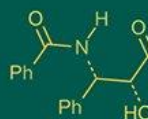


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Sudhir Kumar Pathak
Department of Horticulture,
Allahabad School of
Agriculture, Sam
Higginbottom Institute of
Agriculture Technology and
Sciences, Allahabad,
Prayagraj, Uttar Pradesh,
India

John P Collis
Department of Horticulture,
Allahabad School of
Agriculture, Sam
Higginbottom Institute of
Agriculture Technology and
Sciences, Allahabad,
Prayagraj, Uttar Pradesh,
India

Corresponding Author:
Sudhir Kumar Pathak
Department of Horticulture,
Allahabad School of
Agriculture, Sam
Higginbottom Institute of
Agriculture Technology and
Sciences, Allahabad,
Prayagraj, Uttar Pradesh,
India

Effect of nitrogen and phosphorus levels on vegetative growth of chrysanthemum (*Chrysanthemum morifolium* Ramat.) cv. Snowball

Sudhir Kumar Pathak and John P Collis

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Abstract

Balanced nutrient management is essential for achieving optimum vegetative growth in chrysanthemum (*Chrysanthemum morifolium* Ramat.), one of the most important ornamental flower crops. The present study was undertaken to determine the optimum levels of nitrogen and phosphorus for promoting vegetative growth of chrysanthemum cv. Snowball under the agro-climatic conditions of Prayagraj, India. The experiment was conducted during the winter season of 2009-10 in a factorial randomized block design comprising four nitrogen levels (0, 40, 60 and 80 kg N ha⁻¹) and three phosphorus levels (0, 100 and 120 kg P₂O₅ ha⁻¹) with three replications. Potassium was applied uniformly at 100 kg K₂O ha⁻¹ in all treatments. Plant height, plant spread, number of branches per plant and number of leaves per plant were recorded at 30, 45, 60 and 75 days after transplanting (DAT). Nitrogen and phosphorus significantly influenced all vegetative growth parameters. Among the treatment combinations, N₂P₁ (60 kg N ha⁻¹ + 100 kg P₂O₅ ha⁻¹) consistently produced superior growth throughout the crop growth period. At 75 DAT, N₂P₁ recorded the maximum plant height (35.78 cm), plant spread (36.47 cm), number of branches per plant (19.89) and number of leaves per plant (129.41), compared with 32.89 cm, 30.34 cm, 14.64 and 121.11, respectively, in the control treatment. Growth parameters increased with increasing nitrogen up to 60 kg ha⁻¹ and phosphorus up to 100 kg P₂O₅ ha⁻¹, whereas further increases resulted in a slight decline. The results indicate that application of 60 kg N ha⁻¹ and 100 kg P₂O₅ ha⁻¹ along with 100 kg K₂O ha⁻¹ is the optimum nutrient combination for maximizing vegetative growth of chrysanthemum cv. Snowball.

Keywords: *Chrysanthemum*, nitrogen, phosphorus, vegetative growth, nutrient management, Snowball

Introduction

Chrysanthemum (*Chrysanthemum morifolium* Ramat.) is one of the most important ornamental flowering crops cultivated worldwide for cut flowers, loose flowers, garden decoration, and landscaping purposes. The crop is highly valued for its wide range of flower forms, colours, and adaptability to diverse agro-climatic conditions. The growth, flowering, yield, and quality of chrysanthemum are greatly influenced by nutrient management practices, making balanced fertilization an essential component of its successful cultivation (Karik and Tunturk, 2019) [5].

Chrysanthemum is considered a heavy feeder because of its shallow root system, which limits nutrient uptake from deeper soil layers. Consequently, an adequate and balanced supply of nutrients is necessary to sustain vigorous vegetative growth and optimum flower production (Gu *et al.*, 2022; Hosseinzadeh *et al.*, 2015) [3, 4]. Although varietal characteristics largely determine flower quality, environmental conditions, soil fertility status, and nutrient availability also play significant roles in influencing plant growth and productivity. Therefore, the selection of appropriate fertilizer doses according to cultivar requirements and local soil conditions is crucial for maximizing crop performance (Shahrajabian *et al.*, 2019) [9].

Among essential plant nutrients, nitrogen (N) and phosphorus (P) are particularly important for chrysanthemum growth. Nitrogen is a major constituent of amino acids, proteins, nucleic acids, and chlorophyll, and is directly involved in photosynthesis and vegetative development. Adequate nitrogen nutrition promotes plant height, leaf production, branching, and overall plant vigor.

Phosphorus, on the other hand, plays a vital role in energy transfer, root development, cell division, and metabolic activities. It is an integral component of nucleic acids, phospholipids, and several enzymes that regulate plant growth and development (Li *et al.*, 2019; Chaitra *et al.*, 2018) [6, 1].

Previous studies have demonstrated that growth, flowering, yield, and quality attributes of chrysanthemum can be significantly improved through the application of appropriate levels of nitrogen, phosphorus, and other nutrients. Variations in fertilizer doses have been reported to influence vegetative growth, flower production, and overall crop performance in different chrysanthemum cultivars (Rajan *et al.*, 2019; Choudhary *et al.*, 2022) [8, 2]. However, nutrient requirements vary among cultivars and environmental conditions, making it necessary to identify optimum fertilizer levels for specific cultivars under local growing conditions.

Considering the importance of balanced nutrition and the limited information available for chrysanthemum cv. Snowball under the agro-climatic conditions of Prayagraj, the present investigation was undertaken to evaluate the effects of different levels of nitrogen and phosphorus on vegetative growth parameters, namely plant height, plant spread, number of branches per plant, and number of leaves per plant, and to determine the optimum nutrient combination for achieving maximum growth.

Materials and Methods

The experiment was conducted during the winter season of 2009-10 at the Research Farm of the Department of Horticulture, Sam Higginbottom Institute of Agriculture, Technology and Sciences (SHUATS), Prayagraj, India. The experimental soil was sandy loam with pH 7.1, organic carbon 0.48%, available nitrogen 0.25 kg ha⁻¹, available phosphorus 181.6 kg ha⁻¹, and available potassium 28.69 kg ha⁻¹.

The experiment was laid out in a factorial randomized block design (FRBD) with four nitrogen levels (0, 40, 60, and 80 kg N ha⁻¹) and three phosphorus levels (0, 100, and 150 kg P₂O₅ ha⁻¹), resulting in 12 treatment combinations (Table 1). Each treatment was replicated three times. Potassium was applied uniformly at 100 kg K₂O ha⁻¹ in all plots.

Rooted cuttings of chrysanthemum cv. Snowball were transplanted on 30 October 2009. Nitrogen was supplied through urea and phosphorus through single super phosphate. Half of the nitrogen along with the full dose of phosphorus and potassium was applied as basal fertilizer before transplanting, while the remaining nitrogen was applied as top dressing 20 days after transplanting. Recommended agronomic practices, including irrigation, weeding, and plant protection measures, were followed uniformly for all treatments throughout the crop growth period.

Five plants were randomly selected and tagged in each plot for recording observations. Growth parameters including plant height (cm), plant spread (cm), number of branches per plant, and number of leaves per plant were recorded at 30, 45, 60, and 75 days after transplanting (DAT). Plant height was measured from the soil surface to the apex of the plant. Plant spread was recorded as the average of east-west and north-south canopy spread. The numbers of branches and leaves were counted manually.

The recorded data were subjected to analysis of variance (ANOVA) appropriate for a factorial randomized block design following the procedure described by Fisher (1950). Treatment means were compared using the critical difference (CD) test at the 5% probability level.

Table 1: Treatment combinations used in the experiment

Treatment	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	Symbol
T ₀	0	0	N0 P0
T ₁	0	100	N0 P1
T ₂	0	150	N0 P2
T ₃	40	0	N1 P0
T ₄	40	100	N1 P1
T ₅	40	150	N1 P2
T ₆	60	0	N2 P0
T ₇	60	100	N2 P1
T ₈	60	150	N2 P2
T ₉	80	0	N3 P0
T ₁₀	80	100	N3 P1
T ₁₁	80	150	N3 P2

K₂O @ 100 kg ha⁻¹ was uniformly applied in all the plots

Results and Discussion

Plant height

Plant height was significantly influenced by nitrogen, phosphorus and their interaction at 45, 60 and 75 DAT, whereas treatment effects were non-significant at 30 DAT (Supplementary Tables S1 and S2). At 75 DAT, the maximum plant height (35.78 cm) was recorded under N₂P₁ (60 kg N ha⁻¹ + 100 kg P₂O₅ ha⁻¹), followed by N₂P₂ (34.84 cm), while the minimum value (32.89 cm) was observed in the control treatment (N₀P₀) (Table 2). A similar trend was observed throughout the crop growth period, where N₂P₁ consistently recorded the highest plant height at 30 DAT (16.66 cm), 45 DAT (25.43 cm) and 60 DAT (34.50 cm), compared with 11.74, 21.44 and 31.45 cm, respectively, under the control treatment (Supplementary Tables 1 and 2). The increase in plant height with nitrogen application up to 60 kg ha⁻¹ and phosphorus application up to 100 kg P₂O₅ ha⁻¹ may be attributed to enhanced chlorophyll synthesis, photosynthetic activity, protein formation and cell elongation. However, further increase in nutrient levels resulted in a slight decline in plant height.

Plant spread

Nitrogen, phosphorus and their interaction significantly affected plant spread at 45, 60 and 75 DAT, whereas interaction effects were non-significant at 30 DAT (Supplementary Tables S3 and S4). At 75 DAT, N₂P₁ produced the maximum plant spread (36.47 cm), followed by N₂P₂ (34.65 cm), whereas the control treatment recorded the minimum value (30.34 cm) (Table 2). The superiority of N₂P₁ was evident throughout the growth period, recording plant spread values of 20.65, 24.57 and 32.69 cm at 30, 45 and 60 DAT, respectively, compared with 13.53, 20.69 and 27.76 cm under the control treatment (Supplementary Tables 3 and 4). The improved plant spread under optimum nutrient application may be due to enhanced vegetative growth, greater assimilate production and efficient translocation of photosynthates to developing tissues. The decline observed at higher nutrient levels suggests that excessive fertilization was less effective in promoting canopy development.

Number of branches per plant

The number of branches per plant was significantly affected by nitrogen and phosphorus at 45, 60 and 75 DAT, while treatment effects were non-significant at 30 DAT (Supplementary Tables S5 and S6). The highest number of branches per plant at 75 DAT was recorded under N₂P₁ (19.89), followed by N₂P₂ (19.77), whereas the lowest value (14.64) was observed in the control treatment (Table 2). The same treatment also produced the highest number of branches at 30 DAT (4.41), 45 DAT (6.71) and 60 DAT (12.82), compared with 2.56, 4.59 and 8.46 branches plant⁻¹, respectively, under the control treatment (Supplementary Tables 5 and 6). The increased branching under optimum nutrient supply may be attributed to enhanced meristematic activity and greater availability of metabolites required for vegetative growth. Phosphorus-mediated improvement in root development and nutrient uptake may have further contributed to branch formation.

Number of leaves per plant

The number of leaves per plant increased significantly with nitrogen and phosphorus application at 45, 60 and 75 DAT, whereas treatment effects were non-significant at 30 DAT (Supplementary Tables S7 and S8). At 75 DAT, the maximum number of leaves per plant (129.41) was recorded under N₂P₁, followed closely by N₂P₂ (129.20), while the minimum value (121.11) was recorded in the control treatment (Table 2). The superiority of N₂P₁ was maintained throughout the crop growth period, recording 25.85, 50.89 and 121.61 leaves plant⁻¹ at 30, 45 and 60 DAT, respectively, compared with 18.64, 35.65 and 83.92 leaves plant⁻¹ under the control treatment (Supplementary Tables 7 and 8). Increased leaf production under optimum nitrogen and phosphorus nutrition may be attributed to enhanced photosynthetic activity, chlorophyll synthesis, protein formation and metabolic regulation. The results indicate that application of 60 kg N ha⁻¹ and 100 kg P₂O₅ ha⁻¹ was most effective in promoting vegetative growth of chrysanthemum cv. Snowball under the conditions of the present study.

Table 2: Effect of nitrogen and phosphorus levels on vegetative growth of chrysanthemum cv. Snowball at 75 DAT

Treatment	Plant height (cm)	Plant spread (cm)	Branches plant ⁻¹	Leaves plant ⁻¹
NoP ₀	32.89	30.34	14.64	121.11
NoP ₁	33.7	30.73	16.61	123.08
NoP ₂	33.33	30.68	16.56	122.87
N ₁ P ₀	33.2	30.6	15.6	121.61
N ₁ P ₁	34.59	33.53	18.64	125.9
N ₁ P ₂	34.34	33.49	18.6	125.47
N ₂ P ₀	34.33	33.49	18.55	125.17
N ₂ P ₁	35.78	36.47	19.89	129.41
N ₂ P ₂	34.84	34.65	19.77	129.2
N ₃ P ₀	33.74	32.8	16.78	123.88
N ₃ P ₁	34.78	33.71	19.64	127.01
N ₃ P ₂	34.67	33.57	19.42	126.05
Nitrogen (N)	S	S	S	S
Phosphorus (P)	S	S	S	S
N × P	S	S	S	S
CD (P = 0.05) for N	0.09	0.17	0.2	0.23
CD (P = 0.05) for P	0.08	0.14	0.17	0.2
CD (P = 0.05) for N × P	0.16	0.29	0.34	0.37

S = Significant at $p \leq 0.05$; CD = Critical Difference at 5% level of significance; Values represent treatment means of three replications.

Discussion

Nitrogen and phosphorus significantly influenced vegetative growth of chrysanthemum cv. Snowball. The superior performance of the treatment combination N₂P₁ (60 kg N ha⁻¹ + 100 kg P₂O₅ ha⁻¹) in terms of plant height, plant spread, number of branches, and number of leaves indicates that balanced nutrient application promoted vigorous vegetative growth. Nitrogen is a major constituent of chlorophyll, amino acids, proteins, and nucleic acids and plays a key role in photosynthesis and cell division. Adequate nitrogen availability therefore enhances vegetative growth and canopy development. Phosphorus is involved in energy transfer, root growth, and various metabolic processes, thereby improving nutrient uptake and utilization efficiency (Marschner, 2012) [7]. The improvement in growth parameters observed with increasing nitrogen up to 60 kg ha⁻¹ and phosphorus up to 100 kg P₂O₅ ha⁻¹ may be attributed to enhanced photosynthetic activity, increased assimilate production, and efficient translocation of metabolites to actively growing tissues. Similar beneficial effects of balanced nitrogen and phosphorus nutrition on

vegetative growth of chrysanthemum have been reported by Chaitra *et al.* (2018) [1] and Rajan *et al.* (2019) [8]. The increase in branch and leaf production under optimum nutrient supply could be associated with enhanced meristematic activity and improved synthesis of structural compounds required for vegetative development. A slight decline in growth parameters at higher nitrogen and phosphorus levels suggests that nutrient application beyond the optimum requirement did not further improve plant growth. Similar observations have been reported in chrysanthemum and other ornamental crops, where excessive fertilizer application resulted in reduced nutrient-use efficiency and marginal growth responses (Taiz *et al.*, 2015) [10]. Therefore, balanced fertilization appears to be more important than increasing fertilizer dose beyond the crop requirement. The present findings indicate that application of 60 kg N ha⁻¹ and 100 kg P₂O₅ ha⁻¹ provides an optimum nutrient combination for promoting vegetative growth of chrysanthemum cv. Snowball under the agro-climatic conditions of Prayagraj.

Supplementary Table 1: Effect of different levels of nitrogen, phosphorus and their interaction of plant height (cm) Chrysanthemum at different intervals (30 and 45 DAT)

Levels of Nitrogen (N)	30 DAT				45 DAT			
	Levels of Phosphorus (P)				Levels of Phosphorus			
	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean
N ₀ (0 kg ha ⁻¹)	11.74	12.38	12.04	12.05	21.44	22.33	22.33	22.03
N ₁ (40 kg ha ⁻¹)	11.81	15.71	15.47	14.33	21.66	23.43	23.38	22.83
N ₂ (60 kg ha ⁻¹)	14.61	16.66	16.45	15.91	22.55	25.43	24.66	24.21
N ₃ (80 kg ha ⁻¹)	13.53	16.27	16.15	15.32	22.44	24.55	24.21	23.73
Mean	12.92	15.25	15.03	-	22.02	23.94	23.65	-
		F-test	S.Ed. (±)	C.D. at 5%		F-test	S.Ed. (±)	C.D. at 5%
Nitrogen (N)		NS	-	-		S	0.16	0.33
Phosphorus (P)		NS	-	-		S	0.14	0.29
Interaction (N×P)		NS	-	-		S	0.28	0.58

S = Significant at $p \leq 0.05$; NS = Non-significant. CD = Critical Difference at 5% level of significance; Values represent treatment means of three replications.

Supplementary Table 2: Effect of different levels of nitrogen, phosphorus and their interaction of plant height (cm) Chrysanthemum at different intervals (60 and 60 DAT)

Levels of Nitrogen (N)	60 DAT				75 DAT			
	Levels of Phosphorus (P)				Levels of Phosphorus			
	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean
N ₀ (0 kg ha ⁻¹)	31.45	31.93	31.75	31.71	32.89	33.70	33.33	33.31
N ₁ (40 kg ha ⁻¹)	31.50	32.69	32.66	32.28	33.20	34.59	34.34	34.04
N ₂ (60 kg ha ⁻¹)	32.65	34.50	34.50	33.88	34.33	35.78	34.84	34.98
N ₃ (80 kg ha ⁻¹)	32.45	33.70	33.54	33.23	33.74	34.78	34.67	34.41
Mean	32.01	33.21	33.11	-	33.54	34.73	34.30	-
		F-test	S.Ed. (±)	C.D. at 5%		F-test	S.Ed. (±)	C.D. at 5%
Nitrogen (N)		S	0.13	0.27		S	0.04	0.09
Phosphorus (P)		S	0.11	0.23		S	0.04	0.08
Interaction (N×P)		S	0.22	0.46		S	0.08	0.16

S = Significant at $p \leq 0.05$; NS = Non-significant. CD = Critical Difference at 5% level of significance; Values represent treatment means of three replications.

Supplementary Table 3: Effect of different levels of nitrogen, phosphorus and their interaction of plant spread (cm) Chrysanthemum at different intervals (30 and 45 DAT)

Levels of Nitrogen (N)	30 DAT				45 DAT			
	Levels of Phosphorus (P)				Levels of Phosphorus			
	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean
N ₀ (0 kg ha ⁻¹)	13.53	16.57	15.57	15.22	20.69	21.58	21.55	21.27
N ₁ (40 kg ha ⁻¹)	14.65	17.74	17.56	16.75	21.35	22.65	22.53	22.18
N ₂ (60 kg ha ⁻¹)	17.46	20.65	19.28	19.13	21.68	24.57	24.33	23.53
N ₃ (80 kg ha ⁻¹)	16.62	18.44	17.75	17.60	21.60	23.35	22.75	22.57
Mean	15.57	18.35	17.54	-	21.33	23.04	22.79	-
		F-test	S.Ed. (±)	C.D. at 5%		F-test	S.Ed. (±)	C.D. at 5%
Nitrogen (N)		S	0.53	1.10		S	0.06	0.33
Phosphorus (P)		S	0.46	0.95		S	0.05	0.11
Interaction (N×P)		NS	-	-		S	0.11	0.22

S = Significant at $p \leq 0.05$; NS = Non-significant. CD = Critical Difference at 5% level of significance; Values represent treatment means of three replications.

Supplementary Table 4: Effect of different levels of nitrogen, phosphorus and their interaction of plant spread (cm) Chrysanthemum at different intervals (60 and 60 DAT)

Levels of Nitrogen (N)	60 DAT				75 DAT			
	Levels of Phosphorus (P)				Levels of Phosphorus			
	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean
N ₀ (0 kg ha ⁻¹)	27.76	29.55	28.74	28.69	30.34	30.73	30.68	20.59
N ₁ (40 kg ha ⁻¹)	28.71	30.46	29.79	29.66	30.60	33.53	33.49	32.54
N ₂ (60 kg ha ⁻¹)	29.75	32.69	31.61	31.35	33.49	36.47	34.65	34.87
N ₃ (80 kg ha ⁻¹)	29.61	30.72	30.65	30.32	32.80	33.71	33.57	33.36
Mean	28.96	30.86	30.20	-	31.81	33.61	33.10	-
		F-test	S.Ed. (±)	C.D. at 5%		F-test	S.Ed. (±)	C.D. at 5%
Nitrogen (N)		S	0.07	0.16		S	0.08	0.17
Phosphorus (P)		S	0.06	0.13		S	0.07	0.14
Interaction (N×P)		S	0.13	0.27		S	0.14	0.29

S = Significant at $p \leq 0.05$; NS = Non-significant. CD = Critical Difference at 5% level of significance; Values represent treatment means of three replications.

Supplementary Table 5: Effect of different levels of nitrogen, phosphorus and their interaction of number of branches per plant of Chrysanthemum at different intervals (30 and 45 DAT)

Levels of Nitrogen (N)	30 DAT				45 DAT			
	Levels of Phosphorus (P)				Levels of Phosphorus			
	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean
N ₀ (0 kg ha ⁻¹)	2.56	2.74	2.71	2.67	4.59	5.45	5.45	5.16
N ₁ (40 kg ha ⁻¹)	2.57	3.40	3.33	3.10	5.44	6.44	6.42	6.10
N ₂ (60 kg ha ⁻¹)	3.30	4.41	3.51	3.74	5.84	6.71	6.65	6.40
N ₃ (80 kg ha ⁻¹)	2.77	3.51	3.41	3.23	5.61	6.51	6.51	6.21
Mean	2.80	3.51	3.24	-	5.37	6.28	6.26	-
		F-test	S.Ed. (±)	C.D. at 5%		F-test	S.Ed. (±)	C.D. at 5%
Nitrogen (N)		NS	—	—		S	0.11	0.24
Phosphorus (P)		NS	—	—		S	0.10	0.21
Interaction (N×P)		NS	—	—		NS	-	-

S = Significant at $p \leq 0.05$; NS = Non-significant. CD = Critical Difference at 5% level of significance; Values represent treatment means of three replications.

Supplementary Table 6: Effect of different levels of nitrogen, phosphorus and their interaction of branches per plant of Chrysanthemum at different intervals (60 and 60 DAT)

Levels of Nitrogen (N)	60 DAT				75 DAT			
	Levels of Phosphorus (P)				Levels of Phosphorus			
	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean
N ₀ (0 kg ha ⁻¹)	8.46	9.40	8.63	8.83	14.64	16.61	16.56	15.94
N ₁ (40 kg ha ⁻¹)	8.53	10.71	10.56	9.93	15.60	18.64	18.60	17.61
N ₂ (60 kg ha ⁻¹)	9.57	12.82	12.64	11.68	18.55	19.89	19.77	19.41
N ₃ (80 kg ha ⁻¹)	9.47	12.61	11.49	11.19	16.78	19.64	19.42	18.61
Mean	9.01	11.39	10.83	-	16.39	18.70	18.59	-
		F-test	S.Ed. (±)	C.D. at 5%		F-test	S.Ed. (±)	C.D. at 5%
Nitrogen (N)		S	0.09	0.19		S	0.10	0.20
Phosphorus (P)		S	0.08	0.17		S	0.08	0.17
Interaction (N×P)		S	0.16	0.34		S	0.17	0.34

S = Significant at $p \leq 0.05$; NS = Non-significant. CD = Critical Difference at 5% level of significance; Values represent treatment means of three replications.

Supplementary Table 7: Effect of different levels of nitrogen, phosphorus and their interaction of number of leaves per plant of Chrysanthemum at different intervals (30 and 45 DAT)

Levels of Nitrogen (N)	30 DAT				45 DAT			
	Levels of Phosphorus (P)				Levels of Phosphorus			
	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean
N ₀ (0 kg ha ⁻¹)	18.64	21.60	19.78	20.01	35.65	39.65	38.46	37.92
N ₁ (40 kg ha ⁻¹)	18.76	23.75	22.87	21.79	36.65	41.74	42.66	40.02
N ₂ (60 kg ha ⁻¹)	22.52	25.85	25.56	24.64	40.79	50.89	48.52	46.73
N ₃ (80 kg ha ⁻¹)	21.79	24.65	24.54	23.66	40.51	45.92	44.61	43.68
Mean	20.43	23.96	23.19	-	38.40	44.55	43.31	-
		F-test	S.Ed. (±)	C.D. at 5%		F-test	S.Ed. (±)	C.D. at 5%
Nitrogen (N)		NS	—	—		S	0.13	0.26
Phosphorus (P)		NS	—	—		S	0.11	0.23
Interaction (N×P)		NS	—	—		S	0.22	0.46

S = Significant at $p \leq 0.05$; NS = Non-significant. CD = Critical Difference at 5% level of significance; Values represent treatment means of three replications.

Supplementary Table 8: Effect of different levels of nitrogen, phosphorus and their interaction of leaves per plant of Chrysanthemum at different intervals (60 and 60 DAT)

Levels of Nitrogen (N)	60 DAT				75 DAT			
	Levels of Phosphorus (P)				Levels of Phosphorus			
	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean	P ₀ (0 kg ha ⁻¹)	P ₁ (100 kg ha ⁻¹)	P ₂ (120 kg ha ⁻¹)	Mean
N ₀ (0 kg ha ⁻¹)	83.92	101.74	100.70	95.45	121.11	123.08	122.87	123.35
N ₁ (40 kg ha ⁻¹)	95.39	107.40	106.50	103.09	121.61	125.90	125.47	124.32
N ₂ (60 kg ha ⁻¹)	104.88	121.61	116.84	114.44	125.17	129.41	129.20	127.93
N ₃ (80 kg ha ⁻¹)	102.74	115.51	109.71	109.32	123.88	127.01	126.05	125.65
Mean	96.73	111.56	108.44	-	122.94	126.35	125.90	-
		F-test	S.Ed. (±)	C.D. at 5%		F-test	S.Ed. (±)	C.D. at 5%
Nitrogen (N)		S	0.21	0.43		S	0.11	0.23
Phosphorus (P)		S	0.18	0.37		S	0.09	0.20
Interaction (N×P)		S	0.36	0.74		S	0.19	0.37

S = Significant at $p \leq 0.05$; NS = Non-significant. CD = Critical Difference at 5% level of significance; Values represent treatment means of three replications.

Conclusion

The present study demonstrated that nitrogen and phosphorus significantly influenced the vegetative growth of chrysanthemum cv. Snowball. Among the nutrient combinations evaluated, application of 60 kg N ha⁻¹ and 100 kg P₂O₅ ha⁻¹ (N₂P₁) consistently produced the highest plant height, plant spread, number of branches per plant, and number of leaves per plant throughout the growth period. Further increases in nitrogen and phosphorus levels did not result in additional growth improvement. Therefore, application of 60 kg N ha⁻¹ and 100 kg P₂O₅ ha⁻¹, together with 100 kg K₂O ha⁻¹, may be recommended for promoting optimum vegetative growth of chrysanthemum cv. Snowball under the agro-climatic conditions of Prayagraj, India.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflict of interest.

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