*INT. J. BIOL. BIOTECH.,* 22 (3): 699-709. 2025.

# RESPONSE OF DIFFERENT NITROGEN DOSES ON GROWTH AND FLOWERING OF ORNAMENTAL SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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## ABSTRACT

A field experiment was conducted during 2024-25 at GUL FLORIST/ Z-organic Agricultural form Badin, Sindh, Pakistan. to evaluate the effects of different nitrogen doses on the growth and flowering performance of ornamental sunflower (*Helianthus annuus* L.). The experiment followed a Randomized Complete Block Design (RCBD) with three replications. The sunflower variety 'Vincent's-2' was selected for this study, and seeds were perished from Sakata Seed Company. Five nitrogen treatments were applied: Control (0 kg $ha^{-1}$), 45 kg $ha^{-1}$, 90 kg $ha^{-1}$, 135 kg $ha^{-1}$, and 180 kg $ha^{-1}$. The objective was to determine the optimal nitrogen level for maximizing vegetative growth and floral attributes. The application of nitrogen significantly influenced various morphological and reproductive traits. The highest plant height (108.43 cm), number of leaves $plant^{-1}$ (24.00), flower diameter (134.17 mm), leaf length (18.67 cm), leaf width (15.90 cm), collar diameter (20.83 mm), and petiole length (5.73 cm) were observed in the 135 kg $ha^{-1}$ nitrogen treatment. Furthermore, this treatment also enhanced flower characteristics, including single flower weight (23.91 g), number of petals $flower^{-1}$ (27.66), and weight of disk florets (19.69 g). However, an increase in nitrogen application beyond this level (180 kg $ha^{-1}$) resulted in reduced growth and flowering performance, indicating a threshold level beyond which excessive nitrogen has detrimental effects. Statistical analysis confirmed that nitrogen treatments significantly affected most measured parameters, with p-values ranging from 0.0001 to 0.0171. The coefficient of variation (CV) remained within acceptable limits, ensuring the reliability of results. The findings suggest that a nitrogen application rate of 135 kg $ha^{-1}$ is optimal for achieving maximum vegetative growth and floral productivity in ornamental sunflower under the given agro-climatic conditions. These results provide valuable insights for commercial growers and horticulturists aiming to optimize nitrogen fertilization strategies for sunflower cultivation.

**Keywords:** Ornamental Sunflower, Vincent's-2' Variety, Nitrogen Fertilizer, Growth and Flowering.

## INTRODUCTION

### Importance of Ornamental Plants

Ornamental plants play a significant role in human well-being, aesthetics, and environmental improvement. They contribute to the beautification of landscapes, parks, urban areas, and households (Schoellhorn, 2011). Beyond aesthetic values, ornamental horticulture significantly contributes to the economy, particularly in the floriculture industry, which includes cut flowers, potted plants, bedding plants, and ornamental foliage. In many countries, this sector is growing rapidly due to increased demand for beautification and event decoration.

### Sunflower as an Ornamental Plant

Among ornamental plants, sunflower (*Helianthus annuus* L.) holds a special place. Traditionally cultivated for oilseed production, sunflower is now gaining popularity as an ornamental plant due to its vibrant and attractive floral display, rapid growth, and adaptability to different environmental conditions (Kumar and Singh, 2018). Ornamental sunflowers are appreciated for their large, bright yellow inflorescences and tall, upright growth habit. They are widely used in landscaping, garden borders, and as cut flowers.

Sunflowers belong to the family Asteraceae and are native to North America. Their heliotropic nature—the ability to follow the sun—is not only fascinating but also contributes to maximizing photosynthetic efficiency, particularly during the early vegetative stages (Seiler, 2007). The increasing use of ornamental sunflower cultivars in landscape design demands a deeper understanding of their cultural and nutritional requirements, especially with respect to nutrient management to enhance their aesthetic value and marketability.

## Role of Plant Nutrition in Ornamental Crop Production

Plant nutrition is a critical factor influencing growth, development, yield, and flower quality in ornamental crops. Among all essential elements, nitrogen (N) is one of the most vital nutrients. It plays a major role in chlorophyll formation, protein synthesis, nucleic acid formation, and enzymatic activity (Marschner, 2012). Nitrogen is known to influence both the vegetative and reproductive phases of plants, including leaf expansion, stem elongation, flower initiation, and overall biomass production (Epstein and Bloom, 2005).

In ornamental crops, nutrient management strategies not only target yield enhancement but also focus on improving visual characteristics such as plant height, branching, leaf color, and flower size. Therefore, the proper dose and timing of nitrogen application are crucial to achieving optimum plant growth and desirable ornamental traits (Soundy *et al*., 2001).

## Nitrogen and Its Functions in Plants

Nitrogen is a component of many important plant structures and compounds such as amino acids, proteins, nucleotides, and chlorophyll. It promotes cell division and expansion, contributing to rapid vegetative growth. It is highly mobile within the plant and is often the most limiting nutrient in agricultural systems (Mengel & Kirkby, 2001). Nitrogen deficiency can result in chlorosis, reduced plant size, delayed flowering, and poor flower quality, whereas excessive nitrogen may lead to lush vegetative growth at the expense of flowering and may increase susceptibility to pests and lodging.

The uptake of nitrogen occurs primarily in the form of nitrate ($NO_3^-$) and ammonium ($NH_4^+$), and its availability is influenced by several factors such as soil type, pH, temperature, and microbial activity (Brady & Weil, 2010). Fertilizer application, therefore, must be optimized to avoid both deficiencies and environmental pollution due to nitrogen leaching or volatilization.

## Importance of Nitrogen in Ornamental Sunflower Production

For ornamental sunflowers, nitrogen application is directly associated with traits such as plant height, leaf number, stem girth, flower size, and flower count—all of which are important in the ornamental market (Zubair *et al*., 2009). Sunflowers require an optimal nitrogen supply to produce lush foliage and strong, erect stems capable of supporting large inflorescences.

Too little nitrogen results in stunted growth, pale leaves, and fewer flowers, while excessive nitrogen may delay flowering and reduce the overall ornamental appeal. Several studies have demonstrated that optimal nitrogen levels enhance the visual characteristics and marketability of ornamental sunflower cultivars (Bodhipadma *et al*., 2014).

## Nitrogen Dose Optimization

Optimizing nitrogen dosage is essential for improving both the aesthetic quality and productivity of ornamental sunflowers. This involves determining the appropriate amount of nitrogen that maximizes growth and flowering while minimizing negative effects such as lodging or excessive vegetative growth. Researchers have investigated different nitrogen levels in sunflowers and reported varying outcomes based on cultivar, soil condition, and climatic factors (Rahman *et al*., 2014).

The response of ornamental sunflower to nitrogen can be cultivar-specific. For example, dwarf sunflower cultivars may require lower nitrogen levels compared to tall cultivars, due to their shorter growth cycle and compact structure. Additionally, nitrogen use efficiency (NUE) is a key trait that should be considered while formulating fertilizer recommendations for different sunflower types.

## Research Trends on Nitrogen and Ornamental Sunflower

Several studies have focused on the effect of nitrogen on sunflower growth and development. For instance, Zubair *et al*. (2009) studied the impact of different nitrogen levels on plant height, leaf area, and flower diameter in sunflowers and found significant improvements in growth and flowering at moderate nitrogen doses. Similarly, Khaliq *et al*. (2015) observed that nitrogen application significantly influenced the flowering time and number of flower heads per plant in ornamental sunflowers.

Research also emphasizes the importance of timing and method of nitrogen application. Split applications (e.g., half at sowing and half during vegetative growth) have shown better results compared to single applications. Moreover, slow-release nitrogen fertilizers and organic sources (e.g., compost and poultry manure) have been investigated for sustainable nutrient management in floriculture (Baruah *et al*., 2018).

### Environmental and Economic Considerations

Nitrogen fertilizers are often a major input cost in ornamental crop production. Excessive application not only leads to economic losses but also poses environmental risks, including nitrate leaching into groundwater, emission of nitrous oxide (a potent greenhouse gas), and eutrophication of aquatic systems (Galloway *et al*., 2003). Therefore, rational and efficient nitrogen management is crucial for sustainable ornamental horticulture.

Integrated nutrient management (INM), which combines chemical fertilizers with organic amendments and biofertilizers, is emerging as an effective strategy for improving nitrogen use efficiency and reducing environmental impacts (Tilman *et al*., 2002).

### Research Gaps and Justification of Study

While many studies have been conducted on oilseed sunflower, limited research is available on the nutrient requirements of ornamental sunflower cultivars, especially under different agro-climatic conditions. There is a need to generate region-specific recommendations on nitrogen management for ornamental sunflower to help growers achieve high-quality floral displays.

Moreover, quantifying the growth and flowering response to graded nitrogen doses can aid in identifying the most cost-effective and sustainable fertilization strategy. This study aims to bridge this research gap by evaluating the effects of different nitrogen levels on the growth, flowering, and aesthetic quality of ornamental sunflower.

## MATERIALS AND METHODS

### Study Location and Duration

The field experiment was conducted during the 2024–2025 growing season at the GUL FLORIST/Z-Organic Agricultural Farm, located in Badin, Sindh, Pakistan (25.1742475° N, 68.6712426° E), a region characterized by its agricultural landscape and suitable climatic conditions for horticultural research. This region is characterized by a semi-arid climate with sandy loam soils, making it conducive for sunflower cultivation. The primary objective was to evaluate the impact of varying nitrogen levels on the growth and flowering performance of ornamental sunflower (*Helianthus annuus* L.).

### Experimental Design and Layout

A Randomized Complete Block Design (RCBD) was employed to ensure the reliability of results and minimize environmental variability. The experiment comprised three replications (blocks), each containing five treatment plots, resulting in a total of 15 experimental units.

**Sunflower Variety**: 'Vincent's-2', selected for its ornamental appeal and uniform flowering characteristics.

**Plot Size**: Each plot measured 5 feet × 5 feet (25 square feet), with plant to plant 6 inches distance and row to row 1 feet distance.

### Nitrogen Fertilizer Treatments

Nitrogen was applied in the form of Urea fertilizer (46% N). Five nitrogen levels were tested: *Viz* $N_1$ (Control)**:** 0 kg N $ha^{-1}$ (No fertilizer applied), $N_2$: 45 kg N $ha^{-1}$, $N_3$: 90 kg N $ha^{-1}$, $N_4$: 135 kg N $ha^{-1}$, $N_5$: 180 kg N $ha^{-1}$ for treatments $N_2$ to $N_5$, the total nitrogen dose was split into two equal applications: half at the time of sowing and the remaining half at 30 days after sowing (DAS) to align with the crop's vegetative growth phase.

### Crop Management Practices

Uniform agronomic practices were maintained across all treatments to ensure that observed differences could be attributed solely to nitrogen levels.

**Sowing**: Seeds were sown manually at a uniform depth, ensuring optimal plant population density.

**Irrigation**: Irrigation was applied uniformly across all plots based on the crop's water requirements and prevailing weather conditions.

**Weed Control**: Manual weeding was performed regularly to minimize competition for nutrients and light.

**Pest and Disease Management**: Regular monitoring was conducted, and appropriate measures were taken to control any pest or disease outbreaks.

**Data Collection and Observations**
Comprehensive data were collected on various growth and flowering parameters to assess the impact of different nitrogen levels.

***Growth Parameters***
**Plant Height (cm)**: Measured from the base to the apex of the plant at full bloom.

**Number of Leaves per Plant**: Counted at the peak vegetative stage.

**Leaf Length and Width (cm)**: Measured on the third fully expanded leaf from the top.

**Leaf Thickness (mm)**: Assessed using a digital caliper on the same leaf used for length and width measurements.

**Collar Diameter (mm)**: Measured at the base of the stem using a vernier caliper.

**Petiole Length and Diameter (cm and mm)**: Measured on the third fully expanded leaf.

**Sturdiness Quotient**: Calculated as the ratio of plant height to collar diameter, indicating plant robustness.

***Flowering and Floral Characteristics***
**Number of Flowers per Plant**: Counted at the peak flowering stage.

**Flower Diameter (mm)**: Measured across the widest part of the flower head.

**Single Flower Weight (g)**: Determined by weighing freshly harvested flowers.

**Petal Length and Width (cm)**: Measured on the central petal of the flower.

**Number of Petals per Flower**: Counted manually.

**Petal Thickness (mm)**: Measured using a micrometer.

**Single Petal Weight (g)**: Determined by weighing individual petals.

**Disk Florets Diameter (mm)**: Measured across the central disk of the flower.

**Weight of Disk Florets (g)**: Weighed after separating from the flower.

**Corolla Weight (g)**: Measured by weighing the corolla after separation.

**Statistical Analysis**
The collected data were subjected to statistical analysis using Statistix 8.1 software (Statistix, 2006). Analysis of Variance (ANOVA) was performed to determine the significance of treatment effects. Where significant differences were observed, the Least Significant Difference (LSD) test at a 5% probability level ($P \leq 0.05$) was employed to compare treatment means.

## RESULT AND DISCUSSION

**Plant Height (cm)**
The results revealed that plant height was significantly influenced by varying nitrogen doses ($P \leq 0.05$). The tallest plants (108.43 cm) were observed at 135 kg N $ha^{-1}$, followed by 90 kg N $ha^{-1}$ (94.83 cm), while the shortest plants (31.13 cm) were recorded in the control (no nitrogen). The highest nitrogen level (180 kg N $ha^{-1}$) unexpectedly reduced plant height (58.97 cm), suggesting a potential inhibitory effect due to excessive nitrogen.

These findings are consistent with those reported by Mohanamba (1992) and Ahmad *et al*. (2018), who demonstrated that nitrogen enhances vegetative growth in sunflower by promoting cell division and elongation. However, excessive nitrogen can result in imbalanced growth or toxicity, as also noted by El-Kady *et al*. (2010). Thus, the optimal dose for maximizing plant height in this study appears to be 135 kg $ha^{-1}$.

**Collar Diameter (mm)**

A significant variation in collar diameter was also observed among treatments. The maximum collar diameter (20.83 mm) was recorded under 135 kg N $ha^{-1}$, while the minimum was observed in the control (4.56 mm) and 180 kg N $ha^{-1}$ (4.73 mm). Intermediate values were noted at 90 kg (12.23 mm) and 45 kg N $ha^{-1}$ (7.50 mm).

These results indicate that nitrogen promotes stem girth up to an optimal level. A well-developed collar diameter is critical for plant strength and resistance to lodging. Sher *et al*. (2017) reported similar results, emphasizing the importance of balanced nitrogen levels to achieve strong stem growth. The poor collar diameter at 180 kg N $ha^{-1}$ further indicates the detrimental impact of over-fertilization.

**Sturdiness Quotient**

The sturdiness quotient (plant height/collar diameter) showed significant variation ($P = 0.0171$), ranging from 5.22 (most robust plants) at 135 kg N $ha^{-1}$ to 12.7 (least robust) at 180 kg N $ha^{-1}$. A lower quotient suggests stronger and sturdier plants, while a higher value indicates taller plants with thinner stems prone to lodging.

This outcome implies that although 180 kg N $ha^{-1}$ produced relatively tall plants, the accompanying reduction in collar diameter led to weaker structural integrity. El-Kady *et al*. (2010) and Sher *et al*. (2017) also emphasized the importance of stem sturdiness in crop architecture, particularly for ornamental purposes where visual appeal and plant posture are essential.

**Growth Parameters-I**

| Nitrogen Fertilizer | Plant Height (cm) | Collar Diameter (mm) | Studinees Quotient |
|---|---|---|---|
| **Control** | 31.13 e | 4.56 e | 6.8 e |
| **45 kg ha-1** | 67.70 c | 7.50 c | 9.18 b |
| **90 kg ha-1** | 94.83 b | 12.23 b | 7.78 c |
| **135 kg ha-1** | 108.43 a | 20.83 a | 5.22 d |
| **180 kg ha-1** | 58.97 d | 4.73 d | 12.7 a |
| **F-Value** | 72.78 | 117.91 | 5.81 |
| **P-Value** | 0.0000 | 0.0000 | 0.0171 |
| **CV** | 8.56 | 10.9 | 24.41 |
| **S.E** | 3.56 | 0.71 | 0.56 |
| **LSD** | 5.0465 | 0.8878 | 1.6624 |

**Number of Leaves Plant$^{-1}$**

Significant differences ($P \leq 0.05$) were observed in the number of leaves per plant under different nitrogen treatments. The maximum number of leaves (24.00) was recorded with 135 kg N $ha^{-1}$, followed by 18.00 at 90 kg N $ha^{-1}$, while the minimum (9.00) was found in the control. Plants supplied with 180 kg N $ha^{-1}$ produced only 13.33 leaves, which was statistically lower than optimal doses.

This indicates that moderate nitrogen levels encourage foliage development, supporting greater photosynthetic capacity and biomass accumulation. The findings align with those of (Nasim *et al*., 2011 and Nasim and Bano, 2012) who reported that nitrogen promotes leaf formation due to its key role in chlorophyll synthesis and cell division. However, excessive nitrogen (180 kg $ha^{-1}$) may lead to nutrient imbalances, resulting in reduced leaf production.

**Leaf Length (cm)**

Leaf length showed a strong response to nitrogen doses, with a highly significant P-value (0.0000). The longest leaves (18.67 cm) were observed in the 135 kg N $ha^{-1}$ treatment, followed by 90 kg N $ha^{-1}$ (12.93 cm), and the shortest leaves (6.16 cm) were in the control.

Nitrogen availability enhances vegetative growth by stimulating the expansion of leaf cells and increasing chlorophyll content (Ahmad *et al*., 2018). Leaf length is a key parameter for canopy development and efficient light interception. The poor performance at 180 kg N $ha^{-1}$ may be due to the stress of over-fertilization, corroborating results from similar studies on sunflower and other ornamentals (Polara *et al*., 2015).

**Leaf Width (cm)**

Leaf width also significantly increased with nitrogen levels up to 135 kg $ha^{-1}$ (15.9 cm), followed by 90 kg $ha^{-1}$ (11.96 cm) and 45 kg $ha^{-1}$ (7.66 cm). The minimum width (3.80 cm) was recorded in the control. Again, a reduction at 180 kg N $ha^{-1}$ (6.00 cm) was noted.

The broader leaf area under optimal nitrogen supply reflects improved nutrient assimilation, contributing to enhanced photosynthesis and plant growth. This trend is in agreement with studies by Ata-Ul-Karim *et al*., (2016). who reported that leaf area expansion in sunflower is highly responsive to nitrogen but declines when the supply exceeds optimal requirements.

**Leaf Thickness (mm)**

Leaf thickness, an important anatomical trait, was also significantly influenced by nitrogen levels (P = 0.0015). The maximum thickness (0.50 mm) was noted at 135 kg N $ha^{-1}$, while the lowest (0.24 mm) was recorded in the control. Intermediate values were recorded at 45 kg (0.40 mm), 90 kg (0.38 mm), and 180 kg N $ha^{-1}$ (0.26 mm).

Thicker leaves are often associated with better structural strength and higher chlorophyll concentration. According to the findings of Geo *et al*., (2020). nitrogen deficiency reduces leaf thickness due to poor cell wall development, whereas optimal nitrogen enhances leaf quality and performance. The reduction at 180 kg N $ha^{-1}$ again supports the notion that excessive fertilization disrupts normal physiological processes.

**Growth Parameters-II**

| Nitrogen Fertilizer | Number of leaves plant$^{-1}$ | Length of Leaves (cm) | Width of Leaves (cm) | Thickness of Leaves (mm) |
|---|---|---|---|---|
| **Control** | 9.00 e | 6.16 e | 3.80 e | 0.24 e |
| **45 kg ha-1** | 14.00 c | 11.43 c | 7.66 c | 0.40 b |
| **90 kg ha-1** | 18.00 b | 12.93 b | 11.96 b | 0.38 c |
| **135 kg ha-1** | 24.00 a | 18.67 a | 15.9 a | 0.50 a |
| **180 kg ha-1** | 13.33 d | 8.33 d | 6.00 d | 0.26 d |
| **F-Value** | 19.66 | 41.61 | 39.15 | 12.72 |
| **P-Value** | 0.0003 | 0.0000 | 0.0000 | 0.0015 |
| **CV** | 14.08 | 10.93 | 14.82 | 14.21 |
| **S.E** | 1.27 | 0.72 | 0.77 | 0.02 |
| **LSD** | 1.8012 | 1.0307 | 1.0968 | 0.0416 |

**Number of Flowers Plant$^{-1}$**

A highly significant difference ($P \leq 0.05$) was recorded among nitrogen treatments for the number of flowers per plant. The maximum number of flowers (13.66) was observed with 135 kg N $ha^{-1}$, followed by 90 kg $ha^{-1}$ (10.33). The minimum (1.33) was recorded in the control, indicating nitrogen deficiency severely hampers flowering.

Nitrogen plays a vital role in vegetative growth that supports reproductive development. Adequate nitrogen improves the availability of assimilates, hormone balance, and sink strength, all of which enhance flower formation (Nasiri *et al*., 2010; Bhatt *et al*., 2022). However, flower number declined at 180 kg N $ha^{-1}$, suggesting that over-fertilization could cause excessive vegetative growth at the expense of flowering (Khan *et al*., 2018).

**Flower Diameter (mm)**

The maximum flower diameter (134.17 mm) was recorded at 135 kg N $ha^{-1}$, significantly superior to all other treatments. The lowest value (61.37 mm) was found at 180 kg N $ha^{-1}$, even lower than the control (66.93 mm), possibly due to nutritional stress from excessive nitrogen.

Moderate nitrogen levels promote flower head size by enhancing cell division and expansion, nutrient mobilization, and vascular activity (Khaliq *et al*., 2020). The results are consistent with Arshad *et al*. (2019), who reported enhanced capitulum diameter in sunflower with balanced nitrogen supply.

**Single Flower Weight (g)**

Nitrogen application also significantly influenced single flower weight. The heaviest flowers (23.91 g) were produced at 135 kg N $ha^{-1}$, while the lightest (6.22 g) were from control plots. At 180 kg N $ha^{-1}$, flower weight (18.63 g) decreased, highlighting a possible threshold effect.

Nitrogen contributes to increased biomass by stimulating protein synthesis, water uptake, and photosynthesis—all factors influencing floral development (Shah *et al*., 2016). However, beyond optimal levels, flower quality and weight decline due to excessive vegetative growth and nutrient imbalance.

**Petiole Diameter (mm)**

Although the difference was not statistically significant (P = 0.0742), a rising trend in petiole thickness was noted with increasing nitrogen. The thickest petiole (2.16 mm) was recorded at 180 kg N $ha^{-1}$, and the thinnest (1.26 mm) in the control.

Petiole thickness reflects vascular efficiency and mechanical support for inflorescences. A thicker petiole may not directly contribute to flower performance but supports nutrient transport and overall plant health (López-Bucio *et al*., 2003).

**Petiole Length (cm)**

Significant variation (P = 0.0007) was observed in petiole length. The longest petiole (5.73 cm) was recorded at 135 kg N $ha^{-1}$, followed by 45 kg $ha^{-1}$ (4.93 cm), while the shortest (3.46 cm) was in the control. Excess nitrogen (180 kg $ha^{-1}$) reduced petiole length (4.26 cm).

Petiole elongation correlates with cell expansion and leaf positioning, influenced by nitrogen availability (Ahmed *et al*., 2013). Enhanced petiole length improves leaf exposure to sunlight, aiding photosynthesis.

**Petal Length (cm)**

Petal length was significantly influenced (P = 0.0002) by nitrogen levels. The longest petals (6.16 cm) were recorded with 90 kg N $ha^{-1}$, while the shortest (3.10 cm) occurred in the control. At 135 kg $ha^{-1}$, petal length (4.76 cm) was intermediate.

This may suggest that moderate nitrogen enhances petal expansion, but excessive vegetative vigor at higher nitrogen doses (135–180 kg) can reduce energy allocated to floral organs (Singh and Boomsma, 2015). Similar findings were reported in other ornamental crops, where moderate nitrogen improved floral aesthetics and size (Rehman *et al*., 2018).

**Flower Parameters-I**

| **Nitrogen Fertilizer** | **Number of flowers plant$^{-1}$** | **Flower Diameter (mm)** | **Single Flower Weight (g)** | **petiole diameter (mm)** | **petiole length (cm)** | **petal length (cm)** |
|---|---|---|---|---|---|---|
| Control | 1.33 e | 66.93 d | 6.22 e | 1.26 e | 3.46 e | 3.10 e |
| 45 kg ha-1 | 7.00 d | 72.47 c | 15.03 d | 1.33 d | 4.93 b | 4.00 c |
| 90 kg ha-1 | 10.33 b | 89.30 b | 18.75 b | 1.63 c | 4.36 c | 6.16 a |
| 135 kg ha-1 | 13.66 a | 134.17 a | 23.91 a | 2.00 b | 5.73 a | 4.76 b |
| 180 kg ha-1 | 7.33 c | 61.37 e | 18.63 c | 2.16 a | 4.26 d | 3.60 d |
| F-Value | 20.7 | 47.41 | 30.15 | 3.23 | 15.93 | 23.37 |
| P-Value | 0.0003 | 0.0000 | 0.0001 | 0.0742 | 0.0007 | 0.0002 |
| CV | 22.5 | 8.74 | 12.54 | 22.81 | 8.02 | 9.9 |
| S.E | 1.01 | 4.28 | 1.19 | 0.2212 | 0.211 | 0.2473 |
| LSD | 1.4414 | 6.0564 | 1.6904 | 0.3129 | 0.2983 | 0.3498 |

**Petal Width (cm)**

Petal width was significantly affected by nitrogen levels (P = 0.0058). The widest petals (2.46 cm) were observed at 135 kg N $ha^{-1}$, significantly superior to all treatments. The narrowest petals (1.46 cm) were recorded in the control.

Nitrogen enhances petal expansion by supporting turgor-driven cell enlargement and promoting the accumulation of proteins and pigments in floral tissues. Similar effects of nitrogen on petal morphology were reported by Ahmad *et al*. (2015) in zinnia and marigold, where moderate nitrogen significantly improved petal width and visual quality.

**Number of Petals Flower$^{-1}$**

There was a highly significant difference (P = 0.0042) in the number of petals flower$^{-1}$. Plants treated with 135 kg N $ha^{-1}$ produced the highest number of petals (27.66), while the control had the fewest (17.33).

Adequate nitrogen supports floral meristem activity, which may increase petal initiation and development (Nasiri *et al*., 2010). This aligns with findings by Bhatt *et al*. (2022), who noted a similar increase in petal count in nitrogen-treated ornamental plants.

**Petal Thickness (mm)**

Nitrogen significantly influenced petal thickness (P = 0.013). The thickest petals (0.20 mm) were observed at 90 kg N $ha^{-1}$, followed by 180 kg $ha^{-1}$ (0.15 mm). The thinnest (0.07 mm) were seen in plants treated with 45 kg $ha^{-1}$.

Thicker petals are generally associated with better floral quality and resilience. Moderate nitrogen may aid lignin and protein accumulation in petal tissue, contributing to enhanced thickness (Singh and Boomsma, 2015). However, inconsistency in response across treatments indicates petal thickness may be more genotype-dependent.

**Single Petal Weight (g)**

There was a significant difference (P = 0.0228) in single petal weight. The heaviest single petal (1.30 g) was produced at 135 kg N $ha^{-1}$, while the lightest (0.20 g) came from the control.

Increased nitrogen availability facilitates better translocation of photosynthates to floral parts, thereby increasing biomass and weight of individual petals (Rehman *et al*., 2018). Enhanced single petal weight contributes to flower volume and visual appeal.

**Disk Florets Diameter (mm)**

Disk floret diameter was highly significantly affected (P = 0.0014). The widest diameter (9.83 mm) was recorded at 135 kg N $ha^{-1}$, while the smallest (4.83 mm) occurred at 180 kg $ha^{-1}$.

Nitrogen at optimal levels supports reproductive tissue development, while excessive doses may favor vegetative over floral growth, hence reducing reproductive sink development (Khaliq *et al*., 2020).

**Weight of Disk Florets (g)**

Significant differences (P = 0.0075) were observed in disk floret weight. The heaviest weight (19.69 g) was recorded with 135 kg N $ha^{-1}$, while the lightest (11.93 g) was in the control.

These results confirm nitrogen's role in enhancing reproductive tissue biomass. Balanced nitrogen improves carbohydrate accumulation, supporting the development of heavier florets, as seen in sunflower and zinnia studies (Shah *et al*., 2016).

**Corolla Weight (g)**

A highly significant variation (P = 0.0009) was observed in corolla weight. The maximum corolla weight (2.37 g) was achieved at 135 kg N $ha^{-1}$, while the minimum (1.12 g) occurred in the control.

Corolla weight, an important aesthetic trait in ornamental crops, is directly linked to nitrogen-induced floral development. Increased biomass allocation to the corolla enhances flower size and appeal (Khan *et al*., 2018). Excess nitrogen (180 kg) resulted in reduced corolla weight (1.79 g), again indicating a threshold beyond which benefits decline.

**Flower Parameters-II**

| Nitrogen Fertilizer | Petals Width (cm) | Number of Petal Flower$^{-1}$ | Petal thickness (mm) | Single Petal Weight (g) | Disk florets diameter (mm) | Weight of disk florets (g) | corolla weight (g) |
|---|---|---|---|---|---|---|---|
| Control | 1.46 e | 17.33 e | 0.13 b | 0.20 e | 6.15 c | 11.93 e | 1.12 e |
| 45 kg ha-1 | 2.03 c | 22.33 c | 0.07 d | 0.44 d | 4.93 d | 16.44 c | 2.21 b |
| 90 kg ha-1 | 1.5 d | 21.66 d | 0.2 e | 0.75 b | 8.2 b | 15.33 d | 1.34 d |
| 135 kg ha-1 | 2.46 a | 27.66 a | 0.09 c | 1.30 a | 9.83 a | 19.69 a | 2.37 a |
| 180 kg ha-1 | 2.06 b | 22.66 b | 0.15 a | 0.62 c | 4.83 e | 16.47 b | 1.79 c |
| F-Value | 8.41 | 9.31 | 6.41 | 5.23 | 13.05 | 7.71 | 14.61 |
| P-Value | 0.0058 | 0.0042 | 0.013 | 0.0228 | 0.0014 | 0.0075 | 0.0009 |
| CV | 13.23 | 9.34 | 26.14 | 46.85 | 15.35 | 10.8 | 13.79 |
| S.E | 0.1457 | 1.2 | 0.0196 | 0.17 | 0.602 | 1.003 | 0.141 |
| LSD | 0.206 | 1.7029 | 0.0277 | 0.2542 | 0.8514 | 1.4185 | 0.1995 |

**Conclusion**

The field experiment conducted at GUL FLORIST/Z-Organic Agricultural Farm, Badin, during 2024–25 demonstrated that nitrogen fertilization has a significant impact on the growth and flowering performance of ornamental sunflower (*Helianthus annuus* L., cv. Vincent's-2). Among the five nitrogen treatments tested, the application of 135 kg ha$^{-1}$ nitrogen resulted in the most favorable outcomes across a range of morphological and floral traits, including plant height, number of leaves, flower diameter, leaf dimensions, and flower quality parameters such as single flower weight and number of petals. These findings indicate that 135 kg ha$^{-1}$ is the optimal nitrogen dose under the agro-climatic conditions of Badin for maximizing both vegetative growth and ornamental value of sunflower.

Nitrogen levels higher than this threshold (180 kg ha$^{-1}$) negatively affected plant performance, suggesting the importance of balanced nutrient management. The results provide practical recommendations for commercial growers and landscape horticulturists seeking to enhance the aesthetic and economic value of ornamental sunflower through efficient nitrogen application.

**Suggestion**

Nitrogen Dose: A nitrogen application rate of 135 kg ha$^{-1}$ is suggested for commercial cultivation of ornamental sunflower (cv. Vincent's-2) to achieve maximum vegetative growth and superior floral traits.

Avoid Over-Fertilization: Application beyond 135 kg ha$^{-1}$, especially at 180 kg ha$^{-1}$, should be avoided as it leads to reduced performance, indicating negative effects of excessive nitrogen.

Site-Specific Recommendations: Although 135 kg ha$^{-1}$ proved optimal under Badin's conditions, similar trials should be conducted in different agro-climatic zones to validate these results and develop site-specific nutrient management guidelines.

Sustainable Practices: Integrated nutrient management approaches combining organic and inorganic sources of nitrogen may be explored in future studies to ensure environmental sustainability.

Further Research: Future investigations could include the impact of nitrogen on post-harvest life, flower color intensity, and resistance to pests and diseases to broaden the understanding of nitrogen's role in ornamental sunflower production.

Economic Analysis: A cost-benefit analysis of different nitrogen doses may be conducted to guide growers in selecting the most economically viable fertilization strategy.

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(*Accepted for publication July 2025*)