Journal of Horticultural Science and Technology 2(1): 1-4 (2019)
ISSN (Print) 2617-3220
http://www.pshsciences.org

Original Research

Optimizing planting density for cut *Helianthus annuus* and *Zinnia elegans*

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ABSTRACT

A study was conducted to optimize plant spacing for cut *Helianthus annuus* cv. Pro Cut Orange and *Zinnia elegans* cv. Double Super Yoga. Seedlings were raised in 128-celled plastic plug trays containing coco coir, compost and silt (1:1:1; v/v/v) as substrate. At 2-4 true leaf stage, seedlings were transplanted outdoors in thoroughly tilled and leveled flat beds at plant and row spacing of 15.0 × 15.0, 15.0 × 22.5, 22.5 × 22.5, 22.5 × 30.0, or 30.0 × 30.0 cm with plant populations of 40, 26, 17, 13 or 10 plants per m^2, respectively. Experiments were laid out in randomized complete block design with three replications individually for each species. Findings revealed that for *Helianthus annuus*, plants grown at 15.0 × 15.0 cm spacing produced tallest plants with greatest plant canopy diameter. While leaf area, stem diameter and vase life were highest for plants spaced at 30.0 × 30.0 cm. Plant spacing had no effect on number of leaves per plant, fresh weight of stem, flower quality and internodal distance. Similar results were recorded when this experiment was repeated on *Helianthus annuus* during next year for confirmation of results. In case of *Zinnia elegans*, plants spaced at 30.0 × 30.0 cm exhibited highest plant canopy diameter, number of leaves per plant and number of flowers per plant, while plants spaced at 15.0 × 15.0 cm had highest plant height and leaf area. Flower diameter, stem diameter, flower quality, internodal distance, fresh weight of a stem and vase life were similar irrespective of plant spacing. Based on the findings, it can be concluded that quality cut *Helianthus annuus* production was greatly improved when plants were spaced at 15.0 × 15.0 cm, while 30.0 × 30.0 cm spacing was optimal for cut *Zinnia elegans* production and may be used for commercial cultivation of *Helianthus and Zinnia* in Punjab, Pakistan.

***Keywords**: Plant spacing, specialty cut flowers, substrate, sunflower, zinnia.*

***Article History:** Received 29 September 2018; Revised 18 March 2019; Accepted 22 March 2019; Published 31 March 2019.*

INTRODUCTION

Besides the growing attraction toward specialty cut flowers, flowering annuals are one of the most popular specialty cut flowers with great diversification of cultivars for different regions. Low input cost and maintenance requirements, diversification in cultivars and colors, long vase life, and wide adaptability contribute to their popularity (Starman et al., 1995; Dole et al., 2009; Ahmad et al., 2014). The increase in cut flowers' demand at domestic and international markets has led the commercial production of cut flowers to increase several folds during last decade (Ahmad et al., 2017). World production of fresh flowers is shifting towards specialty cuts. Specialty cut flowers are nontraditional flowering crops other than roses, carnation and chrysanthemum, used for aesthetic purposes primarily in floral arrangements and bouquets. Numerous annuals, perennials, shrubs, trees, and woody vines are grown as specialty cut flowers on commercial bases all over the world (Armitage, 1993; Dole et al., 2009). However, Pakistani floriculture industry still revolves around commercial production of roses, gladioli and tuberoses and needs to be diversified with new flower crops in order to fulfill aesthetic needs of the people (Ahmad et al., 2017).

Plants require appropriate space to grow and sufficient amount of water, air and light for proper growth and development. Plants have to get these inputs from the limited space in which they grow. Therefore, they are more susceptible to deficiency of the essential nutrients if they are not provided adequate living space. Correct planting distance affects the available space for growth of plants and, therefore, bulbs, seeds and corms should be planted keeping in view of their requirements. In addition, the depth of planting also affects the time of emergence and consequently the flowering time and the total duration of the harvest. Hence, planting at an even distance is essential for a uniform crop (Amjad and Ahmad, 2012).

Sunflower (*Helianthus annuus*), a member of family Asteraceae, is an annual flowering diploid plant probably the most ancient plant grown for oil seed by human. Mexico and Peru have been proposed as a center of origin for sunflower. Basically, sunflower is a crop of warm regions of subtopics and tropics. It has high light and temperature requirements, which make it sensitive for low temperature (Mohamed et al., 1992; Sangoi and Kruse, 1993). Sunflower currently holds an increasing economic worth as specialty cut flower, so that on Dutch flower auctions market it passed, from 1994 to 2000, from the 35th rank to the 18th, respectively (43 million stems were sold). Its cultivation on large

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scale as a cut flower began in the 90s (Armitage, 1993). In Liguria (Italy), its annual production is around 30-40,000 flowering stems (Gimelli et al., 2002).

Zinnia is a genus of Asteraceae family, which has *Zinnia elegans* and *Zinnia haagaena,* the two most auspicious species from 20-30 species (Javid et al., 2005). *Zinnia* can easily be grown in pots, window boxes, beds and rock gardens (Yassin and Ismail, 1994). *Zinnia* is a classic cut flower, which is holding significant position in cut flower industry for its adaptability, an array of colors and comparatively less maintenance requirements (Riaz et al., 2007). *Zinnia* flowers are multi-colored having cherry, lavender, purple, pink, orange, rose, red, golden, white, salmon, yellow, light cream and green colors and has erect stem with height of 10 to 100 cm. From May to October, flowers of *Zinnia* are available in Pakistan (Javid et al., 2005).

Pakistan cut flower industry is dominated by roses, gladioli, and tuberoses and there are limited choices available for growers as well as consumers to fulfill their aesthetic needs. As a result, there is a dire need to introduce and evaluate new specialty cut flower crops and cultivars suitable for local agro-climatic conditions. Keeping in view, the importance of new cut flowers, a study was conducted to evaluate exotic cultivars of *Helianthus annuus* and *Zinnia elegans* in Faisalabad, Punjab, Pakistan, to find out their optimal planting densities for getting highest yields and best quality cut stems.

MATERIALS AND METHODS

A study was conducted at Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad (GPS latitude 31.438673 and longitude 73.070045), Pakistan, during 2015-16 and 2016-17, to optimize the planting densities for cut *Helianthus annuus* and *Zinnia elegans.* Seeds of *Helianthus annuus* cv. 'Pro Cut Orange' and *Zinnia elegans* cv. 'Double Super Yoga' were purchased from an importing agency, Florina International, Lahore, and nursery was raised during 3rd week of February in plastic plug trays containing coco coir: compost: silt (1:1:1; v/v/v) as substrate. After thorough soil preparation, slow release compound fertilizer (NPK 20:20:20 @ 250 kg per ha) was added to soil at transplanting. All other cultural practices such as fertilization, irrigation, weeding, insect-pest and disease management etc. were similar for all treatments during entire period of study. At 2-4 true leaf stage, seedlings were transplanted outdoors during 3rd week of March in thoroughly tilled and leveled flat beds at following plant and row spacing: 15.0 × 15.0 cm with 40 plants per m^2, 15.0 × 22.5 cm with 26 plants per m^2, 22.5 × 22.5 cm with 17 plants per m^2, 22.5 × 30.0 cm with 13 plants per m^2, and 30.0 × 30.0 cm with 10 plants per m^2.

There were five treatments replicated three times and, in each replication, there were 40, 26, 17, 13 and 10 plants per m^2 in each treatment, respectively. The experiment was laid out according to randomized complete block design (RCBD). Data on five randomly selected plants in each replication were recorded at harvest. Experiment for *Helianthus annuus* was also repeated during next year for confirmation of results. Data on plant height (cm), plant canopy diameter (cm), number of leaves per plant, leaf area (cm^2), relative leaf chlorophyll contents (SPAD), stem diameter (mm), flower diameter (mm), fresh weight of a flower stem (g), number of flowers per plant, flower quality (1-9), inter-nodal distance (cm) and vase life (days) were recorded. Plant canopy diameter was measured at harvest at two widest points and average was computed, while leaf area was recorded by measuring maximum length and width of the leaf and multiplying with 0.68 (constant factor) according to Carleton and Foote (1965). Relative leaf chlorophyll content (SPAD) was measured using a chlorophyll meter, while flower quality was rated on a scale of 1-9, where 1 was poor quality and 9 was considered as best quality flower stem (Dest and Guillard, 1987; Cooper and Spokas, 1991). Data were analyzed using analysis of variance (ANOVA) technique according to Fisher's analysis of variance technique and treatment means were compared according to Least Significant Difference (LSD) test at $P \leq 0.05$ (Steel et al., 1997).

RESULTS AND DISCUSSION

Plant height for *Helianthus* (113.9 to 97.8 cm) decreased with increasing plant spacing, but plant spacing had no effect on plant height of *Zinnia* (Table 1). These results are in accordance with Chaudhary et al. (2007), who reported that increasing plant spacing decreased plant height of *Zinnia*. Plants canopy diameter increased with increasing plant spacing for both the tested species. The maximum plant canopy diameter was recorded in 30.0 × 30.0 cm spacing with 10 plants per m^2 for *Helianthus* (57.9 cm) and *Zinnia* (39.7 cm) (Table 1). Light is an important environmental factor, which affects photosynthesis and other metabolic processes, ultimately affecting plant growth (Francescangeli et al., 2006). The amount of light getting inside the canopy and captivated by the plant vary with plant density. Number of leaves per plant increased with increase in plant spacing of *Zinnia* (60.9), while plant spacing had no significant effects on number of leaves per plant of *Helianthus* (Table 1). Number of leaves per plant increased with increasing plant spacing in various ornamental plants (Chaudhary et al., 2007; Amjad and Ahmad, 2012). Leaf area was significantly affected by plant spacing for both flowering plants (Table 1). For *Helianthus*, leaf area increased with increasing plant spacing (327.8 cm^2), while for *Zinnia*, the maximum leaf area (38.0 cm^2) was recorded in plants spaced at 15.0 × 15.0 cm, while the minimum leaf area (30.3 cm^2) was recorded for plants spaced at 22.5 × 30.0 cm. These results are in line with findings of Amjad and Ahmad (2012), who recorded maximum leaf area for plants spaced closer in lilium.

Relative leaf chlorophyll content (SPAD) in *Helianthus* was not affected by plant spacing, while in case of *Zinnia*, 18.2 SPAD leaf chlorophyll content was recorded in 15.0 × 22.5 spaced plants (Table 2). Amjad and Ahmad (2012) have also reported higher chlorophyll content when lilium plants were planted at closer spacing. Close planting created competition among plants, which caused increase in upright plant growth. More plant height encouraged photosynthetic activity, which thereby increased chlorophyll content. For *Helianthus*, the maximum stem diameter (20.1 mm) was recorded when plants were spaced at 22.5 × 22.5 cm, while *Zinnia* had no effect of plant spacing on stem diameter. In a previous study, stem diameter was also not affected by plant spacing in lilium (Amjad and Ahmad, 2012).

Table 1: Plant height, plant canopy diameter, number of leaves per plant and leaf area of *Helianthus annuus* cv. 'Pro Cut Orange' and *Zinnia elegans* cv. 'Double Super Yoga' as affected by various planting densities. All data represent means of five plants per replication.

Plant spacings (cm)	Plant height (cm)			Plant canopy diameter (cm)			Number of leaves per plant			Leaf area (cm^2)		
	Helianthus		*Zinnia*	*Helianthus*		*Zinnia*	*Helianthus*		*Zinnia*	*Helianthus*		*Zinnia*
	2015-16	2016-17		2015-16	2016-17		2015-16	2016-17		2015-16	2016-17	
15.0 × 15.0	113.9 a[z]	111.8 a[z]	70.3	27.5 c	28.6 c	29.4 c	12.1	12.1	41.5 c	197.0 c	199.0 c	38.0 a
15.0 × 22.5	104.9 ab	104.5 ab	66.2	28.6 c	30.4 c	33.6 bc	11.0	11.0	49.8 bc	211.6 c	225.0 c	33.0 abc
22.5 × 22.5	55.2 c	57.0 c	67.7	49.9 b	49.7 b	32.9 bc	12.0	12.0	50.6 abc	244.1 bc	254.2 bc	36.4 ab
22.5 × 30.0	53.0 c	54.0 c	64.3	53.5 ab	54.4 ab	36.8 ab	12.0	12.1	56.7 ab	287.1 ab	298.2 ab	30.3 c
30.0 × 30.0	97.8 b	100.0 b	62.6	57.9 a	56.3 a	39.7 a	13.0	13.0	60.9 a	327.8 a	318.7 a	32.3 bc
Significance[y]	<0.0001	<0.0001	ns	<0.0001	<0.0001	0.0097	ns	ns	0.0076	0.0005	0.0005	0.0425

[z] Mean separation within columns by Fisher's LSD at $P \leq 0.05$.
[y] *P* values were obtained using General Linear Models procedures of Statistix (version 8.1) for significant effects of plant spacings.
[ns] Non-significant at $P > 0.05$.

Table 2: Relative leaf chlorophyll content, stem diameter, flower diameter and fresh weight of a flower stem of *Helianthus annuus* cv. 'Pro Cut Orange' and *Zinnia elegans* cv. 'Double Super Yoga' as affected by various planting densities. All data represent means of five plants per replication.

Plant spacings (cm)	Relative leaf chlorophyll content (SPAD)			Stem diameter (mm)			Flower diameter (mm)			Fresh weight of a flower stem (g)		
	Helianthus		*Zinnia*	*Helianthus*		*Zinnia*	*Helianthus*		*Zinnia*	*Helianthus*		Zinnia
	2015-16	2016-17		2015-16	2016-17		2015-16	2016-17		2015-16	2016-17	
15.0 × 15.0	17.81 c	16.98 c	12.37 c	17.81 c	16.67 c	12.37 c	76.91 b	78.87 c	77.89 c	72.2 c	81.3 d	13.1 b
15.0 × 22.5	18.63 b	18.34 b	18.18 a	18.63 b	18.54 b	18.18 a	95.69 ab	93.39 b	84.67 a	143.8 ab	146.6 a	13.5 b
22.5 × 22.5	20.08 a	21.88 a	13.63 bc	20.08 a	21.87 a	13.63 bc	94.82 ab	94.45 ab	83.90 b	141.6 b	143.5 ab	14.9 ab
22.5 × 30.0	18.97 b	18.23 b	17.05 a	18.97 b	18.75 b	17.05 a	103.84 a	105.43 a	83.10 b	123.6 a	125.8 b	13.9 b
30.0 × 30.0	19.96 ab	19.99 ab	16.39 ab	19.96 ab	19.87 ab	16.39 ab	104.82 a	106.65 a	84.84 a	122.7 a	120.6 c	15.4 a
Significance[y]	Ns	ns	0.0021	ns	ns	0.0021	0.0001	0.0001	ns	0.0001	0.0001	ns

[z] Mean separation within columns by Fisher's LSD at $P \leq 0.05$.
[y] *P* values were obtained using General Linear Models procedures of Statistix (version 8.1) for significant effects of plant spacings.
[ns] Non-significant at $P > 0.05$.

Table 3: Number of flowers per plant, flower quality, internodal distance and vase life of *Helianthus annuus* cv. 'Pro Cut Orange' and *Zinnia elegans* cv. 'Double Super Yoga' as affected by various planting densities. All data represent means of five plants per replication.

Plant spacings (cm)	Number of flowers per plant			Flower quality (1-9)[z]			Internodal distance (cm)			Vase life (days)		
	Helianthus		Zinnia	Helianthus		Zinnia	Helianthus		Zinnia	Helianthus		Zinnia
	2015-16	2016-17		2015-16	2016-17		2015-16	2016-17		2015-16	2016-17	
15.0 × 15.0	1.0	1.0	6.4 b[y]	6.7	7.0	7.5	9.3	9.4	7.9	14.1 b	14.7 b	12.2
15.0 × 22.5	1.0	1.0	7.2 b	7.3	8.0	7.1	8.7	8.9	7.8	13.7 b	12.9 d	12.0
22.5 × 22.5	1.0	1.0	6.9 b	7.5	8.3	7.0	9.8	9.9	8.3	13.9 b	13.8 c	11.6
22.5 × 30.0	1.0	1.0	9.6 a	7.1	7.3	7.2	8.7	8.9	7.2	15.5 a	15.8 ab	10.9
30.0 × 30.0	1.0	1.0	10.7 a	7.2	7.5	6.8	9.9	9.9	7.9	15.7a	16.0 a	10.5
Significance[x]	ns	ns	0.0010	ns	ns	ns	ns	ns	ns	<0.001	<0.001	ns

[z] Flower quality was rated on a scale of 1-9, where 1 was poor quality, 5 was average quality and 9 was best quality.
[y] Mean separation within columns by Fisher's LSD at $P \leq 0.05$.
[x] *P* values were obtained using General Linear Models procedures of Statistix (version 8.1) for significant effects of plant spacings.
[ns] Non-significant at $P > 0.05$.

Findings further revealed that flower diameter of *Helianthus* was significantly affected by plant spacing and the maximum flower diameter (104.8 mm) was recorded when plants were spaced at 30.0 × 30.0 cm, while *Zinnia* had no effects of plant spacing on flower diameter (Table 2). According to Chaudhary et al. (2007), wider plant spacings increase flower diameter. For *Helianthus*, highest fresh weight of flower stem (122.7 g) was recorded when plants were spaced at 30.0 × 30.0 cm, while *Zinnia* had no effect of plant spacing on fresh weight of flower stem (Table 2), which are contradicted to the findings as reported by Amjad and Ahmad (2012), who observed significant increase in fresh weight of flower with increase in plant spacing.

Number of flowers per plant was greater for wider plant spacing recorded for *Zinnia* (10.7), while *Helianthus* had no effect of plant spacing on number of flowers per plant (Table 3). These results are in line with Chaudhary et al. (2007), who reported increase in number of flowers per plant with increase in plant spacing.

Flower quality and inter-nodal distance were not affected by plant spacing (Table 3). Vase life was recorded by placing flowers in DD (distilled water). Results showed that plant spacing had significant effects on vase life of *Helianthus* (15.7 d), while no effects on vase life of *Zinnia*. Vase life was increased with increase in plant spacing of *Helianthus*, which might be due to more accumulation of photosynthates and food reserves. However, these findings were contradictory with Kazaz et al. (2011) who reported that vase life of carnation was decreased with increase in plant spacing.

CONCLUSION

Plant spacing of 15 × 15 cm proved best for good quality cut *Helianthus annuus* production, while 30 × 30 cm spacing was optimal for cut *Zinnia elegans* production, and may be used for commercial production of both tested species.

ACKNOWLEDGEMENTS

Authors are grateful to Higher Education Commission, Islamabad, Pakistan, for providing partial funding for this research under the project No. NRPU 4946.

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