



Original Research

Nitrogen Fertilization Enhances Growth, Quality and Seed Production of Celosia (*Celosia cristata* L.), Marigold (*Tagetes erecta* L.) and Zinnia (*Zinnia elegans* L.)

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ABSTRACT

Cock's comb (*Celosia cristata* L.), marigold (*Tagetes erecta* L.) and zinnia (*Zinnia elegans* Jacq.) are popular ornamentals which are extensively cultivated as annual bedding adornments. A study was carried out during 2021-2023 on celosia, marigold and zinnia to scrutinize the effects of nitrogen fertilization. Greatest plant height for celosia (66.3 cm), orange marigold (90.5 cm), yellow marigold (72.8 cm) and zinnia (75.2 cm) was recorded when plants were fertilized with NPK combination @ 30:10:10 g m⁻². The least production time was recorded in celosia (21 days), (23.7 days) in zinnia with treatment combination 30 g m⁻² nitrogen application, whilst marigold cultivars exhibited the least production time (79 and 101 days) in orange and yellow marigold in control @0:10:10 g m⁻², respectively. The highest seed yield per plant in orange marigold (6.1 g), yellow marigold (8.1 g) and zinnia (0.9 g) was measured @ 30:10:10 g m⁻² NPK application. Celosia plants showed almost similar results regarding seed yield per plant and were statistically at par. Leaf nitrogen uptake in celosia (0.6%), orange marigold (0.5%), yellow marigold (1.3%) and zinnia (0.8%) and leaf phosphorus uptake celosia (1.9%), orange marigold (0.4%), yellow marigold (0.6%) and zinnia (0.4%) were recorded highest @ 30:10:10 g m⁻². Leaf potassium uptake in celosia (1.9%) and yellow marigold (0.8%) was recorded as 30:10:10, and in orange marigold (0.9%), zinnia (1.7%). In summary, NPK combination @ 30:10:10 g m⁻² proved best regarding vegetative, reproductive, and flower attributes, seed yield and biochemical plant attributes in tested annual flower species/cultivars in local subtropical agro-climatic conditions.

Keywords: Annual flowers, cultivars, flower quality, nutrient uptake, growth attributes, harvest index, seed attributes.

Article History: Received 14 June 2025; Revised 15 July 2025; Accepted 23 July 2025; Published 30 September 2025.

INTRODUCTION

The floriculture segment is gaining popularity during recent times, resulting in the production of bulk quantities of ornamentals (Saravanan, 2020). Floricultural products are highly demanded worldwide. A substantial rise in the production of ornamentals is ultimately boosting the international flower trade (Afsaneh et al., 2022). Flower production hub has shifted to regions where the climatic conditions are favourable and cultivation expenses are the least, as compared to conventional producers, such as the Netherlands (Zhao et al., 2008). Production of ornamental plants is increasing and

significant obstacle to their thriving culture is the absence of recommended fertilization practices (Ahmad et al., 2017). In comparison with other horticultural and conventional crops, floriculture production is emerging as a commercial and rewarding occupation with higher gross returns (Sudhagar, 2013). Pakistan is blessed with excellent agro-climatic conditions for the production of ornamental crops as compared with other countries (Oosterhuis et al., 2014).

Seed production is a chief crossroads in numerous unindustrialized states. Most growers have minimal access to viable and quality seed, and this limitation has constrained the selection of new cultivars. Replacing nutrients that have been lost from the soil as a result of leaching or continuous plant uptake is the primary goal of applying fertilizers (Jakli et al., 2017). Quality seed is essential criterion to get good crop yield and subsidize approximately five to twenty percent in total yield. Balanced nutritional supply is necessary in sufficient amounts to enhance nutrient use efficiency in growing plants (Law-Ogbomo and Eghareva, 2009).

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J. Hort. Sci. Technol. © 2025 Pakistan Society for Horticultural Science

Essential primary nutrients, which make a significant contribution, nitrogen (N), phosphorus (P), and potassium (K), are the main components of mineral nutrition (Younis et al., 2013). Nitrogen is the fundamental nutrient element that contributes to plant growth and productivity. Its prime role in building amino acids makes it conspicuous for protein synthesis, protoplasm formation, cell size regulation and photosynthetic activity. Furthermore, nitrogen fertilizer application plays a significant role in influencing multiple growth attributes such as, branching and pod production, plant biomass and leaf area. A crucial factor in promoting plant productivity is increased flower and seed production. The primary purpose of fertilizer application is to restore soil nutrient balances by replacing essential elements to support healthy plant development and for maximum crop yield. Nitrogen application enhances vegetative growth and biomass production (Khosa et al., 2011). Mineral nutrition management is a critical factor influencing yield in horticulture, so its optimization is essential for ornamental growers to maximize production. A sufficient amount of nitrogen is necessary for the production of cut flowers, making it a vital aspect of horticultural practices. (Kolade et al., 2018).

Cock's comb (*Celosia cristata* L.) is annually cultivated as a rainy season annual flower, a member of the Amaranthaceae family. Marigold (*Tagetes erecta* L.), a member of the family Asteraceae, grown as a winter annual, is gaining popularity in both rural and urban areas as a bedding annual flower. *Zinnia elegans*, a member of the Compositae family, is highly appreciated among the flowering summer annuals. However, there is a continuous demand for ornamental cultivars with new forms and colours in modern industrialized horticulture (Yunus et al., 2013). Achieving quality plants and flowers in areas with high pH soils and semi-arid climates has always been a challenge. Consequently, to get more crop production, nitrogen application is indispensable. Keeping in view the mentioned scenario and increasing demand for bedding annual flowers, it was hypothesized that the use of an optimum quantity of fertilizers will enhance the growth, flower yield, seed yield and quality for a booming indigenous flower seed production industry. Therefore, this study was conducted to examine the influence of nitrogen (N) fertilizer and to scrutinize the optimum nutrient combination for vegetative, reproductive, and seed yield as well as biochemical parameters of the tested species.

MATERIALS AND METHODS

Experimental sites

A Study was carried out at Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, on cock's comb (*Celosia cristata* L.), marigold (*Tagetes erecta* L.), and zinnia (*Zinnia elegans* Jacq.), for consecutive winter, rainy and summer seasons (2021-2023). From each site, 1 kg soil samples were collected to measure pH, electrical conductivity (EC), organic matter, and the concentrations of nitrogen, phosphorus, and potassium. The physicochemical characteristics of the soil in the experimental area were analyzed before transplanting. Tested soil texture was loam with pH of 8, EC 0.2 dS cm⁻¹, organic matter 1.05%, saturation percentage 34%, N contents 0.06 ppm, P contents 10.1 ppm, K contents 320 ppm. Physicochemical analysis of canal water

depicted pH 6.6, EC 0.2 dS cm⁻¹, total soluble solids 154 ppm and total hardness 77.6 ppm.

Crop husbandry

Seeds of all tested ornamental species were obtained from a reputable seed supplier in Lahore, Pakistan. Nursery raising was carried out in 128-cell plastic germination trays filled with a growing medium prepared by mixing silt, sugarcane press mud, and coco coir in equal proportions (1:1:1; v/v/v). After four weeks, vigorous seedlings with 2-4 true leaves were transplanted to the field following proper soil preparation and plot layout. Urea (46% N), single superphosphate (18% P₂O₅) and sulphate of potash (50% K₂O) served as the fertilizer sources for nitrogen, phosphorus and potassium, respectively.

Experimental treatments

There were four treatments, including control, which were tested on two African marigold cultivars, viz., 'Orange', and 'Yellow', one celosia cultivar, viz. 'Fire Chief' and one zinnia cultivar 'Giant Dahlia Flowered Mix' having nitrogen @ 0, 10, 20, 30 g m⁻² and 10 g m⁻² for each phosphorus and potash, respectively. Experiments for individual species/cultivars were carried out in a randomized complete block design (RCBD) replicated thrice. Treatments for each of the tested species were as follows: (0:10:10) NPK g m⁻² control, (10:10:10) NPK g m⁻², (20:10:10) NPK g m⁻², (30:10:10) NPK g m⁻². Phosphorus and potassium were applied in a single dose, at the time of soil preparation, before transplanting, while nitrogen was supplied in 3 splits. First dose at the time of transplanting, followed by 2nd

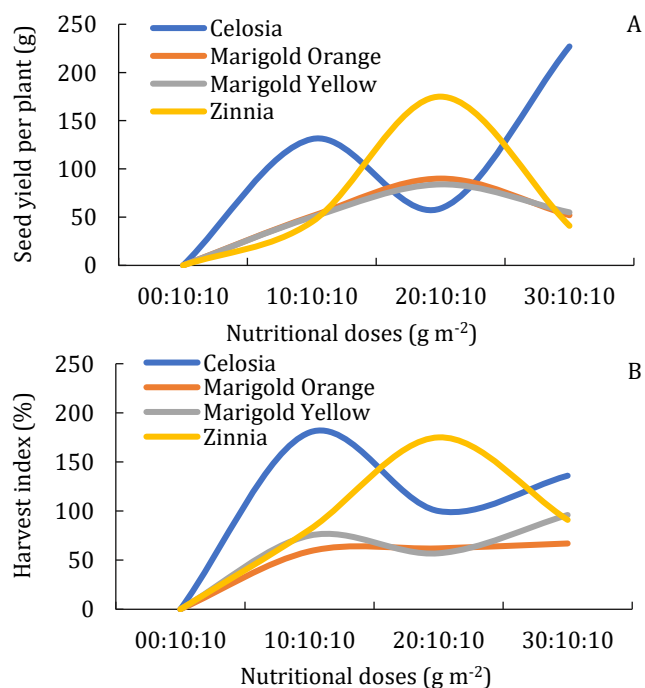


Figure 1: Changes in (A) seed yield per plant (%) and (B) harvest index (%) of celosia, marigold and zinnia, as influenced by various nitrogen levels. Data represents means of 15 plants.

Table 1: Effect of various doses of nitrogenous fertilizer on plant height (cm), production time (days), total leaf chlorophyll contents (SPAD), number of flowers (no.), flower diameter (mm), Plant fresh weight (g), Plant dry weight (g), seed yield per plant (g), total leaf nitrogen contents (%), total leaf phosphorus contents (%) and total leaf potassium contents (%) of celosia cultivar "Fire Chief". Data represents the means of 15 plants.

Treatments N:P: K (g m ⁻²)	Plant height (cm)	Production time (days)	Total leaf chlorophyll contents (SPAD)	Number of flowers (no.)	Flower diameter (mm)	Plant fresh weight (g)	Plant dry weight (g)	Seed yield per plant (g)	Total leaf N (%)	Total leaf P (%)	Total leaf K (%)
0:10:10	26.7 c ^z	35.3 a	38.2 b	1.3 d ^z	23.8 c ^z	30.0 c ^z	5.5 c	0.91	0.6 c	0.07 c	0.1 d
10:10:10	35.9 bc	23 c	57.9 a	3.0 b	56.2 b	41.5 b	7.8 b	0.69	0.5 d	0.01 d	0.5 c
20:10:10	46.3 b	31 b	42.6 b	2.0 c	45.1 b	49.0 a	13.0 a	1.16	0.6 b	1.5 b	0.9 b
30:10:10	66.3 a	19.7 c	57.8 a	5.0 a	74.1 a	38.7 b	7.8 b	0.51	0.7 a	1.9 a	1.9 a
Significance ^y	0.0003	0.0002	0.0026	<0.0001	0.0003	0.0003	0.0002	NS	<0.0001	<0.0001	<0.0001

^z Means separation within columns by Fisher's LSD $p \leq 0.05$.^y P values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different nitrogen levels on vegetative, reproductive and seed attributes of *Celosia cristata* L. cultivar "Fire Chief".

N= Nitrogen, P= Phosphorus, K= Potassium

Table 2: Effect of various doses of nitrogenous fertilizer on plant height (cm), production time (days), total leaf chlorophyll contents (SPAD), number of flowers (no.), flower diameter (mm), plant fresh weight (g), plant dry weight (g), seed yield per plant (g), total leaf nitrogen contents (%), total leaf phosphorus contents (%) and total leaf potassium contents (%) of marigold cultivar "African Orange". Data represents the means of 15 plants.

Treatments N:P:K (g m ⁻²)	Plant height (cm)	Production time (days)	Total leaf chlorophyll contents (SPAD)	Number of flowers (no.)	Flower diameter (mm)	Plant fresh weight (g)	Plant dry weight (g)	Seed yield per plant (g)	Total leaf N (%)	Total leaf P (%)	Total leaf K (%)
0:10:10	52.5 d	78.8 d	31.7 c	17.6 a	68.7 c	60.9 b	19.9 c	1.5 d	0.7 bc	0.4 c	1.2 a
10:10:10	73.1 b	98.2 c	47.4 b	11.7 b	91.9 b	69.0 a	22.7 a	2.9 c	0.9 b	0.3 d	1.0 b
20:10:10	65.6 c	112.0 b	51.9 b	8.3 c	67.1 c	47.8 c ^z	15.7 c	3.2 b	0.6 c	0.5 b	2.0 c
30:10:10	90.5 a	125.9 a	64.5 a	4.2 d	104.9 a	61.8 ab	20.3 ab	6.1 a	1.3 a	0.6 a	0.9 d
Significance ^y	<0.0001	<0.0001	0.0001	0.0002	<0.0001	0.0002	0.0035	0.0002	0.0031	<0.0001	<0.0001

^z Means separation within columns by Fisher's LSD $p \leq 0.05$.^y P values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different nitrogen levels on vegetative, reproductive and seed attributes of *Tagetes erecta* L. cultivar "African Orange".

N= Nitrogen, P= Phosphorus, K= Potassium

dose after one month, and the remaining dose at the flower initiation stage for getting the best results.

Observations

Measurements included plant height (cm), days to production, leaf chlorophyll level, number of flowers, flower diameter (mm), fresh and dry plant weight (g), seed yield per plant (g), harvest index (%), and the percentage of nitrogen, phosphorus, and potassium in the leaves.

Statistical Analysis

Data were analyzed using ANOVA (General Linear Model). Mean differences were tested with Fisher's LSD at $p \leq 0.05$ (Steel et al., 1997).

RESULTS

Celosia

Results demonstrated that the tallest plant height (66.3 cm), the least production time (19.7 days), and the most significant number of blooms were recorded when celosia was supplemented with nitrogen level @ 30:10:10 g m⁻². Total leaf chlorophyll contents were highest recorded (57.9 SPAD) in plants nourished with nitrogen @ 10:10:10 g m⁻², which executed almost similar results as with nutrient combination 30:10:10 g m⁻². Widest flower diameter (74.1 mm) was recorded in combination 30:10:10 g m⁻², followed by 56.2 mm with @ 10:10:10 g m⁻². Plants supplied with no nitrogen (control) exhibited stunted growth, the least plant height (26.7 cm), the longest production time (35.3 days), the shortest flower heads (23.8 mm) and the least amount of chlorophyll content (38.2 SPAD). The most significant plant fresh weight (49 g), plant dry weight (13 g) and seed yield per plant (1.2 g) are recorded for plants supplied with @ 20:10:10 g m⁻². Macronutrient uptake in plants exhibited the highest value for nitrogen (0.7%), phosphorus (1.9%) and potassium (1.9%) (Table 1). Percentage change in seed yield per plant and harvest index (%) was also represented as the highest value in @ 10:10:10 g m⁻² (Fig. 1).

Table 3: Effect of various doses of nitrogenous fertilizer on plant height (cm), production time (days), total leaf chlorophyll contents (SPAD), number of flowers (no.), flower diameter (mm), plant fresh weight (g), plant dry weight (g), seed yield per plant (g), total leaf nitrogen contents (%), total leaf phosphorus contents (%) and total leaf potassium contents (%) of marigold cultivar "African Yellow". Data represents the means of 15 plants.

Treatments N:P:K (g m ⁻²)	Plant height (cm)	Production time (days)	Total leaf chlorophyll contents (SPAD)	Number of flowers (no.)	Flower diameter (mm)	Plant fresh weight (g)	Plant dry weight (g)	Seed yield per plant (g)	Total leaf N (%)	Total leaf P (%)	Total leaf K (%)
0:10:10	41.7 d ^z	101.4 d	48.4 c	4 d	54.6 c	31.2 b	12.5	1.9 c	0.2 d	0.1 d	0.3 a
10:10:10	62.3 b	112.9 c	55.2 b	7.7 c	64.7 b	48.5 ab	18.9	3.8 b	0.5 c	0.2 c	0.1 b
20:10:10	49.8 c	121.7 b	61.7 a	11.3 b	44 d	32.1 b	12.8	4.5 b	0.8 b	0.3 b	0.7 a
30:10:10	72.8 a	134.2 a	55.8 b	16 a	73.5 a	53.6	20.9	8.1 a	0.9 a	0.4 a	0.8 a
Significance ^y	0.0001	<0.0001	0.0001	0.001	0.0001	0.046	NS	0.0011	<0.0001	<0.0001	0.46

^z Means separation within columns by Fisher's LSD $p \leq 0.05$.

^y P values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different nitrogen levels on vegetative, reproductive and seed attributes of *Tagetes erecta* L. cultivar "African Yellow".

N= Nitrogen, P= Phosphorus, K= Potassium

Table 4: Effect of various doses of nitrogenous fertilizer on plant height (cm), production time (days), total leaf chlorophyll contents (SPAD), number of flowers (no.), flower diameter (mm), plant fresh weight (g), plant dry weight (g), seed yield per plant (g), total leaf nitrogen contents (%), total leaf phosphorus contents (%) and total leaf potassium contents (%) of zinnia cultivar "Giant Dahlia Flowered". Data represents the means of 15 plants.

Treatments N:P:K (g m ⁻²)	Plant height (cm)	Production time (days)	Total leaf chlorophyll contents (SPAD)	Number of flowers (no.)	Flower diameter (mm)	Plant fresh weight (g)	Plant dry weight (g)	Seed yield per plant (g)	Total leaf N (%)	Total leaf P (%)	Total leaf K (%)
0:10:10	39.3 c ^z	33.2 a	38.6 c	1.8 c	32.2 d	21.4 c	2.2 b	0.33 d	0.1 d	0.3 d	3.3 a
10:10:10	60.0 b	27.1 a	40.6 bc	4.4 c	55.8 c	36.8 b	3.9 b	0.72 b	0.2 c	0.3 c	2.2 b
20:10:10	61.1 b	28.1 b	43.0 ab	4.7 b	67.4 b	37.8 b	3.9 b	0.41 c	0.4 b	0.3 b	1.7 c
30:10:10	75.2 a	23.7 b	45.0 a	6.8 a	82.5 a	50.1 a	8.5 a	0.98 a	0.5 a	0.4 a	1.3 d
Significance ^y	<0.0001	0.0012	0.0049	0.0032	<0.0001	0.0053	0.0016	<0.0001	<0.0001	<0.0001	<0.0001

^z Means separation within columns by Fisher's LSD $p \leq 0.05$.

^y P values were obtained using general linear models (GLM) procedures of Statistix (version 8.1, analytical software) for significant effects of different nitrogen levels on vegetative, reproductive and seed attributes of *Tagetes erecta* L. cultivar "Giant Dahlia Flowered".

N= Nitrogen, P= Phosphorus, K= Potassium

Marigold

Data regarding marigold tested species 'African cultivars' viz, orange and yellow, were tested individually. Tallest plants (90.5 cm), highest leaf chlorophyll contents (64.5 SPAD), widest flower diameter (104.9 mm), and highest seed yield per plant (6.1 g) were recorded in orange marigold with application of 30:10:10 g m⁻² nutrient combination. The least production time (78.8 days) with the most significant number of flowers (17.6) were recorded in plants supplied with a 30:10:10 g m⁻² nutrient combination, followed by 10:10:10 g m⁻². Highest plant fresh weight (69 g) and plant dry weight (22.7 g) was recorded when plants were supplied with 10:10:10 g m⁻². The highest nutrient uptake in plants regarding nitrogen (1.3%), phosphorus (0.6%) was recorded in nutrient combination 30:10:10 g m⁻². Leaf potassium contents were recorded as higher (2%) with 20:10:10 g m⁻², followed by 1.2% in 0:10:10 g m⁻² (Table 2). Regarding yellow marigold tested cultivar, tallest plants (72.8 cm), greater number of flowers (16), widest flower diameter (73.5 mm), highest plant fresh weight (53.6 g), seed yield per plant (8.1 g) were recorded in plants supplied with greater amount of nitrogen 30:10:10 g m⁻². The least production time (101.4 days) was recorded in 0:10:10 g m⁻² (control), followed by 10:10:10 g m⁻². A higher amount of nitrogen delayed flower initiation in yellow marigold. Data regarding nutrient uptake also exhibited significant results with the highest nitrogen uptake (0.9%), phosphorus (0.4%) and potassium (0.8%). Highest chlorophyll contents (61.7 SPAD) were recorded with 20:10:10 g m⁻², followed by 55.8 SPAD with nutrient combination 30:10:10 g m⁻² (Table 3).

Zinnia

Greatest plant height (75.2 cm), least production time (23.7 days), highest total leaf chlorophyll contents (45 SPAD), with a higher number of blooms (6.8), and the widest flower diameter (82.5 mm) were recorded in plants supplied with 30:10:10 g m⁻² NPK. Highest plant fresh weight (50.1 g), plant dry weight (8.5 g), seed yield per

plant (0.98 g), leaf total nitrogen contents (0.5%), leaf phosphorus contents (0.4%) was also recorded in plants treated with 30:10:10 g m⁻² NPK whilst, leaf potassium (3.3%) contents were recorded highest in control treatment followed by 2.2% in 20:10:10 g m⁻² NPK (Table 4). Percentage change in harvest seed yield per plant and harvest index also depicted significant results for the tested zinnia crops (Fig. 1).

DISCUSSION

Plants, when supplied with an ample amount of nitrogen along with phosphorus and potassium, produced the tallest plants for celosia (66.6 cm), marigold (90.5 and 72.8 cm), with a greater number of flowers in the tested species. Nitrogen, being a crucial element for growth, plays a pivotal role in initiating meristematic plant activities, resulting in the tallest plants (Ahmad et al., 2017; Sarwar et al., 2013). Ample nitrogen applied also improved cellular activities. These findings are in line with the results of Verma et al. (2010), which show that stem length and flower yield were maximized by applying N and P fertilizers in gladiolus. It was observed that when macro nutrients were used, the tallest plants were produced in *Dahlia hybrida* (Kashif et al., 2014). Stunted plant growth in the control treatment is due to a shortage or absence of nitrogen (Alkurdi, 2014). Plant height was promoted by applying NH₄NO₃ as a nitrogen source. The shortest production time was recorded in celosia (19.7 days) and zinnia (23.7 days), which were recorded in plants supplemented with 30:10:10 g m⁻². However, the marigold plant exhibited the fewest days to flowering in the control treatment. These findings are similar to the study on calendula plants supplied with nitrogen and phosphorus, which took the least (160 days) to flower initiation (Kumar et al., 2015). Organic and inorganic fertilizers application on petunia revealed the least production time (60 days) when fertilized inorganically (Zhang et al., 2012).

Leaf total chlorophyll contents were recorded as highest in celosia (57.9 SPAD), orange marigold (64.5 SPAD), yellow marigold (61.7 SPAD) and zinnia (45 SPAD) in NPK combination 30:10:10 g m⁻² in the tested flower species. Optimal plant nutrition may assist in synthesizing essential plant pigments like chlorophyll content while utilizing sunlight in a proper proportion. Similar findings were observed in *Tulipa gesneriana* when supplied with NPK @ 17:17:17, which produced the highest chlorophyll contents (Ali et al., 2014). Celosia plants, when provided with macronutrients, boosted vegetative growth as well as increased chlorophyll contents (El Gayed et al., 2018). Widest flower diameter in celosia (74.1 mm), marigold (104.9 and 75 mm), and zinnia (842.5 mm) in plants supplied with NPK combination 30:10:10 g m⁻². The greatest flower diameter was also recorded in *Dahlia hybrida* when supplied with macro and micronutrients (Kashif et al., 2014). Bhattacharjee et al. (1983) studied that marigold plants, when treated with an ample supply of nitrogen and phosphorus, produced flowers with a greater diameter. Seedlings treated with NPK fertilizer revealed the highest number of spikes (Ayeni, 2016). Plant biomass production is highest when supplied nutrients are appropriately utilized and boost vegetative and reproductive growth. Plant biomass production increased in pot marigold plants supplied with 150 kg ha⁻¹ nitrogen (Shahrabaki et al., 2013). This work is in line with a study where a significant increase in vegetative

and floral parameters was observed by applying nitrogen and phosphorus @ 150 g per plant and 75 g per plant (Parekh et al., 2012). Nutrient solution consisting of 150 mg L⁻¹ N, 31 mg L⁻¹ P, 234 mg L⁻¹ potash and micronutrients developed superior plants with quality flowers in gerbera (*Gerbera jamesonii*) (Sirin, 2011). The role of nitrogen in the synthesis of basic plant parts is essential, which critically affects plant development and biomass production. Deficiency and overapplication of nitrogen have adverse effects on crop plants. A significant increase in seed parameters and leaf NPK contents was also observed in plants where an ample supply of nitrogen was given. The lowest seed yield was observed in plants treated as controls. The use of optimal plant nutrition improves soil health by boosting nutrient status, which results in better quality flowers as well as seed yield per plant (Ahmad et al., 2011). Calendula plants, when treated with @ 90 kg ha⁻¹ nitrogen, resulted in bigger flower heads and improved seed yield (Rahmani et al., 2009). Same findings were exhibited regarding vegetative traits of zinnia cultivar, studied under nitrogen applied @ 0 (control), 33, 67, and 100 kg ha⁻¹ exhibited that treatment having 100 kg N ha⁻¹ exhibited, highest nutrient uptake in leaf NPK percentage, stem girth and flower diameter (Ahmad et al., 2007).

CONCLUSION

The present study exhibited a positive relationship between plant growth rate (vegetative + reproductive + seed + leaf NPK attributes) and applied nitrogen while keeping phosphorus and potash constant. Tested quantity of P and K used for annual flower species is @ 10 g m⁻². Nitrogen @ 30 g m⁻² produced optimum results. For delivering superior quality, healthy and large-sized blooms and healthy seeds for celosia, marigold, and zinnia plants, NPK @ 30:10:10 g m⁻² is an optimum combination and may be used.

DECLARATION OF COMPETING INTERESTS

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION STATEMENT

Tazkia Hussain: Conducted experiments, collected and compiled data, performed data analysis, and wrote the 1st draft of the manuscript. **Iftikhar Ahmad:** Conceived the idea, provided technical guidance, and technically reviewed the manuscript. **Khurram Ziaf:** Reviewed the manuscript technically. **Naveed Ahmad:** Assisted in field experimentation. **Zunaira Hussain:** Assisted in data collection. **Sadia Sardar:** Reviewed manuscript. All authors have read and approved the final version of the manuscript.

FUNDING

Authors are grateful to the Higher Education Commission of Pakistan (HEC) for HEC Project # 20-15609, entitled "Enhancing Indigenous Flower Seed Production through Optimizing Production and Handling Protocols and Human Resource Development", for providing partial assistance regarding research materials.

ETHICAL STATEMENT

Not applicable.

AVAILABILITY OF DATA AND MATERIAL

All data is published in this research article.

INFORMED CONSENT

Not applicable.

CONSENT FOR PUBLICATION

All authors have submitted consent to publish this research article in the 'Journal of Horticulture Science and Technology'.

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