOVA ($p \leq 0.05$).

The current study examined treatment T₁₂ with 50% RDF + 0.82 ton/ha PM + 4 Kg/ha *Azotobacter* + 4.50 L/ha VAM influenced the DAFFB due to balanced the carbon-nitrogen ratio (C: N Ratio) and enhanced nutrient availability to the plant (Indhumathi *et al.* 2023), which is essential for bud initiation and flower development (Adhikari *et al.* 2020). Similar results were also observed by Ayoub and Masoodi (2023) on the hyacinth crop, where the minimum number of days taken to bud appearance was found in the treatment that was treated with a combination of RDF, organic manure, and bio-fertilisers. Indhumathi *et al.* (2023) also reported similar results in the gaillardia flower crop with the combination of RDF, organic manure, and bio-fertilizer.

Days Taken to Color Break (DTCB)

The maximum reduction in days to color break (5.33 days) was observed in treatment T₅ (75 %RDF + 0.83 ton/ha VC + 2 Kg/ha *Azospirillum* + 4.50 L/ha VAM), followed by treatment T₁ > T₁₂ > T₆, which were statistically superior. However, treatment T₁₇ (25% RDF + 2.5 ton/ha VC + 6 Kg/ha *Azospirillum* + 4.50 L/ha VAM) was recorded with the lowest reduction in days to color break (6.75 days). From a physiological point of view, balanced N, P, and K is a prerequisite for bud initiation and its development (Adhikari *et al.* 2020). These elements are crucial for floral primordial production (Choudhary *et al.* 2021). Phytohormones from *Azotobacter* and VAM promote cell division and expansion, accelerating blooming (Abdel-Ghany *et al.* 2019; Ayoub and Masoodi 2023; Paul *et al.* 2024). These results are in close conformity with the findings of Ayoub and Masoodi 2023 on the hyacinth flower crop.

Days Taken to First Flower Opening (DAFFO) and Days Taken to Flower Opening (DAFO)

Treatments T₁₂ (50% RDF + 0.82 ton/ha PM + 4 Kg/ha *Azotobacter* + 4.50 L/ha VAM), recorded the earliest first flower opening (62.17 days), followed by treatment T₁₃ > T₈ > T₄, which were significantly earlier than T₁ (93.92 days). In contrast, taken maximum days for first flower opening was counted in treatment T₁.

In terms of DAFO, T₁₂ (50% RDF + 0.82 ton/ha PM + 4 Kg/ha *Azotobacter* + 4.50 L/ha VAM) and T₅ (75 %RDF + 0.83 ton/ha VC + 2 Kg/ha *Azospirillum* + 4.50 L/ha VAM), both treatments taken same days to flower opening (9.00 days), followed by T₁₃ > T₉ > T₆ > T₂, while the treatment T₁ (control) required the longest duration for flower opening (12.42 days).

In the present investigation, treatment T₁₂ (50% RDF + 0.82 ton/ha PM + 4 Kg/ha *Azotobacter* + 4.50 L/ha VAM) significantly reduced the days taken to first flower opening and days taken to flower opening, primarily by optimizing the C:N ratio and enhancing nutrient bioavailability, which is essential for floral development or floral primordia initiation (Singh *et al.* 2015; Ahmed *et al.* 2023; Shah *et al.* 2024), while phytohormones synthesized by *Azotobacter* and VAM (Singh *et al.* 2015), such as Auxins, gibberellins and cytokinins, promote cell division and expansion, thereby accelerating flowering (Ahmed *et al.* 2023; Paul *et al.* 2024). Similar findings have been reported in hyacinth, where integrated application of RDF, organic manure, and biofertilizers resulted in earlier flower opening (Ayoub and Masoodi 2023), and in Gaillardia under combined nutrient management (Indhumathi *et al.* 2023)

Duration of Flowering (DOF)

The maximum duration of flowering (74.75 days) was observed in T₁₂ (50% RDF + 0.82 ton/ha PM + 4 Kg/ha *Azotobacter* + 4.50 L/ha VAM), which was followed by T₁₃

$T_8 > T_4$, while the treatment T_1 (control) recorded the minimum days of flowering (43.17 days). Treatment T_{12} (50% RDF + 0.82 ton/ha PM + 4 Kg/ha *Azotobacter* + 4.50 L/ha VAM) significantly influenced the duration of flowering. This effect is attributed to the slow mineralization of PM, which serves as a sustainable source of N, P, and K, thereby ensuring continuous nutrient supply and enhanced assimilation (James *et al.* 2020; Kumar *et al.* 2024b), which encouraged the long duration of flowering. Similar experiment results were also reported by Indhumathi *et al.* (2023) in the Gaillardia flower crop. Ayoub and Masoodi (2023) also recorded similar results in the hyacinth crop.

Stalk Diameter (StD) (mm)

T_{17} (25% RDF + 2.5 ton/ha VC + 6 Kg/ha *Azospirillum* + 4.50 L/ha VAM) recorded the maximum stalk diameter (10.30 mm), followed by $T_{16} > T_4 > T_2$, whereas the lowest stem diameter (1.87 mm) was noted in T_7 (75% RDF + 0.41 ton/ha PM + 2 kg/ha *Azospirillum* + 4.50 L/ha VAM). Vermicompost has high microbial activity due to presence of fungi, bacteria and actinomycetes (Prasad *et al.* 2018). These microbes are reported to produce plant growth regulators (PGRs) such as auxins, gibberellins, cytokinins, ethylene, and abscisic acid (Dikr and Belete 2017). Similar results were also observed by Ayoub and Masoodi (2023) on the hyacinth crop, where the maximum stalk thickness was found in the treatment that was treated with a combination of RDF, organic manure, and bio-fertilisers.

Fresh and Dry Weight of Flowers (FWF and DWF) (gm)

The highest fresh flower weight was obtained in T_{12} (34.60 gm), followed by $T_{13} > T_{10} > T_7$, while the T_1 control recorded the lowest (24.70 gm).

Similarly, the maximum dry flower weight was recorded in T_{12} (3.46 gm), followed by $T_{13} > T_{10} > T_7$, whereas the treatment T_1 (control) had the lowest (2.47 gm).

The observed enhancement may be attributed to the synergistic effects of PM and *Azotobacter*, wherein improved nutrient availability and microbial activity promoted greater floral expansion, leading to increased flower diameter and corolla length, which consequently contributed to higher individual flower weight (Indhumathi *et al.* 2023). Similar results were also mentioned by Prasad *et al.* (2018) on dahlia crop and close conformity with the findings of Kaushik and Singh (2020) in the marigold crop.

Flower Diameter (FD) (cm²)

Maximum flower diameter (18.00 cm²) was observed in T_{17} (25% RDF + 2.5 ton/ha VC + 6 Kg/ha *Azospirillum* + 4.50 L/ha VAM), followed by $T_{16} > T_{15} > T_{19}$, which were significantly larger than the T_1 (control) (11.28 cm²). These enhancement may be attributed to the effects of PM and *Azotobacter*, which improved nutrient availability and microbial activity, thereby promoting floral expansion and resulting in increased flower diameter and corolla length (Kaushik and Singh 2018). The experimental results are in accordance with the findings of Koli and Jayanthi (2018) in marigold crop with organic and inorganic combinations of different treatments. Prasad *et al.* (2018) also reported similar results in dahlia with integrated nutrient managements. Abhishek *et al.* (2024) also observed the effect of organic manures in the marigold crop.

Vase Life (VL)

The longest vase life (7.10 days) was observed in T₁₀ (50 %RDF + 1.6 ton/ha VC +4 Kg/ha *Azotobacter* + 4.50 L/ha VAM), followed by T₁₇ > T₁₁ > T₁₉, while the shortest was recorded in T₁ with 100% RDF (3.8 days).

Table 2. Effect of Integrated Nutrient Management on Flowering of Dahlia

Treat-ments	DAFFB (days)	DTCB (days)	DFFO (days)	DAFO (days)	DOF (days)	StD (mm)	FWF (gm)	DWF (gm)	FD (cm ²)	VL (days)
T ₁	81.83 ± 3.60 a	5.33 ± 0.14 b	93.92 ± 2.42 a	12.42 ± 0.28 a	43.17 ± 2.40 d	3.47 ± 0.05 jk	24.70 ± 0.37 k	2.47 ± 0.03 k	11.28 ± 0.18 ij	3.77 ± 0.25 e
T ₂	79.92 ± 3.32 a	5.75 ± 0.25 ab	91.00 ± 2.94 ab	10.00 ± 0.00 de	45.92 ± 3.05 cd	7.21 ± 0.23 cd	30.20 ± 0.57 cde	3.02 ± 0.05 cde	13.56 ± 0.25 fg	5.00 ± 0.50 bcde
T ₃	81.00 ± 1.32 a	6.08 ± 0.14 ab	92.5 ± 1.14 a	11.33 ± 0.38 bc	44.50 ± 1.25 d	2.83 ± 0.04 kl	30.80 ± 0.91 cd	3.08 ± 0.09 cd	12.64 ± 0.00 gh	5.00 ± 0.50 bcde
T ₄	54.00 ± 0.00 c	6.00 ± 0.14 b	65.75 ± 0.43 cd	12.08 ± 0.14 a	71.25 ± 0.43 ab	7.59 ± 0.46 c	27.00 ± 0.99 ghijk	2.70 ± 0.09 ghijk	11.40 ± 0.37 ij	4.53 ± 0.25 cde
T ₅	79.08 ± 1.46 ab	5.33 ± 0.66 ab	89.00 ± 2.04 ab	9.00 ± 0.00 f	48.08 ± 2.02 cd	6.74 ± 0.45 de	29.00 ± 1.07 cdefgh	2.90 ± 0.10 cdefgh	14.20 ± 0.01 f	4.43 ± 0.60 cde
T ₆	78.08 ± 1.18 ab	5.75 ± 0.00 ab	89.33 ± 0.28 ab	10.00 ± 0.00 de	47.67 ± 0.28 cd	5.01 ± 0.21 fgh	28.20 ± 0.78 efghi	2.82 ± 0.08 efghi	10.50 ± 0.14 jk	5.20 ± 0.17 bcd
T ₇	55.17 ± 1.25 c	6.33 ± 0.52 ab	67.08 ± 0.62 cd	12.08 ± 0.14 a	70.00 ± 0.50 ab	1.87 ± 0.10 m	31.20 ± 0.53 c	3.12 ± 0.05 c	16.50 ± 0.55 c	4.20 ± 0.17 cde
T ₈	53.92 ± 0.14 c	6.08 ± 0.14 ab	64.67 ± 1.94 cd	11.00 ± 0.00 c	72.42 ± 1.84 ab	4.34 ± 0.06 i	26.70 ± 0.96 hijk	2.67 ± 0.09 hijk	16.42 ± 0.11 cd	4.03 ± 0.46 de
T ₉	57.08 ± 0.38 c	5.92 ± 0.14 ab	69.17 ± 0.38 c	10.00 ± 0.25 de	68.00 ± 0.43 b	6.31 ± 0.11 e	26.30 ± 0.61 ijk	2.63 ± 0.06 ijk	13.64 ± 0.24 fg	4.20 ± 0.52 cde
T ₁₀	80.08 ± 2.98 a	5.83 ± 0.57 ab	91.83 ± 0.80 ab	11.08 ± 0.14 c	45.25 ± 0.90 cd	5.45 ± 0.35 fg	31.30 ± 0.14 bc	3.13 ± 0.01 bc	12.28 ± 0.43 hi	7.10 ± 0.52 a
T ₁₁	73.92 ± 2.32 b	6.58 ± 0.38 a	85.92 ± 3.88 b	12.00 ± 0.00 ab	51.17 ± 3.74 c	3.63 ± 0.04 j	28.30 ± 0.56 defghi	2.83 ± 0.05 defghi	14.38 ± 0.20 ef	5.33 ± 0.28 bc
T ₁₂	52.00 ± 0.00 c	5.75 ± 0.25 ab	62.17 ± 1.42 d	9.00 ± 0.00 f	74.75 ± 1.56 a	5.53 ± 0.03 f	34.60 ± 1.46 a	3.46 ± 1.14 a	13.70 ± 0.52 fg	4.27 ± 0.25 cde
T ₁₃	53.00 ± 1.39 c	6.17 ± 0.14 ab	64.00 ± 0.50 cd	9.92 ± 0.14 e	72.92 ± 0.62 ab	4.85 ± 0.31 ghi	33.80 ± 0.81 ab	3.38 ± 0.08 ab	10.20 ± 0.32 k	4.20 ± 0.17 cde
T ₁₄	80.00 ± 1.56 a	6.08 ± 0.52 ab	92.33 ± 3.16 ab	12.17 ± 0.14 a	44.58 ± 3.30 d	2.84 ± 0.14 kl	25.30 ± 1.08 jk	2.53 ± 0.10 jk	9.69 ± 0.07 k	4.93 ± 0.40 cde
T ₁₅	76.92 ± 2.84 ab	6.08 ± 0.14 ab	88.83 ± 3.64 ab	11.08 ± 0.14 c	48.33 ± 3.68 cd	2.51 ± 0.26 lm	27.40 ± 0.66 fghij	2.74 ± 0.06 fghij	16.91 ± 0.42 bc	4.37 ± 0.11 cde
T ₁₆	79.00 ± 1.56 ab	6.5 ± 0.66 a	90.42 ± 1.04 ab	10.08 ± 0.14 de	46.58 ± 0.80 cd	8.75 ± 0.06 b	28.40 ± 0.79 defghi	2.84 ± 0.07 defghi	17.63 ± 0.46 ab	5.03 ± 0.25 bcd
T ₁₇	77.08 ± 1.46 ab	6.75 ± 0.25 a	89.08 ± 1.04 ab	12.00 ± 0.00 ab	47.92 ± 1.04 cd	10.30 ± 0.09 a	29.70 ± 0.69 cdef	2.97 ± 0.07 cdef	18.00 ± 0.19 a	6.20 ± 0.17 ab
T ₁₈	82.00 ± 1.56 a	5.92 ± 0.14 ab	92.83 ± 3.71 a	10.67 ± 0.57 cd	44.25 ± 3.60 d	4.33 ± 0.03 i	29.40 ± 0.98 cdefg	2.94 ± 0.09 cdefg	15.38 ± 0.67 de	4.43 ± 0.51 cde
T ₁₉	81.08 ± 1.42 a	6.58 ± 0.14 a	93.25 ± 0.75 a	12.42 ± 0.38 a	43.67 ± 0.76 d	4.65 ± 0.08 hi	26.80 ± 0.38 hijk	2.68 ± 0.03 hijk	16.50 ± 0.09 c	5.13 ± 1.25 bcd
CD (P <0.05)	3.08	0.58	3.50	0.36	3.50	0.34	1.36	0.13	0.57	0.66
SE(m)	1.07	0.20	1.22	0.12	1.22	0.12	0.47	0.04	0.19	0.23
CV (%)	2.61	5.82	2.55	2.02	3.90	3.19	2.85	2.86	2.47	8.40

DAFFB, Days taken to appearance first flower bud; DTCB, Days taken to color break; DAFFO, Days taken to first flower opening; DAFO, Days taken to flower opening; DOF, Duration of flowering; StD, Stalk diameter; FWF, Fresh weight of flower; DWF, Dry weight of flower; FD, Flower diameter; VL, Vase life

Note: Different letters in each column indicate significant differences, according to ANOVA ($p \leq 0.05$).

The delay degeneration of water-conducting tissues in dahlia may be attributed to the phytohormonal activities of vermicompost and biofertilizer, which collectively contributed to prolonged floral freshness (Jha *et al.* 2020; Indhumathi *et al.* 2023). The application of biofertilizers likely extended vase life due to the higher retention of water in the cells of flowers and lower desiccation (Koli and Jayanthi 2018). These results are in close conformity with the findings of Kumar *et al.* (2019a) on the dahlia flower crop. Chaudhary *et al.* (2020) also noticed similar results in dahlia. After that, Sarkar *et al.* (2024) reported similar findings in chrysanthemum.

Effect of Integrated Nutrient Management on Soil Chemical Properties

Significant differences ($P < 0.05$) were observed among treatments for all soil chemical properties at both the planting and harvesting stages in dahlia, shown in Tables 3 and 4.

Available Nitrogen at Planting Time (ANP) and after Harvesting Time (ANH) (Kg/ha)

At planting time, the highest available nitrogen (253 kg/ha) was recorded in T₇ (75% RDF + 0.41ton/ha Poultry manure + 2Kg/ha *Azospirillum* + 4.50 L/ha VAM), which was statistically followed by T₆ > T₄ > T₅. However, the lowest value was found in the control T₁ (220 kg/ha).

After harvesting of the crop, T₇ (75% RDF + 0.41ton/ha Poultry manure + 2Kg/ha *Azospirillum* + 4.50 L/ha VAM) again showed the maximum nitrogen content (238 kg/ha), followed closely by T₆ > T₅ > T₄, while T₁ recorded the minimum (196 kg/ha) available nitrogen in soil after the harvest.

The improvement in nitrogen availability under INM treatments may be attributed to the synergistic role of organic amendments and biofertilizers, which enhance microbial activity and mineralization processes (Zhang *et al.* 2023; Neelima *et al.* 2022). Poultry manure provides a slow and sustained release of nitrogen, reducing leaching losses compared with sole inorganic fertilizers (Tomar and Saikia 2022). Furthermore, *Azospirillum* improves nitrogen fixation and enhances rhizosphere activity, thereby increasing N availability (Wang *et al.* 2020). These results are consistent with earlier studies demonstrating that INM improves soil nitrogen dynamics compared with chemical fertilization alone (Madhurya *et al.* 2022; Al-Shammary *et al.* 2024).

Available Potassium at Planting Time (AKP) and after Harvesting (AKH) (Kg/ha)

At planting, the highest available potassium (199.36 kg/ha) was observed in T₇ (75% RDF + 0.41ton/ha Poultry manure + 2Kg/ha *Azospirillum* + 4.50 L/ha VAM), followed by T₆ > T₅ > T₄, which were significantly superior to most other treatments. The lowest potassium value was recorded in T₁₉ (170.67 kg/ha).

After harvest, T₆ (75 %RDF + 0.41 ton/ha PM + 2 Kg/ha *Azotobacter* + 4.50 L/ha VAM) maintained the maximum potassium level (159 kg/ha), which was followed by T₇ > T₁₂ > T₄, while the treatment T₁ control recorded the minimum potassium level (133 kg/ha) after harvesting crop. The increase in potassium availability under INM treatments can be explained by the role of organic manures and biofertilizers in mobilizing nutrients, enhancing cation exchange capacity, and reducing nutrient depletion (Neelima *et al.* 2022; Zhang *et al.* 2023). This finding corroborates the observations of Tomar and Saikia (2022)

and Indhumathi (2023), who reported enhanced soil K availability with integrated approaches.

Table 3. Effect of Integrated Nutrient Management on Soil Chemical Properties in Dahlia

Treatments	ANP (kg/ha)	ANH (kg/ha)	AKP (kg/ha)	AKH (kg/ha)	APP (kg/ha)	APH (kg/ha)
T ₁	220.04 ± 1.03 b	195.80 ± 16.70 b	190.51 ± 3.80 abc	132.74 ± 1.67 b	17.21 ± 0.73 abc	12.27 ± 1.68 b
T ₂	227.61 ± 5.96 ab	210.81 ± 20.26 ab	186.96 ± 4.47 abc	139.79 ± 8.30 ab	16.47 ± 0.45 abc	12.98 ± 0.66 ab
T ₃	222.65 ± 4.56 ab	210.65 ± 16.39 ab	193.49 ± 6.34 ab	139.57 ± 2.64 ab	16.33 ± 1.01 abc	12.99 ± 0.66 ab
T ₄	250.31 ± 7.29 ab	235.01 ± 5.60 a	193.46 ± 8.19 a	155.68 ± 16.19 ab	18.48 ± 1.21 abc	15.48 ± 1.37 a
T ₅	248.27 ± 2.50 ab	235.19 ± 1.45	197.58 ± 4.51 a	154.48 ± 3.29 ab	19.06 ± 0.84 ab	15.47 ± 1.09 a
T ₆	251.23 ± 2.71 ab	236.24 ± 3.85	198.54 ± 4.22 a	159.47 ± 3.00 a	19.36 ± 0.92 a	15.92 ± 0.46 a
T ₇	252.81 ± 5.61 a	237.76 ± 4.04 a	199.36 ± 22.05 a	158.92 ± 6.64 a	18.68 ± 1.24 abc	15.68 ± 1.06 a
T ₈	222.54 ± 10.67 ab	209.24 ± 13.20 ab	192.11 ± 3.18 abc	144.63 ± 4.38 ab	16.63 ± 1.28 abc	13.30 ± 0.73 ab
T ₉	221.24 ± 20.66 ab	207.43 ± 24.30 ab	190.46 ± 5.84 abc	137.43 ± 1.42 ab	16.45 ± 1.45 abc	14.12 ± 0.45 ab
T ₁₀	239.38 ± 14.51 ab	225.69 ± 6.44 ab	197.13 ± 5.82 ab	138.37 ± 1.28 ab	17.31 ± 0.99 abc	14.31 ± 1.03 ab
T ₁₁	237.98 ± 6.82 ab	224.41 ± 3.57 ab	197.75 ± 7.24 a	137.91 ± 11.01 ab	17.11 ± 1.61 abc	14.11 ± 1.63 ab
T ₁₂	245.08 ± 4.10 ab	233.03 ± 4.84 ab	195.44 ± 7.36 ab	156.36 ± 18.57 ab	18.36 ± 1.50 abc	15.36 ± 0.80 a
T ₁₃	247.05 ± 4.36 ab	234.73 ± 3.65 a	193.24 ± 11.16 abc	154.28 ± 3.54 ab	18.28 ± 0.85 abc	15.28 ± 1.65 ab
T ₁₄	221.89 ± 10.63 ab	204.58 ± 3.85 ab	179.24 ± 8.95 abc	135.61 ± 2.26 ab	16.22 ± 1.43 abc	13.23 ± 1.45 ab
T ₁₅	229.21 ± 6.01 ab	200.35 ± 19.86 ab	174.96 ± 8.50 ab	135.29 ± 9.53 ab	16.28 ± 0.70 abc	13.28 ± 0.32 ab
T ₁₆	235.12 ± 16.95 ab	211.12 ± 22.66 ab	185.89 ± 2.45 abc	137.52 ± 2.14 ab	15.94 ± 0.59 bc	13.27 ± 0.77 ab
T ₁₇	232.46 ± 19.80 ab	210.46 ± 9.65 ab	186.52 ± 1.20 abc	140.36 ± 12.78 ab	15.96 ± 0.83 bc	13.62 ± 0.79 ab
T ₁₈	238.32 ± 4.88 ab	217.32 ± 11.57 ab	180.59 ± 1.28 abc	141.71 ± 9.64 ab	15.61 ± 0.80 c	13.28 ± 0.29 ab
T ₁₉	237.46 ± 12.84 ab	216.46 ± 6.21 ab	170.67 ± 1.81 c	142.07 ± 2.79 ab	15.87 ± 1.10 bc	13.54 ± 0.27 ab
CD (P <0.05)	17.02	20.10	12.13	13.66	1.80	1.65
SE(m)	5.93	7.01	4.23	4.70	0.63	0.57
CV (%)	4.35	5.55	3.85	5.71	6.37	7.08

ANP, Available nitrogen in soil at planting time; ANH, Available nitrogen in soil after harvesting; AKP, Available potassium in soil at planting time; AKH, Available potassium in soil after harvesting; APP, Available phosphorous in soil at planting time; APH, Available phosphorous in soil after harvesting; Note: Different letters in each column indicate significant differences, according to ANOVA ($p \leq 0.05$).

Available Phosphorous at Planting Time (APP) and after Harvesting Time (APH) (Kg/ha)

Phosphorus availability at planting (19.36 kg/ha) was highest in T₆ (75 %RDF + 0.41 ton/ha PM + 2 Kg/ha *Azotobacter* + 4.50 L/ha VAM), which was followed by T₅ > T₇ > T₄, significantly higher than the treatment T₁₈ (15.61 kg/ha).

After harvest, the maximum phosphorus level (15.9 kg/ha) was recorded in the treatment T₆ (75 %RDF + 0.41 ton/ha PM + 2 Kg/ha *Azotobacter* + 4.50 L/ha VAM) and followed by T₇ > T₄ > T₅, while the lowest was observed in the treatment T₁ (12.27 kg/ha).

The improvement in phosphorus status under INM treatments is attributed to the role of poultry manure and VAM in solubilizing and mobilizing phosphorus. VAM fungi act as chelating agents and produce organic acids and phosphatases, which release bound phosphorus for plant uptake (Debnath *et al.* 2023; Indhumathi 2023; Sinha *et al.* 2024). Similar phosphorus enhancement under INM practices has been documented in multiple studies (Madhurya *et al.* 2022; Al-Shammmary *et al.* 2024).

Table 4. Effect of Integrated Nutrient Management on Soil Chemical Properties in Dahlia

Treat-ments	AOCP (%)	AOCH (%)	ECP (dSm ⁻¹)	ECH (dSm ⁻¹)	pHP	pHH
T ₁	0.36 ± 0.02 b	0.34 ± 0.01 d	0.21 ± 0.01 ef	0.19 ± 0.005 de	7.80 ± 0.40	7.70 ± 0.44
T ₂	0.42 ± 0.01 ab	0.39 ± 0.04 bcd	0.24 ± 0.01 abcdef	0.20 ± 0.02 bcde	7.71 ± 0.22	7.61 ± 0.92
T ₃	0.43 ± 0.01 ab	0.37 ± 0.03 cd	0.22 ± 0.01 def	0.19 ± 0.02 cde	7.69 ± 0.70	7.59 ± 0.57
T ₄	0.44 ± 0.01 ab	0.39 ± 0.02 bcd	0.21 ± 0.01 f	0.18 ± 0.01 de	7.67 ± 0.87	7.57 ± 0.68
T ₅	0.42 ± 0.04 ab	0.38 ± 0.01 bcd	0.21 ± 0.02 def	0.17 ± 0.01 e	7.65 ± 0.21	7.55 ± 0.85
T ₆	0.43 ± 0.03 ab	0.41 ± 0.01 abcd	0.21 ± 0.005 f	0.18 ± 0.01 e	7.64 ± 0.60	7.54 ± 0.75
T ₇	0.44 ± 0.02 ab	0.40 ± 0.02 abcd	0.23 ± 0.02 abcdef	0.19 ± 0.01 de	7.66 ± 0.75	7.56 ± 0.22
T ₈	0.43 ± 0.02 ab	0.42 ± 0.02 abcd	0.26 ± 0.02 abcd	0.23 ± 0.01 abcd	6.90 ± 0.74	6.80 ± 0.24
T ₉	0.49 ± 0.005 a	0.43 ± 0.03 abcd	0.25 ± 0.02 abcdef	0.22 ± 0.005 abcde	6.80 ± 0.34	6.70 ± 0.73
T ₁₀	0.46 ± 0.01 a	0.40 ± 0.02 abcd	0.24 ± 0.005 abcdef	0.21 ± 0.02 abcde	7.55 ± 0.26	7.45 ± 0.69
T ₁₁	0.45 ± 0.03 a	0.41 ± 0.02 abcd	0.23 ± 0.015 bcdef	0.20 ± 0.01 cde	7.50 ± 0.40	7.40 ± 0.68
T ₁₂	0.45 ± 0.03 a	0.40 ± 0.04 abcd	0.22 ± 0.02 cdef	0.19 ± 0.02 cde	7.60 ± 0.62	7.50 ± 0.49
T ₁₃	0.44 ± 0.05 ab	0.40 ± 0.04 abcd	0.23 ± 0.005 bcdef	0.19 ± 0.01 de	7.70 ± 0.17	7.60 ± 0.27
T ₁₄	0.49 ± 0.01 a	0.47 ± 0.03 a	0.28 ± 0.01 a	0.26 ± 0.02 a	6.60 ± 0.21	6.50 ± 0.46
T ₁₅	0.51 ± 0.03 a	0.49 ± 0.01 ab	0.28 ± 0.015 ab	0.25 ± 0.02 ab	6.70 ± 0.59	6.60 ± 0.57
T ₁₆	0.48 ± 0.03 a	0.44 ± 0.01 abc	0.27 ± 0.02 abc	0.24 ± 0.02 abc	7.10 ± 0.77	7.00 ± 0.44
T ₁₇	0.49 ± 0.03 a	0.45 ± 0.02 abc	0.26 ± 0.02 abcde	0.23 ± 0.02 abcd	7.27 ± 0.85	7.17 ± 0.47
T ₁₈	0.46 ± 0.05 a	0.42 ± 0.02 abc	0.24 ± 0.01 abcdef	0.21 ± 0.01 bcde	7.28 ± 0.17	7.18 ± 0.24
T ₁₉	0.45 ± 0.02 a	0.41 ± 0.05 abc	0.24 ± 0.02 abcdef	0.21 ± 0.005 bcde	7.30 ± 0.33	7.20 ± 0.29
CD (P <0.05)	0.049	0.049	0.028	0.028	0.90	0.93
SE(m)	0.017	0.017	0.009	0.009	0.31	0.32
CV (%)	6.68	7.22	7.10	8.17	7.41	7.73

AOCP, Available organic carbon in soil at planting time; AOCH, Available organic carbon in soil after harvesting; ECP, Electrical conductivity at planting time; ECH, Electrical conductivity after harvesting; pHP, pH of soil at planting time; pHH, pH of soil after harvesting; Different letters within each column indicates significant different at $p \leq 0.05$.

Soil Organic Carbon (SOC) at Planting (AOCp) and after Harvest (AOCH) (percentage %)

The maximum organic carbon at planting (0.51%) was recorded in T₁₅ (25 %RDF + 7.5 ton/ha FYM + 6 Kg/ha *Azospirillum* + 4.50 L/ha VAM), which were followed by T₁₄ > T₁₇ > T₉. In contrast, the control (T₁) showed the lowest value (0.36%).

After harvest, AOCp (0.49%) was found highest in T₁₅ (25 %RDF + 7.5 ton/ha FYM + 6 Kg/ha *Azospirillum* + 4.50 L/ha VAM), followed by T₁₄ > T₁₇ > T₁₆. Meanwhile, Treatment T₁ was found to have the lowest in soil organic carbon after harvesting (0.34%).

The addition of FYM, and biofertilizers has been found to contribute to organic matter accumulation and microbial proliferation, thereby improving SOC retention (Raj *et al.* 2024; Choudhary *et al.* 2022). Enhanced microbial activity accelerates organic matter turnover, maintaining SOC levels (Mori *et al.* 2024). In contrast, sole inorganic fertilizer application was found to lead to reduced SOC, consistent with earlier findings (Bhunia *et al.* 2021; Esmaeilian *et al.* 2024).

Electrical Conductivity (EC) at Planting (ECP) and After Harvest (ECH) (dSm⁻¹)

EC at planting (0.28 dS m⁻¹) was highest in both the treatments T₁₄ (25 %RDF + 7.5 ton/ha FYM + 6 Kg/ha *Azotobacter* + 4.50 L/ha VAM) and T₁₅ (25 %RDF + 7.5 ton/ha FYM + 6 Kg/ha *Azospirillum* + 4.50 L/ha VAM), followed by T₁₆ > T₁₇ > T₈, which were significantly greater than T₅ (0.21 dS m⁻¹).

After harvest, T₁₄ (25 %RDF + 7.5 ton/ha FYM + 6 Kg/ha *Azotobacter* + 4.50 L/ha VAM) again maintained the highest ECH (0.26 dS m⁻¹), which was followed by T₁₅ > T₁₆ > T₁₇, while T₅ recorded the lowest ECH (0.17 dS m⁻¹).

Slight increases in EC under organic-integrated treatments are linked to the release of soluble ions during organic matter decomposition (Raj *et al.* 2024). This moderate rise in EC indicates improved nutrient availability without exceeding optimal soil ionic balance. Previous studies also highlighted the positive role of INM in maintaining favorable EC values (Madhurya *et al.* 2022; Choudhary *et al.* 2022).

Soil pH at Planting (pHP) and After Harvest (pHH)

Soil pH showed significant variation, with lower values observed under organic-integrated treatments compared with the control. At planting time, the best pH (6.60) was recorded in T₁₄ (25 %RDF + 7.5 ton/ha FYM + 6 Kg/ha *Azotobacter* + 4.50 L/ha VAM), which was followed by T₁₅ > T₉ > T₈, whereas the control T₁ maintained the highest pH (7.80).

A similar trend was observed after harvest, with the best pH (6.50) being recorded in T₁₄ (25 %RDF + 7.5 ton/ha FYM + 6 Kg/ha *Azotobacter* + 4.50 L/ha VAM), followed by T₁₅ > T₉ > T₈. While the treatment T₁ was recorded with the highest pH (7.70).

The reduction in soil pH can be attributed to proton release during organic matter mineralization and enhanced microbial activity, which leads to the production of organic acids (Sinha *et al.* 2024). Organic amendments are known to buffer soil pH and maintain it closer to neutral compared with sole chemical fertilizers (McFarland *et al.* 2024). Similar pH-lowering effects of INM have been documented by Choudhary *et al.* (2022), Indhumathi (2023), and Ananthi and Shree (2024).

CONCLUSIONS

1. The study demonstrated that integrated nutrient management (INM) significantly affected vegetative development and blooming of *D. variabilis* L. cv. Zail Singh compared with sole reliance on inorganic fertilizers. Treatment T₁₂ showed superior in primary branch count, leaf area, leaf area index (LAI), nitrogen index, and chlorophyll index. Days to first flower bud appearance, flower opening, first flower opening, and flower weight (fresh and dried) were among its strengths.
2. Treatment T₁₇, which had 25% of the recommended dosage of fertilizer (RDF), vermicompost (VC), *Azospirillum*, and Vesicular arbuscular mycorrhizal (VAM), had the biggest stem, stalk, and flower diameters. In contrast, treatment T₅ caused the color to break early. Treatment T₁₀ improved the vase life of *Dahlia* cv. Zail Singh.
3. Both T₇ and T₆ improved nitrogen, phosphorus, and potassium (NPK) levels in the soil, while T₁₄ and T₁₅ improved levels of organic carbon, electrical conductivity (EC), and pH in the soil. Treating T₁ with 100% inorganic fertilizers failed to improve most metrics, highlighting the drawbacks of chemical fertilizers.
4. Overall, the treatment T₁₂ (50% RDF + 0.82 ton/ha PM + 4 Kg/ha *Azotobacter* + 4.50 L/ha VAM) was found best in all among the treatments in respective to most of the vegetative and flowering parameters, thereby offering sustainable ornamental horticulture.

Conflict of Interest Statement

The authors state that none of the work described in this study could have been influenced by any known competing financial interests or personal relationships.

Author's Contributions

Krishna Kaushik conducted the study, designed the methodology, analyzed data, and drafted the manuscript. Mukesh Kumar assisted in the conceptualized research, contributing to editing, and revising the manuscript. Kedar Mahadev Gheware supported data analysis, provided technical help, and contributed to the literature review and manuscript accuracy. Ravi Kumar assisted in research and manuscript revisions. Rohan Tomar, Devanshu Shukla, Abhay Vedwan, Shivani Chahar, and Mahima Sharma coordinated research activities, managed logistics, provided statistical support, and contributed to manuscript preparation. All authors approved the final manuscript and are accountable for the work.

REFERENCES CITED

- Aashutosh, Kumar, M., Malik, S., Singh, M. K., Singh, S. P., Chaudhary, V., and Sharma, V. R. (2019). "Optimization of spacing, doses of vermi-compost and foliar application of salicylic acid on growth, flowering and soil health of chrysanthemum (*Dendranthema grandiflora* Tzvelev) cv. Guldasta," *International Journal of Agriculture, Environment and Biotechnology* 12(3), 213-224.
- Abbasi, Hisamuddin, Akhtar, A., and Sharf, R. (2015). "Vesicular arbuscular mycorrhizal (VAM) fungi: a tool for sustainable agriculture," *American Journal of Plant Nutrition and Fertilization Technology* 5(2), 40-49. DOI: 10.3923/ajpnft.2015.40.49

- Abdel-Ghany, T. M., Mohamed, Z. H., Abboud, M. A. A., Helmy, E. A., Al-Rajhi, A. M., and Shater, A. R. M. (2019). "Solubilization of inorganic phosphate by rhizospheric fungi isolated from soil cultivated with *Sorghum bicolor* L.," *BioResources* 14(3), 5521-5532. DOI: 10.15376/biores.14.3.5521-5532
- Abhishek, Singh, H., Ahirwar, G. K., and Dushyant (2024). "Assessment of different organic manures on morphological and floral attributes of marigold (*Tagetes erecta* L.)," *Journal of Scientific Research and Reports* 30(8), 936-941. DOI: 10.9734/jsrr/2024/v30i82313
- Adhikari, P., Mishra, K., Marasini, S., Neupane, R. C., Shrestha, A. K., Shrestha, J., and Subedi, S. (2020). "Effect of nitrogen doses on growth and yield of marigold (*Tagetes erecta* L.) in subtropical climate of Nepal," *Fundamental and Applied Agriculture* 5(3), 414-420. DOI: 10.5455/faa.108327
- Adison, R., Maisnam, G., Devi, T. D., and Kangjam, D. (2024). "Impact of bio-fertilizers on growth, yield and quality of Spinach (*Spinacia oleracea* L.) in Noida UP," *BIO Web of Conferences* 110, article ID 03002. DOI: 10.1051/bioconf/202411003002
- Ahmed, M. A. A., Alebidi, A., Al-Obeed, R., and Omar, A. (2023). "Effect of foliar spray of yeast extract and potassium nitrate on yield and fruit quality on *Ziziphus jujuba* L. trees," *Acta Scientiarum Polonorum Hortorum Cultus* 22(1), 3-10. DOI: 10.24326/asphc.2023.4117
- Al-Shammary, A. A. G., Al-Shihmani, L. S. S., Fernández-Gálvez, J., and Caballero-Calvo, A. (2024). "Optimizing sustainable agriculture: A comprehensive review of agronomic practices and their impacts on soil attributes," *Journal of Environmental Management* 364, article ID 121487. DOI: 10.1016/j.jenvman.2024.121487
- Ananthi, T., and Shree, J. S. (2024). "Influence of integrated nutrient management practices on soil fertility and yield of fodder maize in Chennai," *International Journal of Plant and Soil Science* 36(5), 143-151. DOI: 10.9734/ijpss/2024/v36i54511
- Arancon, N., Cleave, J. V., Hamasaki, R., Nagata, K., and Felts, J. (2020). "The influence of vermicompost water extracts on growth of plants propagated by cuttings," *Journal of Plant Nutrition* 43(2), 176-185. DOI: 10.1080/01904167.2019.1659355
- Ayoub, I., and Masoodi, N. H. (2023). "Integrated nutrient management for improving plant growth, flowering and bulb production in Hyacinth cv. yellow stone," *Agriculture Association of Textile Chemical and Critical Reviews Journal* 11(04), 32-38. DOI: 10.58321/AATCCReview.2023.11.04.32
- Bhattacharjee, S. K., Vinayananda, S., and De, L. (2019). "Dahlia," in: *Advances in Ornamental Horticulture*, Pointer Publishers, Jaipur, Rajasthan, India, pp. 181-200.
- Bhunias, S., Bhowmik, A., Mallick, R., and Mukherjee, J. (2021). "Agronomic efficiency of animal-derived organic fertilizers and their effects on biology and fertility of soil: A review," *Agronomy* 11(5), article 823. DOI: 10.3390/agronomy11050823
- Chaudhary, S., Roy, S., Mishra, S. K., Tiwari, P., and Pandey, J. (2020). "Effect of integrated nutrient management on flowering and flower yield of dahlia (*Dahlia variabilis* L.) cv. 'Kenya orange'," *Journal of Pharmacognosy and Phytochemistry* 9(6), 2281-2283.
- Chirukuri, P., Singh, U. C., Khangjarakpam, G., Nandigam, B., and Athokpam, H. S. (2023). "Effect of integrated nutrient management on growth, flowering and yield of African marigold (*Tagetes erecta* L.) cv. Pusa Basanti Gaiinda," *Journal of Agriculture and Ecology* 15, 69-73. DOI: 10.58628/JAE-2315-111
- Choudhary, A., Kumar, A., Kumar, U., Choudhary, R., Kumar, R., Jat, R., and Ravindran, B. (2022). "Various fertilization managements influence the flowering

- attributes, yield response, biochemical activity and soil nutrient status of chrysanthemum (*Chrysanthemum morifolium* Ramat.),” *Sustainability* 14(8), article 4561. DOI: 10.3390/su14084561
- Choudhary, A., Kumar, A., Nayak, A., Bhuj, B. D., Srivastava, R., Rao, V. K., and Guru, S. K. (2021). “Response of NPK through drip fertigation on growth and floral parameters of chrysanthemum,” *Biological Forum International Journal* 13, 398-401.
- Darlington, C. D. (1973). “Dahlia,” in: *Chromosome Botany and the Origin of Cultivated Plant*, George Allen and Unwin Ltd (ed.), London, UK, pp. 231.
- Debnath, M., Mahanta, C., Sarma, A. K., Upadhyaya, A., and Das, A. (2023). “Participatory design to investigate the effects of farmers’ fertilization practices under unsubmerged conditions toward efficient nutrient uptake in rainfed rice,” *South African Journal of Botany* 163, 338-347. DOI: 10.1016/j.sajb.2023.10.055
- Dikr, W., and Belete, K. (2017). “Review on the effect of organic fertilizers, bio-fertilizers and inorganic fertilizers (NPK) on growth and flower yield of marigold (*Tagetes erecta* L.),” *Academic Research Journal of Agricultural Science and Research* 5(3), 192-204.
- Drózd, D., Malińska, K., Wystalska, K., Meers, E., and Robles-Aguilar, A. (2023). “The influence of poultry manure-derived biochar and compost on soil properties and plant biomass growth,” *Materials* 16(18), article 6314. DOI: 10.3390/ma16186314
- Dutch Flower Industry Report (2023). “Holland’s annual dahlia tuber exports,” Dutch Flower Council, (<http://dutchflowercouncil.org/reports/2023>), Accessed 12 July 2024.
- Esmailian, Y., Babaeian, M., and Iriti, M. (2024). “Towards organic farming in roselle (*Hibiscus sabdariffa* L.) cultivation-feasibility of changing its nutrition management from chemical to bio-organic,” *Journal of Plant Nutrition* 47(19), 3144-3164. DOI: 10.1080/01904167.2024.2376250
- Gangwar, M., Saini, P., Nikhanj, P., and Kaur, S. (2017). “Plant growth-promoting microbes (PGPM) as potential microbial bio-agents for eco-friendly agriculture,” in: *Advances in Soil Microbiology: Recent Trends and Future Prospects: Volume 2: Soil-Microbe-Plant Interaction*, Volume 4, Springer, Singapore, pp. 37-55. DOI: 10.1007/978-981-10-7380-9_3
- Garge, V. C., Malik, S., Kumar, M., Singh, M. K., Prakesh, S., Kumar, S., and Singh, S. P. (2020). “Effect of organic and integrated sources of nutrient on growth and flowering of French marigold (*Tagetes patula* L.) under Northwestern plain zone of Uttar Pradesh,” *Journal of Plant Development Sciences* 12(11), 671-674.
- Gomez, K. A., and Gomez, A. A. (1984). “Elements of experimentation,” in: *Statistical Procedures for Agricultural Research*, John Wiley and Sons, New York, NY, USA, pp. 1-90.
- Indhumathi, M. (2023). *Effect of Integrated Nutrient Management on Gaillardia (Gaillardia pulchella Foug.) Under Hill Zone of Karnataka*, Doctoral Dissertation, College of Horticulture, Mudigere, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, India.
- Indhumathi, M., Chandrashekar, S. Y., Srinivasa, V., Shivaprasad, M., and Girish, R. (2023). “Effect of integrated nutrient management on flowering, flower quality and flower yield of gaillardia (*Gaillardia pulchella* Foug.) under hill zone of Karnataka,” *Biological Forum—An International Journal* 15(1), 119-123.
- Iqbal, A., He, L., Ali, I., Ullah, S., Khan, A., Akhtar, K., and Jiang, L. (2021). “Co-incorporation of manure and inorganic fertilizer improves leaf physiological traits,

- rice production and soil functionality in a paddy field,” *Scientific Reports* 11(1), article 10048. DOI: 10.1038/s41598-021-89246-9
- James, R. O., Akorede, A. A., Abimbola, A. I., and Omoh, O. P. (2020). “Effect of organic manure and potting media on germination and early growth of *Eucalyptus torelliana* F. Muell,” *American Journal of Agriculture and Forestry* 8(4), 100-107. DOI: 10.11648/j.ajaf.20200804.12
- Jha, S., Kaushik, M., Parihar, B. S., and Sinha, P. K. (2020). “Effect of organic and inorganic fertilizer in gladiolus with special reference to growth, yield and flower quality: A review,” *Journal of Pharmacognosy and Phytochemistry* 9(3), 826-830.
- Kaur, Y., Malik, S., Kumar, M., Kumar, S., Singh, S. P., Gangwar, R., and Shukla, D. (2023). “Effect of integrated nutrient management and foliar application of micronutrients on vegetative and quality attributes of gladiolus (*Gladiolus hybridus* Hort.) cv. white prosperity,” *International Journal of Agricultural and Statistical Sciences* 19(1), 959-966. DOI: 10.59467/IJASS.2023.19.959
- Kaur, I., Dhama, S., Mukherjee, A., and Mathur, P. (2023a). “Influence of different organic amendments in modulation of soil physico-chemical characteristics and growth of marigold seedlings,” *Journal of Plant Nutrition* 46(13), 3068-3081. DOI: 10.1080/01904167.2023.2177172
- Kaushik, H., and Singh, J. P. (2020). “Impact of integrated nutrient management (INM) on plant growth and flower yield of African marigold (*Tagetes erecta* L.),” *Journal of Pharmacognosy and Phytochemistry* 9(4), 1481-1484.
- Koli, R., and Jayanthi, R. (2018). “Influence of integrated nutrient management on flower yield and economics of marigold (*Tagetes erecta* L.) cv. Pusa Basanti Gainda,” *International Journal of Chemical Studies* 6(4), 2651-2653.
- Kumar, M., Thakur, P., Kashyap, B., Kumar, P., Sharma, A., Bhardwaj, R., and Shah, A. H. (2024). “Effect of different planting dates on tuber production in dahlia (*Dahlia variabilis* L.) in low hill conditions of Himachal Pradesh, India,” *Plant Cell Biotechnology and Molecular Biology* 25(7-8), 71-78. DOI: 10.56557/pcbmb/2024/v25i7-88743
- Kumar, M. (2014). “Effect of different sources of nutrients on growth and flowering in gladiolus (*Gladiolus hybridus* hort.) cv. Peater pears,” *Annals of Horticulture* 7(2), 154-158.
- Kumar, M. (2015). “Impact of different sources of nutrients on growth and flowering in chrysanthemum (*Chrysanthemum morifolium* Ramat.) cv yellow gold,” *Journal of Plant Development Sciences* 7(1), 49-53.
- Kumar, N., Prasad, V. M., and Yadav, N. P. (2019a). “Effect of chemical fertilizers and bio fertilizers on flower yield, tuberous root yield and quality parameter on dahlia (*Dahlia variabilis* L.) cv. Kenya orange,” *Journal of Pharmacognosy and Phytochemistry* 8(4), 2265-2267.
- Kumar, A., Chandel, N., and Barkha, B. (2024a). “Organic farming vs. integrated nutrient management: A comparative review of agricultural productivity and sustainability,” *International Journal of Plant and Soil Science* 36(6), 460-473. DOI: 10.9734/IJPSS/2024/v36i64648
- Kumar, P., Mishra, S., Bahadur, V., and Bhadu, A. (2024b). “Effect of organic manure and plant growth promoting rhizobacteria enriched biocapsules on growth yield and quality of cape gooseberry (*Physalis Peruviana* L.),” *Journal of Advances in Biology and Biotechnology* 27(7), 447-456.

- Kushwah, N., Billore, V., Sharma, O. P., Singh, D., and Chauhan, A. P. S. (2024). "Integrated nutrient management for optimal plant health and crop yield," *Plant Science Archives* 8(02), 10-12. DOI: 10.5281/zenodo.10399479
- Madhurya, P., Latha, M., Rao, C. S., and Sree, S. P. (2022). "Effect of integrated nutrient management on physical and physico-chemical properties of soil," *International Journal of Plant and Soil Science* 34(24), 1028-1033. DOI: 10.9734/ijpss/2022/v34i242733
- Maniram., Kumar, M., Malik, S., Singh, M. K., and Pal, V. (2012). "Impact of spacing, doses of vermi-compost and foliar application of salicylic acid on growth and flowering of gladiolus (*Gladiolus grandiflorus* L.) cv. white prosperity," *Annals of Horticulture* 5(2), 272-279.
- Mattos Abreu, G., Bobadilha, G. D. S., Guirardi, B. D., Abreu, P. M., de Souza Oliveira, N., Schiavo, J. A., and Mohammadi-Aragh, M. K. (2021). "The influence of compost and arbuscular mycorrhizal fungi on sugarcane growth and nutrient uptake," *BioResources* 16(2), 3005-3016. DOI: 10.15376/biores.16.2.3005-3016
- McFarland, M. L., Haby, V. A., Redmon, L. A., and Bade, D. H. (2024). *Managing Soil Acidity*, Texas Agricultural Experiment Station, Austin, TX, USA.
- Milian, C. (2024). "LatinX genesis: On the origins of a mongrel species," *Cultural Dynamics* 36(1-2), 87-107. DOI: 10.1177/09213740231223837
- Mori, T., Wang, S., Wang, C., Zhang, W., and Mo, J. (2024). "Effect of long-term nitrogen addition on the kinetics of phosphatases in a subtropical forest in southern China," *Applied Soil Ecology* 202, article 105589. DOI:10.1016/j.apsoil.2024.105589
- Motla, R., Malik, S., Kumar, M., Kumar, S., Kumar, D., Gangwar, V., and Pratap, A. (2022). "Integrated effect of bio-fertilizers, organic and inorganic fertilizers on flowering, corms and cormel yield attributes of gladiolus (*Gladiolus grandiflorus* L.) cv. nova lux," *International Journal of Environment and Climate Change* 12(11), 1914-1920. DOI: 10.9734/ijecc/2022/v12i1131179
- Nanda, A., Mohapatra, B. B., Mahapatra, A. P. K., Mahapatra, A. P. K., and Mahapatra, A. P. K. (2021). "Multiple comparison test by Tukey's honestly significant difference (HSD): Do the confident level control type I error," *International Journal of Statistics and Applied Mathematics* 6(1), 59-65.
- Neelima, S., Babhulakar, V. P., Bhoyar, K. D., Wankhade, M. G., and Shende, S. T. (2022). "Impact of nutrient management on soil chemical properties and maize (*Zea mays* L.) yield," *International Journal of Environment and Climate Change* 12(12), 1863-1870. DOI: 10.9734/IJECC/2022/v12i121635
- Paul, S. C., Bharti, R., Lata, S., Paramanik, B., Pradhan, A. K., Verma, R. B., and Siddiqui, M. H. (2024). "Application of different organic amendments influences the different forms of sulphur in the soil of pea-onion-cauliflower cropping system," *BioResources* 19(3), 5384-5395. DOI: 10.15376/biores.19.3.5384-5395
- Prasad, D. S. H., Prasad, V. M., Goutham, S. K., and Bose, S. C. (2018). "Effect of integrated nutrient management on flowering and flower yield of dahlia (*Dahlia variabilis* L) cv. Kenya Orange," *Plant Archives* 18(01), 795-798.

- Raj, S., Thomas, T., Swaroop, N., Kumar, K., and Thomas, A. (2024). "Response of inorganic, organic fertilizer and microbial inoculants on physico-chemical properties of soil in cultivation of wheat (*Triticum aestivum* L.) var. PBW-373," *Journal of Advances in Biology and Biotechnology* 27(6), 483-491. DOI: 10.9734/jabb/2024/v27i6908
- Rajaselvam, M., Sudhagar, R., and Kumaresan, M. (2024). "Determining the effect of integrated nutrient management (INM) on growth and flower yield of tuberose (*Polianthes tuberosa* L.) cv. Prajwal," *International Journal of Plant and Soil Science* 36(6), article 4600. DOI: 10.9734/IJPSS/2024/v36i64600
- Samad, M. A., Sikder, R. K., Karim, M. T., Iqbal, M., Sumon, M. M., Imtiaz, A. A., and Touhidujaman, M. (2024). "Integrated nutrient management strategies: Unraveling the impact of bio-fertilizers and traditional fertilizers on soybean (glycine max) productivity," *European Journal of Nutrition and Food Safety* 16(1), 60-65. DOI: 10.9734/EJNFS/2024/v16i11378
- Sarkar, S., Sarkar, I., Sarkar, D., Maitra, S., and Chatterjee, R. (2024). "Effect of organic sources of nutrients on growth and flowering of spray chrysanthemum," *International Journal of Plant and Soil Science* 36(1), 131-139. DOI: 10.9734/IJPSS/2024/v36i14338
- Shah, I. H., Jinhui, W., Li, X., Hameed, M. K., Manzoor, M. A., Li, P., and Chang, L. (2024). "Exploring the role of nitrogen and potassium in photosynthesis implications for sugar: Accumulation and translocation in horticultural crops," *Scientia Horticulturae* 327, article 112832. DOI: 10.1016/j.scienta.2023.112832
- Shaifali, B., Singh, S. K., Gupta, R. K., Sreethu, S., Alamri, S., and Siddiqui, M. H. (2024). "Soil and leaf nutrient responses in strawberry to nano-urea and *Azotobacter* applications," *BioResources* 19(4), 8136-8153. DOI:10.15376/biores.19.4.8136-8153
- Sharma, R., Kumar, R., Bakshi, P., Jasrotia, A., Sinha, B. K., Sharma, P., and Dadheechi, M. (2024). "Synergistic impact of vermicompost, biochar and jaggery on antioxidants, phenols and flavonoids in Guava cv. L-49," *BioResources* 19(4), 8173-8187. DOI: 10.15376/biores.19.4.8173-8187
- Shukla, U., Kumar, M., Pal, V., Kumari, N., Kumar, M., and Chaudhary, V. (2023). "Performance of different bio-stimulants on vegetative, floral, tuber yield and prolonging vase life quality parameters of Dahlia (*Dahlia variabilis* L.)," *International Journal of Agricultural and Statistical Sciences* 19(1), article 407. DOI: 10.59467/IJASS.2023.19.407
- Singh, J., Sharma, M. K., Singh, S. P., Bano, R., and Mahawar, A. K. (2018). "Effect of organic and inorganic sources of NPK and bio-fertilizer on enhancement of growth attributes and chlorophyll content of sweet potato," *International Journal of Current Microbiology and Applied Science* 7(9), 3659-3667. DOI: 10.20546/ijcmas.2018.709.455
- Singh, P., Prakash, S., Kumar, M., Malik, S., Singh, M. K., and Kumar, A. (2015). "Effect of integrated nutrient management (INM) on growth, flowering and yield in marigold (*Tagetes erecta* L.) cv. Pusa basanti," *Annals of Horticulture* 8(1), 73-80.
- Singh, R., Patel, V., Nishad, D., and Kumar, A. (2024). "Effect of integrated nutrient management on growth and yield of potato, *Solanum tuberosum* L., crop," *Asian Journal of Soil Science and Plant Nutrition* 10(2), 56-63. DOI: 10.9734/ajsspn/2024/v10i2260

- Singh, S., Dhatt, K. K., and Bodla, P. K. (2023). "Exploring genetic diversity of Dahlia (*Dahlia variabilis* Desf.) germplasm using multivariate statistics," *Journal of Horticultural Sciences* 18(1), 67-76. DOI: 10.24154/jhs.v18i1.2149
- Sinha, S. K., Kumar, A. D., Kumari, A., and Singh, A. K. (2024). "The integrated effect of organic manure, biofertilizer and inorganic fertilizer on soil properties, yield and quality in sugarcane plant-ratoon system under calcareous soil of Indo-gangetic Plains of India," *Journal of Scientific Research and Reports* 30(5), 193-206. DOI : 10.9734/jsrr/2024/v30i51934
- Sudhagar, R., Alexander, R., Elisheba, B. P., and Kamalakannan, S. (2019). "Effect of integrated nutrient management on the growth of African marigold (*Tagetes erecta* L.) CV. local orange," *Journal of Pharmacognosy and Phytochemistry* 8(3), 3669-3671.
- Sumita Pradhan, S. P., Mitra, M., Vanlalruati, V., and Sadhukhan, R. (2017). "Response of tuberose cv Prajwal to integrated nutrient management," *Environment and Ecology* 35(4B), 3051-3055. DOI: 10.5555/20173378327
- Tian, M., Yu, R., Guo, S., Yang, W., Liu, S., Du, H., and Zhang, X. (2024). "Effect of vermicompost application on the soil microbial community structure and fruit quality in melon (*Cucumis melo*)," *Agronomy* 14(11), article 2536. DOI: 10.3390/agronomy14112536
- Tiemann, T., and Douchamps, S. (2023). "Opportunities and challenges for integrated smallholder farming systems to improve soil nutrient management in Southeast Asia," *World Development Sustainability* 03, article 100080. DOI: 10.1016/j.wds.2023.100080
- Tiwari, A. K., and Pal, D. B. (2022). "Nutrients contamination and eutrophication in the river ecosystem," in: *Ecological Significance of River Ecosystems*, Elsevier, Amsterdam, Netherlands, pp. 203-216. DOI: 10.1016/B978-0-323-85045-2.00001-7
- Tomar, A., and Saikia, J. (2022). "Effect of integrated nutrient management on soil chemical and biological properties under dolichos bean cultivation," *International Journal of Plant and Soil Science* 34(12), 99-105. DOI: 10.9734/IJPSS/2022/v34i1230966
- Tomar, R., Malik, S., Kumar, M., Kumar, S., Singh, S. P., Singh, B., and Kaushik, K. (2024). "Determining the effect of integrated nutrient management (INM) on the growth of tuberose (*Polianthes tuberosa* L.) cv. Rajat Rekha," *Journal of Advances in Biology and Biotechnology* 27(10), 669-675.
- Tripathi, S., Srivastava, P., Devi, R. S., and Bhadouria, R. (2020). "Influence of synthetic fertilizers and pesticides on soil health and soil microbiology," in: *Agrochemicals Detection, Treatment and Remediation*, M. N. Vara Prasad (ed.), Butterworth-Heinemann, Oxford, UK, pp. 25-54. DOI: 10.1016/B978-0-08-103017-2.00002-7
- Verma, N., Dwivedi, D. H., Kishor, S., and Singh, N. (2017). "Impact of integrated nutrient management on growth and fruit physical attributes in Cape gooseberry, *Physalis peruviana*," *Bioscience Biotechnology Research Communications* 10(4), 672-675. DOI: 10.21786/bbrc/10.4/9
- Wang, Y., Li, P., Zhang, B., Meng, J., Gao, Y., He, X., and Hu, X. (2020). "Identification of phosphate-solubilizing microorganisms and determination of their phosphate-solubilizing activity and growth-promoting capability," *BioResources* 15(2), 2560-2578. DOI: 10.15376/biores.15.2.2560-2578

- Wararkar, S. M., Sarvanan, S., and Prasad, V. M. (2020). "Effect of integrated nutrient management on growth, flowering and yield of dahlia (*Dahlia variabilis* L.). Cv. Kenya white," *Plant Archives* 20(1), 3292-3296.
- Wu, W., and Ma, B. (2015). "Integrated nutrient management (INM) for sustaining crop productivity and reducing environmental impact: A review," *Science of The Total Environment* 512, 415-427. DOI: 10.1016/j.scitotenv.2014.12.101
- Zhang, X., Li, Q., Zhong, Z., Huang, Z., Wen, X., Bian, F., and Yang, C. (2023). "Determining changes in microbial nutrient limitations in bamboo soils under different management practices *via* enzyme stoichiometry," *Catena* 223, article ID 106939. DOI: 10.1016/j.catena.2023.106939

Article submitted: March 28, 2025; Peer review completed: August 15, 2025; Revised version received: September 12, 2025; Accepted: September 16, 2025; Published: October 3, 2025.

DOI: 10.15376/biores.20.4.10028-10050