Pak. J. Bot., 58(1) January 2026.

ARTICLE DOI: http://dx.doi.org/10.30848/PJB2026-1(5)

OPTIMAL PRODUCTION PROTOCOLS FOR CUT CHINA ASTER (*CALLISTEPHUS CHINENSIS* L.) AND SNAPDRAGON (*ANTIRRHINUM MAJUS* L.)

TAZKIA HUSSAIN[1*], IFTIKHAR AHMAD[1*], JOHN M. DOLE[2] AND BILAL KHALID[1]

[1]Institute of Horticultural Sciences, University of Agriculture, Faisalabad-38040, Pakistan
[2]Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695, USA

*Corresponding author's email: tazkiahussain3239@gmail.com, iftikharahmadhashmi@gmail.com

Abstract

China aster (*Callistephus chinensis* L.) and Snapdragon (*Antirrhinum majus* L.), are new specialty cut flowers, which are gaining popularity in several Asian floral markets. Therefore, a study was aimed to evaluate of various production protocols for cut China aster and snapdragon. Four experiments: 1. planting times, 2. planting methods and planting densities, 3. macro and micronutrients along with bio-stimulants and 4. cultivar evaluation of both species were conducted. In Expt. I, least production time (72.8 and 79.6 d) was recorded when China aster and snapdragon were sown on 15 October and 15 November. In Expt. II, shortest production time (79.8 and 80 d) and tallest plants (47.8 and 81.6 cm), respectively, were recorded when China aster and snapdragon were planted on raised beds and spaced 22.5 × 22.5 cm. In Expt. III, tallest plants (39.5 and 101.3 cm), respectively, were recorded when plants were sprayed with NPK at 90:45:45 kg ha^{-1} + micronutrients at 2 mL L^{-1} and NPK at 90:45:45 kg ha^{-1} + isabion at 2 mL L^{-1} for China aster and snapdragon. In Expt. IV, longest stems (62.2 and 83 cm), respectively, were produced for 'Bonita' China aster and 'Potomac Early Pink' snapdragon. In summary, China aster and snapdragon planted on 15 October and 01 November, respectively, on raised beds with 22.5 × 22.5 cm spacing produced best quality cut stems. Moreover, both species supplied with NPK along with micronutrients or isabion, had better cut stems quality. Among tested cultivars, 'Bonita Scarlet' China aster and 'Potomac Early Pink' snapdragon proved best for subtropical regions and may be grown commercially as specialty cut flowers, for local and export markets.

Keywords: Bio-stimulants; Cultivars; Nutritional regimes; Nutrient uptake; Planting periods; Planting patterns; Specialty cuts

Introduction

Floriculture industry is a fast-growing, highly competitive and profitable enterprise. Compared to traditional production centers, cut flower production has been shifted to regions with favorable climates and decreased production costs. Around 45% of all floricultural products traded globally are cut flowers. Specialty cuts are gradually replacing traditional cut flowers (TCF) in the world's cut flower production. Nowadays, floriculture has gained recognition as a lucrative business, shifting the focus of growers towards high-value flower crops. Europe dominates in sales of cut flowers and ornamental potted plants with 31.0% share followed by China (18.6%), the United States (12.5%) and Singapore (14.18%) (Darras, 2021). The global floriculture production is growing at a rate of 10% per year. Almost 45 to 50 countries are actively producing floricultural products on a large scale. In terms of production value, Netherlands, Columbia, Ecuador, Kenya, USA and China are the leading countries (Devrani *et al.*, 2024).

China aster (*Callistephus chinensis* L.), gaining popularity as specialty cut flower (SCF) available in vibrant colors, is also cultivated as cut flower (Swathi, *et al.*, 2023). Aster cut are used in flower decors, bouquets and interior decors, due to its long-lasting blooms (Atal *et al.*, 2019). Loose flowers are also widely used for social events (Biswas *et al.*, 2021). Snapdragon (*Antirrhinum majus* L.) are available in variety of elegant colors with more than 60 cm height and with postharvest life of 5-7 days. Therefore, farm revenues may be increased while using production procedures that can constantly supply quality stems and stored vertically for longer durations to maintain flower quality (Yang *et al.*, 2023). Day length and temperature are the key factors influencing stem elongation and blooming time. The cut flower market in subcontinent is mainly focused on traditional cut flowers (TCF), however, the industry would gain benefit through diversification and introduction of new specialty cuts. In local marketplaces, there has been a rise in demand of specialty cut flowers in recent years. Availability of year-round production processes would assist to fulfill the demand for new specialty cut flowers. Moreover, there is limited literature available on the production of specialty cut species in developing countries like Pakistan that yield high-quality cut stems with a reasonably longer vase life.

Planting time plays a pivotal role in production of high-quality cut stems. Plant developmental processes are significantly influenced by the timing of planting (Lweis *et al.*, 2022). Optimal plant spacing is required to regulate plant metabolic process along with abiotic factors influencing growing patterns.

Imbalanced nutrition levels cause serious disorders and may eventually lead to decline of plant quality and vigor. Low fertilization causes stunted growth and can minimize postharvest longevity. On the other hand, over fertilization might result in excessive nutrient runoff,

Received: 16-08-2024 | Revised: 28-04-2025 | Accepted: 22 07-2025 | Online: 26 08-2025

environmental pollution, and economic losses (Mishra *et al.*, 2024). Balanced nutritional doses containing primary, secondary, micronutrients and bio-stimulants are essential for promoting healthy plant development also minimizing biotic and abiotic stresses on plants (Santos *et al.*, 2021). It is also required to evaluate the most desirable cultivars for the production of cut flowers. Flower farmers can increase their yields of high-quality flowers by selecting suitable cultivars according to their agro-climatic conditions (Islam *et al.*, 2013). China aster and snapdragon are becoming popular specialty cut flowers in local markets. However, limited recommendations on their best production practices are available to growers and stakeholders. Therefore, a study was conducted to optimize planting time, method, plant density, nutritional regimes and cultivar selection for cut China aster and snapdragon in local agro-climatic conditions. It was hypothesized that following optimal planting time, method, plant density, nutritional regimes and use of best suited cultivars for commercial cultivation would help growers to produce best quality cut stems of China aster and snapdragon with long stout stems and longer vase life in the sub-tropical agro-climatic conditions of Punjab, Pakistan.

Materials and Methods

Plant material: A study was conducted at Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, during 2023-24, to evaluate the influence of planting time, planting method and density, macro (nitrogen, phosphorus and potash) basic primary plant nutrients, and micronutrients, boron (B), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn) along with bio-stimulants, viz., Isabion and humic acid (an amino acid based bio-stimulant products marketed by Syngenta, which assists in nutrient uptake, increasing stress tolerance by improving flower quality and extending vase life). Bio-stimulants and micronutrients were applied in form of foliar spray individually, on selected cultivars to improve plant growth, yield, flower quality and vase life of cut China aster (*Callistephus chinensis* L.) and snapdragon (*Antirrhinum majus* L.). Experiments for each species were laid out in randomized complete block design with or without factorial arrangements as per experiment and replicated three times. Seeds of China aster and snapdragon were imported from Pan American Seeds, USA, and transplants were grown in 128 cell plastic germination trays using silt, peat moss, and coco coir (1:1:1; v/v/v) as growing substrate. After 4-6 weeks, healthy seedlings having 2-4 true leaves were transplanted to thoroughly prepared and laid out planting beds in open field. Soil preparation and all cultural practices including IPM, fertilization (except experiment III), irrigation and weeding were similar for all treatments during the entire period of study.

Planting times: Seedlings of 'Bonita' China aster and 'Potomac Early Pink' snapdragon were planted 4 times at 15- or 16-days intervals on raised beds. Twenty plants were planted in each replication with 22.5 × 22.5 cm and 30 × 30 cm spacing for China aster and snapdragon, respectively.

Planting methods and planting densities: There were two factors, with two planting methods (flat beds or raised beds) and three planting densities (22.5 × 22.5, 22.5 × 30, 30 × 30). Twenty plants of 'Bonita' China aster and 'Potomac crimson' snapdragon were planted in each experimental unit on 15 October and 01 November, respectively.

Macro and micronutrients along with bio-stimulants: Treatments included control (no additional fertilizer), N (90 kg ha^{-1}), NPK (90:45:45 kg ha^{-1}), NPK + micronutriments (B, Zn, and Fe) (1%, 1%, and 1%), NPK + isabion (0.4%) and NPK + humic acid (0.4%). Twenty plants of 'Bonita Blue' China aster and 'Potomac Early Pink' snapdragon were planted in each experimental unit at 22.5 × 30 and 22.5 × 22.5 cm spacing on 15 Oct. and 01 Nov. respectively.

Cultivar evaluation: Two cultivars of asters, 'Matsumotu, and 'Bonita' and 'Potomac Early Pink', 'Maryland white'snapdragon, were grown and compared. Twenty plants were planted in each experimental unit at 22.5 × 30 and 22.5 × 22.5 cm spacing on Oct. 15 and Nov. 01, respectively, for China aster and snapdragon.

Measurements: Data were collected on production time (d), plant height (cm), leaf area (cm)^2, leaf total chlorophyll contents (SPAD), flower/raceme diameter (cm), stem diameter (mm), stem fresh weight (g), stem dry weight (g), flower quality (1-9, with nine being best) and vase life (days).

Statistical analyses: All experiments were set up in randomized complete block designs (RCBD) with three replications. Moreover, treatments were arranged factorially where appropriate. Data were subjected to analysis of variance (ANOVA) procedures using General Linear Models procedures and means were separated using least significance difference test (LSD) at $p \leq 0.05$ (Steel *et al.*, 1997).

Results

Planting times: China aster planted on 15 October had shortest production time (72.8 d) followed by 01 October (80.5 d), while those planted on 15 November took longest production time (84 d), which was likely due to reduction in day length as compared to October plantations (Fig. 1). While snapdragon planted on 15 November exhibited shortest production time (79.6 d) followed by 15 October and 01 November (81.8 d). China aster planted on 15 October and snapdragon planted on 01 November had tallest plants (47.2 and 77.7 cm), widest stem diameter (7.3 and 2.1 mm), greatest leaf total chlorophyll contents (47.3 and 52.3 SPAD), highest stem fresh weight (54 and 70.1 g), and stem dry weight (13.5 and 17.5 g), longest capitulum/flower diameter (5.8 and 7.6 cm), best stem quality (9 and 8.3) and longest vase life (9.6 and 6.2 d respectively) (Table 1).

Table 1. Effect of planting times on plant height (cm), leaf area (cm^2), leaf total chlorophyll contents (SPAD), flower/raceme diameter, stem diameter (mm), stem fresh weight (g), stem dry weight (g), flower quality (1-9) and vase life (days) of China aster and snapdragon. All data represents means of 15 plants.

Treatments Planting times	Plant height (cm)	Leaf area (cm^2)	Leaf total chlorophyll contents (SPAD)	Flower/raceme diameter (cm)	Stem diameter (mm)	Stem fresh weight (g)	Stem dry weight (g)	Flower quality (1-9)	Vase life (days)
	China aster								
01 Oct.	31.3 b^z	6.3 b	42.1	4.4 b	2.9 b	42.1 b	9.1 c	9.0	8.1 bc
15 Oct.	47.2 a	16.5 a	47.3	5.1 a	7.3 a	47.3 ab	13.5 a	9.0	9.6 a
01 Nov.	45.4 a	16.5 a	42.9	4.1 b	4.2 b	42.9 b	11.9 b	8.3	8.6 b
15 Nov.	32.4 b	14.1 a	51.7	4.8 a	4.3 b	51.7 a	11.1 b	8.5	7.5 c
Significance^y	0.0001	0.0002	NS	0.0071	<0.0001	0.0007	0.0011	NS	0.0035
	Snapdragon								
15 Oct.	47.0 b^z	6.3	42.1	5.3 c	1.4	60.3 a	15.1 a	9.0 a	4.9 b
01 Nov.	77.7 a	6.7	52.3	7.6 b	2.1	70.1 a	17.5 a	8.3 b	6.2 a
15 Nov.	76.2 a	8.3	44.6	12.1 a	2.1	68.1 a	17 a	8.7 ab	6.3 a
01 Dec.	47.2 b	8.5	46.7	7.6 b	2.2	48.3 b	12.1	8.5 ab	6.7 a
Significance^y	0.0003	NS	NS	0.0005	NS	0.0072	0.0072	0.050	0.0008

^{Z}Means separation within columns by Fisher's LSD at $p<0.05$; ^{Y}P values were obtained using general linear model (GLM) procedures of Statistix (version 8.1) for significant effect of planting times of China aster and snapdragon; ^{NS}Non-significant at $p>0.05$

Table 2. Effect of different planting methods and planting densities on plant height (cm), leaf area (cm^2), leaf total chlorophyll contents (SPAD), flower/raceme diameter, stem diameter (mm), stem fresh weight (g), stem dry weight (g) and vase life (days) of China aster and snapdragon. All data represents means of 15 plants.

Treatments Planting methods	Planting densities	Plant height (cm)	Leaf area $(cm)^2$	Number of flowers	Flower diameter/ raceme length (cm)	Stem diameter (mm)	Stem fresh weight (g)	Stem dry weight (g)	Vase life (days)
					China aster				
Raised bed	22.5 × 22.5 cm	47.8 a^z	34.7 ab	8.3 a	45.3 a	5.3 e	50.7 a	9.3 a	7.9 ab
	22.5 × 30 cm	47.7 ab	40.6 a	8.7 a	43.4 a	9.5 a	48.1 a	9.6 a	8.3 a
	30 × 30 cm	44.2 ab	33.1 b	6.6 b	44.2 a	8.5 b	50.1 a	9.5 a	7.9 ab
Flat bed	22.5 × 22.5 cm	34.5 c	29.8 b	4.3 c	29.1 b	6.3 cd	30.3 b	6.6 b	6.8 b
	22.5 × 30 cm	37.3 c	29.5 b	4.7 c	30.8 b	5.7 de	26.1 b	5.2 c	7 .0 b
	30 × 30 cm	39.5 bc	32.8 b	4.3 c	30.8 b	6.7 c	26.1 b	5.2 c	7.4 ab
Significance^y	Planting method	0.0004	0.0122	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0075
	Planting density	NS	NS	0.0069	NS	<0.0001	0.0799	NS	NS
	PM × PD	NS	NS	0.0331	NS	<0.0001	NS	NS	NS
					Snapdragon				
Raised bed	22.5 × 22.5 cm	81.6 a^z	12.6 a	1.6 a	3.6 a	2 b	57.8 a	14.4 a	4.6 a
	22.5 × 30 cm	61.3 b	10.6 ab	1.6 a	3 ab	2.5 a	53.6 ab	13.4 ab	4.3 ab
	30 × 30 cm	54.0 c	7.5 c	0.33 b	3.3 a	1.8 b	55.6 ab	13.9 ab	3.3 abc
Flat bed	22.5 × 22.5 cm	41.6 e	10.5 ab	0.6 ab	3.3 a	1.1 c	47 bc	11.7 bc	3.3 bc
	22.5 × 30 cm	45.0 de	9.2 bc	0.33 b	2.3 b	1.2 c	47.3 abc	11.8 abc	3 c
	30 × 30 cm	47.3 d	7.4 c	0.67 ab	2.3 b	1.3 c	42.8 c	10.7 c	3.3 bc
Significance^y	Planting method	<0.0001	0.063	0.0319	0.0273	<0.0001	0.0050	0.0050	0.0236
	Planting density	0.0002	0.0006	NS	0.0563	0.0066	NS	NS	NS
	PM × PD	<0.0001	NS	NS	NS	0.0020	NS	NS	NS

^{Z}Means separation within columns by Fisher's LSD at $p<0.05$; ^{Y}P values were obtained using general linear model (GLM) procedures of Statistix (version 8.1) for significant effects of planting methods and densities of China aster and snapdragon; ^{NS}Non-significant at $p>0.05$

Planting methods and planting densities: The shortest production time (79.8 and 80 d) when plants were planted on raised beds along with 22.5 × 22.5 cm spacing for China aster and snapdragon, respectively (Fig. 2). The tallest plant height (47.8 and 81.6 cm) of both the species was recorded when planted on raised beds at 22.5 × 22.5 cm spacing, respectively. For China aster greatest leaf length (40.6 cm) was recorded when planted on raised beds along with 22.5 × 30 cm spacing, while greatest leaf area (12.6 cm) in snapdragon was recorded when plants were planted on raised beds along with 22.5 × 22.5 cm spacing. Largest capitulum/flower diameter (4.5 and 3.6 cm) was recorded when both China aster and snapdragon were planted at raised beds and spaced at 22.5 × 22.5 cm. Greatest stem diameter (9.5 and 2.5 mm) was recorded when both the species were planted on raised and spaced at 22.5 × 30 cm.

Highest stem fresh weight of China aster and snapdragon was recorded (50.7 and 57.8 g, respectively) when plants were planted on raised beds and spaced at 22.5 × 22.5 cm spacing, respectively. Dry weight was recorded highest (9.6 and 14.4 g) when China aster and snapdragon were planted on raised beds with 22.5 × 30 cm and 22.5 × 22.5 cm, respectively. Greatest number of capitula/ flowers/ branches were recorded (8.7 and 1.6) in China aster and snapdragon planted on 22.5 × 30 cm and 22.5 × 22.5 cm spacing, respectively. The longest vase life (8.3 and 4.6 d) was recorded when plants were planted on raised beds with 22.5 cm, 22.5 × 22.5 cm spacing, for China aster and snapdragon, respectively (Table 2).

Macro and micronutrients along with bio-stimulants: Regarding foliar application of macro and micronutrients along with bio-stimulants, least production time (74.3 and 73.4 d) (Fig. 3), tallest plant height (101.3 and 39.5 cm), greatest stem fresh weight (53.9 and 93.6 g), stem dry weight (14.2 and 23.4 g), highest number of capitula/flowers/branches (13.6 and 3.8), highest nitrogen uptake (1% and 1.51%), was recorded when plants were supplied with NPK at 90:45:45 kg ha^{-1} + micronutrients at 2 mL L^{-1} for both tested species, respectively. Greatest leaf area (10.4 cm^2) was recorded in plants sprayed with NPK + isabion at 2 mL L^{-1} for China aster and (9.8 cm^2) in plants sprayed with NPK + micronutrients at 2 mL L^{-1} and NPK, respectively. Highest total leaf chlorophyll contents were recorded (58.3 SPAD) for China aster when sprayed with NPK+ micronutrients at 2 mL L^{-1} and (66.1 SPAD) for snapdragon when plants sprayed with NPK + isabion at 2 mL L^{-1} for snapdragon. Longest vase life (8.6 and 5.6 d) was recorded when plants were sprayed with NPK+ isabion at 2 mL L^{-1} for China aster and snapdragon, respectively. Highest phosphorus uptake (1.2%) was recorded for China aster plants when sprayed with NPK+ isabion at 2 mL L^{-1} and (1.2%) for snapdragon when sprayed with NPK+ humic acid 2g L^{-1}. Highest potassium uptake (39.1 and 38.8%) was recorded for plants sprayed with NPK and NPK + micronutrients @ 2 mL L^{-1} for China aster and snapdragon, respectively (Table 3).

Cultivar evaluation: Among China aster and snapdragon cultivars, 'Bonita and 'Potomac Pink' performed best compared to other tested cultivars in various characters studied. Shortest days to flowering (68.2 d) were recorded for 'Bonita' China aster. For snapdragon 'Maryland white' cultivar exhibited shortest production time (74.3 d) (Fig. 4). 'Bonita' China aster and 'Potomac pink' snapdragon had tallest plant height (62.2 and 94.2 cm), greatest flower/raceme diameter (4.9 and 14.6 cm), greatest leaf total chlorophyll contents (39.7 and 57.8 SPAD), greatest number of flowers/branches (14.7 and 4.1), greatest stem fresh weight (51.2 and 57.9 g), stem dry weight (12.1 and 14.4 g) and longest vase life (11.1 and 6.1 d), respectively. However widest stem diameter (10.2 and 2.7 mm) and greatest leaf area (36.7 and 15.2 cm^2) was recorded in 'Bonita' China aster and 'Potomac Early Pink' snapdragon, respectively (Table 4).

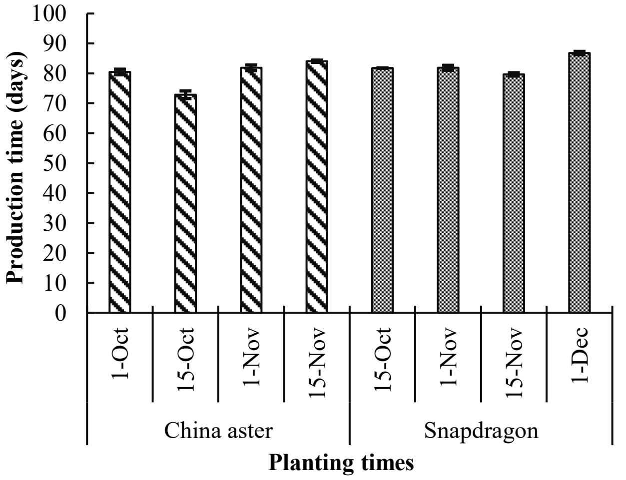

Fig. 1. Effect of different planting times on production time of China aster and snapdragon. All bars represent means of 15 plants ± S.E.

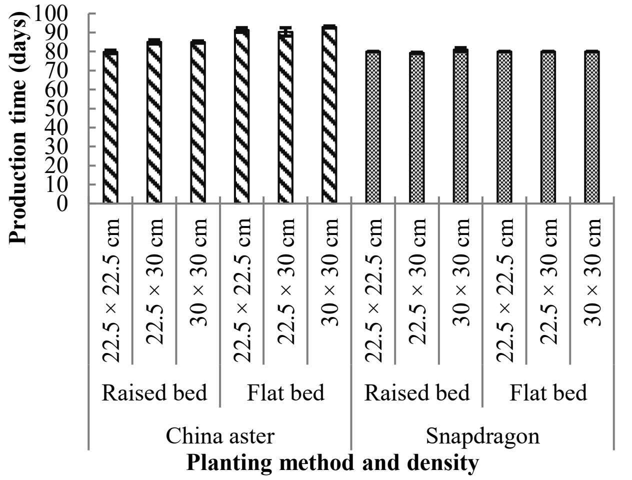

Fig. 2. Effect of different planting methods and densities on production time of China aster and snapdragon. All bars represent means of 15 plants ± S.E.

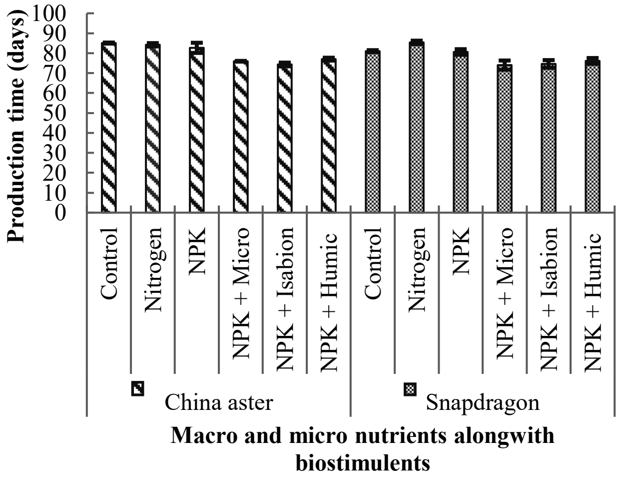

Fig. 3. Effect of macro and micronutrients along with bio-stimulants on production time of China aster and snapdragon. All bars represent means of 15 plants ± S.E.

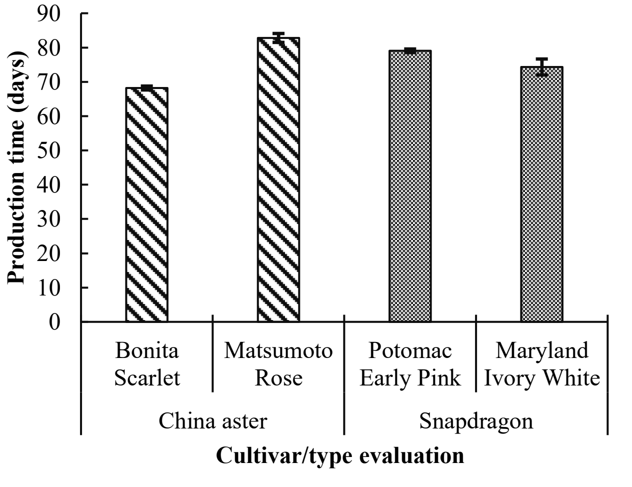

Fig. 4. Effect of types/cultivar evaluation on production time of China aster and snapdragon. All bars represent means of 15 plants ± S.E.

Table 3. Effect of macro and micronutrients along with bio-stimulants on plant height (cm), leaf area (cm^2), leaf total chlorophyll contents (SPAD), flower/raceme diameter, stem diameter (mm), Flower/raceme diameter, number of flowers/branches, vase life (days), leaf nitrogen, phosphorus and potassium contents (%) of China aster and snapdragon. All data represents means of 15 plants.

Treatments: Macro and micronutrients along with bio-stimulants	Plant height (cm)	Leaf area (cm^2)	Leaf total chlorophyll contents (SPAD)	Flower diameter/ raceme length (cm)	Vase life (days)	Number of flowers/ branches	Leaf nitrogen Contents (%)	Leaf hosphorus contents (%)	Leaf potassium contents (%)
China Aster									
Control	25.7 c[z]	8.6	44.2 b	3.7 bc	6.5 c	3.4 c	0.51 f	0.3 d	33.4 d
N	25.2 c	8.5	43 b	3.6 c	5.5 d	5 b	0.81 e	0.5 c	31.1 e
NPK	24.9 c	14.3	48.1 ab	4.7 a	7.2 b	5 bc	0.88 c	0.6 b	39.1 a
NPK + micro	39.5 a	8.5	58.3 a	4.3 ab	7.6 b	13.6 a	1.0 b	0.16 f	37.4 b
NPK + isabion	34.9 ab	10.4	43 b	3.9 bc	8.6 a	11.8 a	1.15 a	1.2 a	38.8 ab
NPK + humic acid	34.7 b	8.1	26.2 c	3.4 c	8.3 a	6.4 c	0.84 d	0.18 e	35.2 c
Significance[y]	0.0001	NS	0.0074	0.0113	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Snapdragon									
Control	44.4 d[z]	6.8 c	58.1 abc	4.4 d	4.2 c	1.9 b	0.5 f	0.1 c	34.6 b
N	68.8 c	8.4 b	56.2 bc	3.7 d	4.2 c	1.9 b	0.7 e	0.1 c	32.4 c
NPK	85.3 b	9.8 a	63.2 ab	10.6 c	4.6 bc	3.6 a	1.3 b	0.2 bc	37.7 a
NPK + micro	101.3 a	9.8 a	53.1 c	13.8 b	5.3 ab	3.8 a	1.5 a	0.3 b	38 a
NPK + isabion	97.6 a	9.1 ab	66.1 a	15 a	5.6 a	3.8 a	1.2 c	0.17 bc	38.3 a
NPK + humic acid	86.7 b	7.9 b	65.6 a	13.4 b	4.6 c	2.4 b	1.1 d	1.2 a	37.1 a
Significance[y]	<0.0001	0.007	0.0320	<0.0001	0.0021	<0.0001	<0.0001	0.0001	0.0011

[Z]Means separation within columns by Fisher's LSD at p<0.05; [Y]P values were obtained using general linear model (GLM) procedures of Statistix (version 8.1) for significant effect of macro and micronutrients along with bio-stimulants of China aster and snapdragon; [NS]Non-significant at p>0.05

Table 4. Effect of cultivar evaluation on plant height (cm), leaf area (cm^2), leaf total chlorophyll contents (SPAD), flower/raceme diameter, stem fresh weight (g), stem dry weight (g), flower quality (1-9) and vase life (days) of China aster and snapdragon. All data represents means of 15 plants.

Treatments: Cultivars	Plant height (cm)	Leaf area (cm^2)	Leaf total chlorophyll contents (SPAD)	Flower/raceme diameter (cm)	Stem diameter (mm)	Stem fresh weight (g)	Stem dry weight (g)	Flower quality (1-9)	Vase life (days)
China Aster									
Matumoto Rose	48.6 b	36.7	37.3 b	43.1 b	7.6 b	51.2	9.9	8.0 b	8.2 b
Bonita Scarlet	62.2 a	31.9	39.7	49.1 a	10.2 a	49.1	12.1	9.0 a	11.1 a
Significance[y]	0.026	NS	0.048	0.035	0.0248	NS	NS	0.0421	0.018
Snapdragon									
Potomac Early Pink	94.2 a	15.2 a	57.8 a	13.7 a	2.7 a	57.9 a	14.4 a	9.0 a	6.1 a
Maryland Ivory	74.2 b	8.9 b	42.4 b	7.5 b	1.4 b	45.1 b	10.8 b	8.6 b	4.2 b
Significance[y]	0.0352	0.0381	0.0257	0.0421	0.0107	0.0159	0.0374	0.0204	0.0304

[Z]Means separation within columns by Fisher's LSD at p<0.05; [Y]P values were obtained using general linear model (GLM) procedures of Statistix (version 8.1) for significant effect of types/cultivar comparison of China aster and snapdragon; [NS]Non-significant at p>0.05.

Discussion

Planting times: China aster and snapdragon planted on 15 October and 15 November exhibited shortest production time. Early sowing in China aster produced good quality flowers with longest vase life while for snapdragon early planted stems took more days to flower, shorter plant height with shorter vase life. These findings confirmed findings on zinnia (*Zinnia violacea* Cav.), where seed sowing in mid-March exhibited best results compared to later planting times for plant height, leaf area, lateral shoots/plant, flower diameter, and seed viability (Asghar *et al.*, 2022) and similar results were reported on early sown sunflower (*Helianthus annuus* L.) in April, which had higher yield compared to later sowing dates in the season (Ahmed *et al.*, 2020). Early or late transplanting may cause delayed harvest with poor quality stems, yielding reduction in marketability (Lewis *et al.*, 2022). Late planting of China aster on November 15 and snapdragon on December 01 produced shortest plant height (32.4 and 47.2 cm), poor stem quality and reduced vase life. These results confirm that if soil temperature is high or low, plants may start showing stunted growth or early flowering with poor quality and petal pigmentation (Puangkrit *et al.*, 2018). Optimal temperature and day length regulates both plant growth and flowering. Plants like China aster require low temperature with 1000-3000 lux light period to grow vegetatively at standard height. Reduction in day length and increase in temperature affect drastically growth and vase life.

Tested cultivars of China aster and snapdragon when planted late November 15 and December 01, produced stems with stunted growth having shorter vase life. These results are aligned with research findings on stock where delayed sowing resulted in reduced crop time, however, with poor quality stems having shorter vase life (Abdullah *et al.*, 2020). Vase life of China aster and snapdragon had also significant differences regardless of planting time. Similar findings on zinnia by Kalinowski *et al.*, (2021) were reported that late sown plants exhibited reduction in vase life, indicating various sessional effects. Every plant species has a specific range of temperatures that are tolerable and allow plant growth, but extreme temperatures may reduce inflorescence quality by increasing production time and reducing stem quality.

Planting methods and planting densities: Least time to harvest occurred in both tested species when planted on raised beds with 22.5 × 22.5 cm spacing. Shortest production time (79.8 and 80 d) and tallest plants (47.8 and 81.6 cm), respectively, were recorded when China aster and snapdragon were planted on raised beds and spaced at 22.5 × 22.5 cm. These results agreed with findings on cut lilies planted on raised beds, which performed better regarding higher quality flowers, reduction in production time and improved growth, with less bulb rot and plant disease incidence compared to the flat bed method (Rodriguez and Perez-Garcia, 2017). Widest stem diameter was observed in China aster and snapdragon when planted on raised beds with 22.5 × 30 cm. Cut snapdragon when planted on raised beds produced highest flower yield and quality. Planting on flat bed method produced lowest yield and quality, due to poor drainage and water logging which may cause stem lodging.

Plant spacing and mineral nutrition greatly affect plant growth and development. However, concentrations of iron, manganese and magnesium enhanced when planting spacing was wider (Saeidi *et al.*, 2021). Similar results were found on cut sunflower when planted at dense plant spacing (25 cm × 25 cm), which exhibited tallest stems with smaller flower diameter. High density spacing had the most significant impact on flower diameter (Mladenovic *et al.*, 2020). Husna *et al.*, (2022) reported that spacing of 30 × 25 cm in lisianthus production positively affected growth and flowering attributes, however, when chrysanthemums grown at a planting arrangement of 28 × 43 cm exhibited enhanced vegetative growth (Sahu *et al.*, 2021).

Macro and micronutrients along with bio-stimulants: Mineral fertilizers and bio-stimulants have been used as a supplement to improve the quality of flowers under protected conditions (Harshavardhan *et al.*, 2016; Ahmad *et al.*, 2025). Tallest plant height, lowest production time, larger leaf area, highest chlorophyll contents, highest stem fresh weight and stem dry weight were recorded when plants were sprayed with NPK+ micronutrients at 2 mL L^{-1} for China aster and snapdragon, respectively. These findings were in line with studies reporting cut flower crops that application of macro and micronutrients improved growth and productivity of tested species (Kashif *et al.*, 2014). Largest leaf area and capitulum/flower diameter was highest in China aster and snapdragon when supplied with NPK and NPK+ isabion at 2 mL L^{-1}. Application of NPK on celosia plants significantly increased plant height and leaf number. Bio-stimulants can also play a beneficial role in plant metabolism, growth and flowering attributes of French marigold (Zelikovic *et al.*, 2023). The role of bio-stimulants is to control and accelerate the life processes of plants, increase the resistance to stress and stimulate development (Zulfiqar *et al.*, 2020). Bio-stimulants and macro-nutrients stimulated vegetative growth and enhanced tuberose plant yield and flower quality (Karim *et al.*, 2017).

Longest vase life was shown in plants sprayed with NPK + isabion at 2 mL L^{-1} for both the species. Application of bio-stimulants on lisianthus and stock plants supported the present finding that plants when supplied with NPK + Isabion and humic acid (commercially used bio-stimulants) improved plant height, flower quality and vase life (Ahmad *et al.*, 2025). Plants showing best flower quality with longer vase life may be due to high nutrient use efficiency, tolerance to abiotic stresses (Paradikovic *et al.*, 2019). Plants with no fertilizer and bio-stimulant application (control) exhibited stunted growth with poor quality flowers. Improper feeding causes stunted growth, shorter stem length and may reduce postharvest longevity (Mishra *et al.*, 2024) Nitrogen (N), potassium (K) and phosphorus (P) are the most highly prized necessary nutrients, for flowering and plant growth on account of their function in enhancing flower quality when added in combination with growth substances as bio-stimulants (Alziyituni, 2023).

Cultivar evaluation: Cultivar comparison of China aster and snapdragon exhibited that ‘Bonita’ China aster and ‘Potomac’ snapdragon performed better than other cultivar in most of the attributes. The production time was the shortest in 'Bonita' China aster and 'Potomac' snapdragon (68.2 and 74.3 d), tallest plants (62.2 and 94.2 cm), greatest capitulum/flower diameter (4.9 and 14.6 cm), stem fresh weight (51.2 and 57.9 g), stem dry weight (12.1 and 14.4 g), number of flowers/branches compared to other tested cultivars of both tested species. Similar outcomes were recorded on 10 exotic cultivars of chrysanthemums when tested morphologically under subtropical conditions regarding their vegetative & floral attributes and postharvest longevity (Hussain *et al.*, 2025). Varietal evaluation of tuberose 'Prajwal' performed best for growth and yield attributes (Dalvi *et al.*, 2021). Based on vegetative and floral traits of C*elosia cristata* 'Amigo Orange' was better than 'Amigo Red' (Miano *et al.*, 2017). Lisianthus cultivars when tested, 'Minuet Dark Purple' performed better with higher number of flowers per stem, bud diameter, while 'Art Marine' had the greatest flower diameter and flower length (Anitha *et al.*, 2015).

Greatest leaf area and widest stem diameter was recorded in var. 'Matsumoto' China aster and var. 'Potomac 'snapdragon. Among 15 cultivars of lisianthus 'Echo Lavender' produced the greatest number of leaves and leaf area (Namratha *et al.*, 2021). Longest vase life was recorded in China aster 'Bonita' and snapdragon 'Potomac' among tested cultivars. These findings are in accordance with tested cultivars of gerbera (*Gerbera jamesonii* L.), where longest vase life was recorded in 'Dune' with tallest stems (Singh *et al.*, 2017).

Conclusion

Both tested species performed best in local agro-climatic conditions and proved suitable for commercial cultivation. It is recommended to plant China aster and snapdragon on 15 October and 15 November, respectively, along with planting on raised beds spaced at 22.5 cm × 22.5 cm and 22.5 cm × 30 cm, respectively to produce tallest stems. Application of NPK (90:45:45 kg ha^{-1}) + micronutrients (B. Zn, Fe) (1%, 1%, and 1%) proved beneficial for China aster and snapdragon followed by NPK (90:45:45 kg ha^{-1}) + isabion (0.4%) for most of the tested growth attributes. Among cultivars, 'Bonita' China aster and 'Potomac' snapdragon had longest vase life compared to other tested cultivars and may be used for commercial cultivation in plains of Pakistan.

Acknowledgements

Authors are grateful to Punjab Agricultural Research Board (PARB) for providing financial assistance through project No. 20-324 entitled "Promotion of Floriculture Industry through Diversification, Value addition and Supply Chain Management Production" and Pan American Seeds, USA, for provision of seeds for the studies. Authors also thank the Commercial Floriculture Lab. graduate students, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, for technical assistance during the studies.

References

Abdullah, B., I. Ahmad and J.M. Dole. 2020. Optimal sowing time and planting density for selected field grown cut *Antirrhinum* and *Matthiola. Sci. Hort.*, 261: 108909. https://doi org/10.1016/j.scienta.2019.108909

Ahmad, I., H. Ashfaq, J.M. Dole, T. Hussain, H. Safdar and A. Jabeen. 2025. Biostimulants improve growth, yield and quality of *Eustoma grandiflorum* L. and *Matthiola incana* L. *Ornam. Hortic.*, 31: 312816. https://doi.org/10.1590/2447-536X.v31.e312816

Ahmed, M.A., A. Abd-Elsaber and M.A. Abdelsatar. 2020. Effect of sowing dates on yield and yield attributes of some sunflower hybrids. *J. Agric*., 113: 131-144. https://doi.org/10.15835/agrisp.v113i1-2.13678

Alziyituni, H.O.M. 2023. Effect of humic acid and gibberellic acid on growth, flowering and chemical composition of African marigold (*Tagetes erecta*). *J. Adv. Agric. Res*., 28: 193-201.

Anitha, K., N. Selvaraj, V. Jegadeeswari and M. Sharathkumar. 2015. Performance evaluation of lisianthus (*Eustoma grandiflorum*) cultivars as an emerging cut flower under Nilgiri conditions. III International Symposium on Underutilized Plant Species. *Acta Hort*., 1241: 293-298.

Asghar, R., K. Ziaf, I. Ahmad, M.A. Ghani and U. Shahzad. 2022. Sowing times affect flowering, pollen viability and seed yield of *Zinnia elegans* cvs.'Lilliput' and' Super Yoga'. *Pak. J. Agric. Sci*., 59: 279-291.

Atal, H.L., H.L. Bairwa, L.N. Mahawer and A.L. Regar. 2019. Studies on performance of China aster (*Callistephus chinensis*) varieties in southern Rajasthan agro-climatic conditions. *J. Ornam. Hort*., 22: 33-37.

Biswas, S., S.K. Bordolui and R. Sadhukhan. 2021. Response of China aster (*Callistephus chinensis* L.) genotypes towards foliar application of GA3. *Int. J. Agric. Sci*., 5: 1-15.

Dalvi, N.V., B.R. Salvi, C.D. Pawar, V.G. Salvi, J.S. Dhekale, M.S. Joshi and R.G. Khandeka. 2021. Varietal evaluation on tuberose (*Polianthes tuberosa* L.) under Konkan agro-climatic conditions. *J. Pharm. Innov*., 10: 444-447.

Darras, A. 2021. Overview of the dynamic role of specialty cut flowers in the international cut flower market. *Hort. Technol*., 7: 51-60.

Devrani, N., P. Kakkar, A. Sahu and C. Tiwari. 2024. Global trends in floriculture. In: (Eds.): Burud, A., S.M. Kolur, D.R. Karthik, D.L. Kumar, D. Yadav and N. Kaushal. *Floriculture and landscaping chronicles*: *A collaborative insight*. Stella International Publication, Sri Lanka., pp. 190-221.

Harshavardhan, M., D.P. Kumar, A.M. Rajesh, H.A. Yathindra and S. Hongal. 2016. Effect of integrated nutrient management on floral attributes of carnation (*Dianthus caryophyllus* L.) *The Bioscan*., 11: 163-1166.

Husna, M.A., M.N. Sultana, M. Maliha, A. Dina and A. Uddin. 2022. Growth and flowering responses of lisianthus to different plant spacing. *J. Biosci. Agric. Res*., 29: 2442-2449.

Hussain, T., I. Ahmad and B. Khalid. 2025. Morpho-physiological evaluation of exotic chrysanthemum (*Chrysanthemum morifolium* L.) cultivars in Faisalabad. *9th International Horticulture Conference & Expo.* Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan. pp. 19.

Islam, M.S., H. Mehraj, M.Z.K. Roni, S. Shahrin and M.F.A.J. Uddin. 2013. Varietal study of Anthurium (*Anthurium andraeanum*) as a cut flower in Bangladesh. *J. Bang. Acad. Sci*., 37: 103-107.

Kalinowski, J., E.P. Moody and J.M. Dole. 2021. Improving hydration and vase life of cut *Zinnia*. *Sci. Hort*., 293: 110661.

Karim, K.B., N.V. Kumar, B. Raghupati and A.K. Pal. 2017. Effect of bio-stimulants on growth and floral attributes of tuberose (*Polianthes tuberosa* L.) cv. 'Prajwal.' *Int. J. Curr. Microbiol. App. Sci*. 6: 2557-2564.

Kashif, M., K. Rizwan, M.A. Khan and A. Younis. 2014. Efficacy of macro and micro-nutrients as foliar application on growth and yield of *Dahlia hybrida* L. (Fresco). *Intl. J. Chem. Biochem. Sci*., 5: 6-10.

Lewis, M., M. Stock, B. Black and D. Drost. 2022. Stock cut flower production in Utah. USU Extension Publication., pp. 1-6. https://digitalcommons.usu.edu/extension_curall/2255

Miano, T.F., A.U.R. Baloch, M. Buriro, A. Miano, T.F. Miano and M. Farooq. 2017. Vegetative growth and flowering behavior of cockscomb (*Celosia cristata* L.) in response to sowing dates. *J. Hort*., 4: 2-4.

Mladenovic, E., S. Cvejic, S. Jocic, N. Cuk, J. Cukanovic, M. Jockovic and A. Marjanovic-Jeromela. 2020. Effect of plant density on stem and flower quality of single-stem ornamental sunflower genotypes. *Hort. Sci*., 47: 45-52.

Namratha, G., S.Y. Chandrashekar, B. Hemla Naik, M. Shivaprasad and L. Hanumantharaya. 2021. Varietal evaluation of lisianthus (*Eustoma grandiflorum* Shinn.) for morphological parameters under protected cultivation. *J. Pharm. Innov*., 10: 2160-2162.

Paradikovic, N., T. Teklic, S. Zeljkovic, M. Lisjak and M. Spoljarevic. 2019. Biostimulants research in some horticultural plant species-A review. *Food Energy Secur*., 8: 1-62.

Puangkit, T., T. Narumi-kawasaki, T. Takamura and S. Fukai. 2018. Inflorescence developmental stage-specific high temperature effect on petal pigmentation in Chrysanthemum. *Environ. Control. Biol*., 56: 99-106.

Rodriguez, E. and V. Perez-Garcia. 2017. Comparison of raised and flat-bed production systems for cut lilies. *Hort. Technol*., 27: 740-745.

Saeidi, M., M. Riahi and M.R. Fatahi Moghadam. 2021. Effect of planting density and salinity on growth and yield of sunflower (*Helianthus annuus* L.). *J. Plant. Nutr*., 44: 143-154.

Sahu, J.K., S.K. Tamrakar, R. Lakpale and T. Tirkey. 2021. Effect of planting geometry and plant growth regulators on growth and flowering of *chrysanthemum*. *Progress. Hortic.*, 53: 105-108.

Santos, E.F., N.S. Mateus, M.O. Rosario, T.B. Garcez, P. Mazzafera and J. Lavres. 2021. Enhancing potassium content in leaves and stems improves drought tolerance of Eucalyptus clones. *Physiol. Plant*., 172: 552-563.

Singh, B., R. Pinder, R. Srivastava and H. Yadav. 2017. Varietal evaluation of gerbera cultivars under shade net conditions. *Chem. Sci. Rev. Lett*., 6: 500-504.

Steel, R.G.D., J.H. Torrie and D.A. Dicky. 1997. Principles and procedures of statistics: A biometrical approach. 3rd Edition. McGraw Hill Book Co., New York. pp. 352-358.

Swathi, G., N. Nalini, A. Shankar, T.L. Neelima and K. Kumar. 2023. Evaluation of China aster (*Callistephus chinensis* L. Nees) cultivars for growth, yield and quality parameters under Southern Telangana zone., *Int. J. Environ. Clim*., 13: 444-450.

Yang, Y., Y. Tian, H. Li, J. Wu, N. Zhang, X. Pang and T. Dou. 2023. Mitigation of gravitropic bending of snapdragon cut flowers through SNP treatment via ROS asymmetry elimination and auxin sensitivity reduction. *Sci. Hort*., 313: 111-890.

Zeljkovic, S., N. Paradikovic, I. Maksimovic, T. Teklic and M.T. Kojic. 2023. Growth and nutrient status of French marigold (*Tagetes patula* L.) under bio-stimulant application. *New Zeal. J. Crop Hort*., 51: 614-624.

Zulfiqar, F., A. Casadesus, H. Brockman and S. Munne-Bosch. 2020. An overview of plant-based natural biostimulants for sustainable horticulture with a particular focus on moringa leaf extracts. *Plant Sci*., 295: 110-194.