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Sowing times affect flowering, pollen viability and seed yield of *Zinnia elegans* cvs. 'Lilliput' and 'Super Yoga'

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A study was conducted to evaluate the influence of various sowing times on flowering, pollen viability and seed yield of zinnia (*Zinnia elegans*) cultivars 'Lilliput' and 'Super Yoga' under Faisalabad, Pakistan conditions. Seeds of both Zinnia cultivars were sown in 128-cell plug trays at 20 days interval from March 14 to August 20, during 2019. Seedlings were transplanted in thoroughly prepared field beds after 15 days of each sowing, according to factorial arranged randomized complete block design, with three replications. Data were recorded for various growths, flowering traits, pollen viability and seed related parameters. Super Yoga excelled over Lilliput for most the studied traits except number of lateral shoots, flowers per plant, unopened flower buds, pollen viability and seed yield per plant; values of these traits were higher for Lilliput than Super Yoga. Significant variation among various sowing times was recorded in both cultivars. Seeds sown on March 14, 2019 performed best compared to later sowing times for plant height, number of lateral shoots per plant, length of the lateral shoots, leaf area, number of flowers per plant, flower diameter, pollen viability, seed yield per plant and seed viability. However, total number of un-opened flower buds, seed weight per flower and 100-seed weight were more in April 03 sowing, although statistically similar to March 14 sowing. Seed yield declined gradually with delay in sowing; 66% less seed yield in June 20 sowing. Further delay in sowing did not produce seed. It was concluded that Zinnia should be sown by mid-March for getting high seed yield of good quality; later sowing, even during first week of April, resulted in 17.5% decrease in seed yield.
Keywords: Zinnia, planting dates, flower production, seed production, seed quality.

INTRODUCTION

Flowers are generally grown for their artistic effects in public places, on various social events and for value addition such as, essential oil extraction and by-products preparation (Byczynski, 1997). Floriculture has been identified as a potential business now-days because of diversion of farmers towards high value floral crops and increasing demand of floral products at various social events around the globe. Therefore, commercial flower production is also gaining momentum in Pakistan and industry is looking for several new specialty cut species which can be grown outdoors with low cost of production. Most imperative cut flower crops in Pakistan are roses, gladiolus, lilies, freesia, statice, tuberoses etc. (Riaz *et al*., 2008). Last few years, new crops have been tested to appraise their suitability to be grown as a specialty cuts for local market, and among those zinnia is a potential specialty cut flower for summer (Ahmad *et al*., 2012). Zinnia (*Zinnia elegans*) is common summer annual, which is generally grown as bedding plant. However, it is gaining popularity as specialty cut as well on account of its variable and elegant flowers available in several colours during entire summer season.

Temperature is the major determinant for the rate of plant development. Temperature beyond critical range shortens the developmental stages of determinate crops, which usually diminishes the yield of a certain variety. Prior flowering and crop development have been found to be associated with warmer (spring) temperatures (Craufurd and Wheeler, 2009). Similarly, temperature also affects Zinnia growth and flowering, by affecting chemical, biological and physiological processes (Kim *et al*., 2009). When temperature exceed 38°C during summer the production of cut flowers and biological processes are badly affected. The plant proteins are denatured under the conditions of extremely high temperature affecting these processes and afterward the quality of flower is adversely affected (Ha, 2014). Under diverse climatic

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conditions different cultivars of Zinnia behaves in different way.

Zinnia is grown as summer annual in most of the districts of Punjab and Sindh, Pakistan, where high temperature prevails during its cultivation period. Mean monthly temperature of summer months in these districts is higher than the reported suitable temperature in previous research reports (Merritt and Kohl-Jr, 1991; Yu *et al*., 2002; Blanchard and Runkle, 2011). Baloch *et al*. (2009) observed the impact of different sowing dates under long and short day conditions on flowering behaviour of Zinnia cv. 'Lilliput' but did not evaluated the impact of these sowing dates on it seed production. Although Zinnia is successfully grown as flowering plant but, studies regarding the impact of sowing time and temperature on its seed production are scarce under the climatic conditions of Faisalabad. Moreover, selection of appropriate cultivars, which set viable seeds having good germination, must be done that would indeed be a top secret to achieve high seed yield by increasing size and number of flowers. It was hypothesized that early sowing may result in high yield of good quality seed due to availability of favorable conditions for longer period before onset of rainy season and whether cultivars vary in their response to sowing time or not. Present research was therefore designed to appraise the Zinnia cultivars performance under agro-climatic condition of Faisalabad for flowering, pollen viability, seed yield and quality attributes.

MATERIALS AND METHODS

Nursery of Zinnia cultivars 'Super Yoga' and 'Lilliput' was raised at different times in 128-celled plastic plug trays, filled with coco coir, rice hulls ash and sugarcane press mud (1:1:1; v/v/v) as substrate, at Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, from March to August, 2019. After two weeks of sowing, healthy seedlings of same size were transplanted in thoroughly prepared flat beds in open field. First irrigation was applied soon after transplanting, while subsequent ones based on environmental conditions and plant requirement. From May to August, field was irrigated before transplanting to avoid transplanting shock and seedling mortality. Recommended cultural practices were followed and dose of NPK was applied as suggested by Ahmad *et al*. (2012).

***Measurements*:** Data were collected for plant height, number of lateral branches, lateral shoots length, leaf area, period taken from transplanting to flowering, total period of blooming, flowers number per plant, flower diameter, number of un-opened flower buds, pollen viability, days to seed setting, seed weight per flower, seed yield per plant, hundred seed weight, and seed germination percentage, from five randomly selected representative plants in each replication of a treatment. Pollen viability was determined using aceto-carmine dye (McKellar and Quesenberry, 1992; Marutani *et al*., 1993). Carmine powder (2g) was dissolved in 95 ml of glacial acetic. Distilled water was added to a final volume of 100 ml. Solution was boiled, cooled and filtered, and stored in a refrigerator. Two-three drops of staining solution were placed on slides and pollen grains from freshly opened flower were dusted on it followed by covering with cover slip. Pollen viability was recorded after 5-10 minutes by observing slides under IRMECO microscope (HD 1500 T, Meiji Techno, Japan). Pollen was considered as viable when it stained pink to yawing red. Whereas, sterile pollens do not take any stain and therefore, remain about transparent and white.

Flowers on selected plants of each treatment were tagged at anthesis and then days till seed setting were recorded, as evidenced from petal fall. Then days from transplanting to seed setting were recorded. Seeds from five flowers in each treatment of a replication were weighed and mean was calculated to determine seed weight per flower. Seeds of all the flowers were collected from selected plants, weighed and averaged to determine seed yield per plant. From all the collected seeds for each treatment, 100 seeds were counted and weighed to determined 100-seed weight.

Seed germination test was performed using 100 seeds per treatment in four replications and seeds for each variety. Twenty-five seeds per Petri dish were placed between two folds of moist filter paper in an appropriate manner with the help of forceps. Then these Petri dishes were placed in the growth room at 25˚C and the germination in each Petri dish was noted on daily basis and entered in excel sheet and the average was computed.

***Statistical Analysis*:** Experiment was laid out in a randomized complete block design (RCBD) with factorial arrangements having nine sowing times for two cultivars and replicated thrice with fifteen plants per replication. Recorded data for various parameters were analyzed using analysis of variance technique and significant differences among treatments were determined using Tukey's test at $P \leq 0.05$ (Steel *et al*., 1997).

RESULTS

***Vegetative Parameters*:** Plant height, length of lateral shoots, and leaf area was more in 'Super Yoga' compared to 'Lilliput' (Table 1). While, number of lateral shoots was higher in 'Lilliput' than 'Super Yoga' (Table 1). Seed sown on March 14 gave highest values for all these vegetative traits (Table 1). Interaction of sowing dates and Zinnia cultivars indicated that Zinnia cultivar 'Super Yoga' and 'Lilliput' grown on 14th March, 2019 had highest plant height (93.7 and 85.5 cm) (Fig. 2), length of lateral shoots (83.2 and 78.9 cm) (Fig. 3), and leaf area (26.4 and 23.2 cm^2) (Fig. 4). Length of lateral shoots ranged from 83.2 to 43.0 cm and 78.2 to 37.6 cm in 'Super Yoga' and 'Lilliput', respectively, but results were not statistically significant. Moreover, for these traits, values of 'Super Yoga' sown on April 03 were statistically similar to values of 'Lilliput' sown on 14th March. However, number of

Table 1. Effect of cultivars and sowing time on vegetative traits of *Zinnia elegans*.

Factor	Plant height (cm)	Number of lateral shoots per plant	Length of the lateral shoots (cm)	Leaf area (cm^2)
Cultivars				
Lilliput	64.14^B	6.0^A	58.3^B	13.4^B
Super Yoga	69.3^A	4.7^B	63.0^A	15.4^A
P- value	0.0000**	0.0000**	0.0000**	0.0000**
Sowing time (2019)				
14th March	89.6^A	6.9^A	80.7^A	24.8^A
3rd April	84.9^B	6.4^B	75.2^B	21.4^B
23rd April	79.9^C	6.1^C	70.3^C	19.3^C
12th May	73.5^D	5.9^C	66.8^D	17.1^D
31st May	65.0^E	5.4^D	60.4^E	13.3^E
20th June	59.4^F	5.0^E	56.3^F	11.1^F
10th July	54.0^G	4.6^F	50.5^G	10.0^F
30th July	50.2^H	4.2^G	45.3^H	7.0^G
20th August	43.9^I	3.7^H	40.3^I	5.5^H
P-value	0.0000**	0.0000**	0.0000**	0.0000**

**=Highly Significant

lateral shoots was significantly higher in 'Lilliput' compared to 'Super Yoga' when both were sown on 14th March (Fig. 5). There was gradual decline in values of all these parameters with delay in sowing, i.e., from 14th March to 20th August.

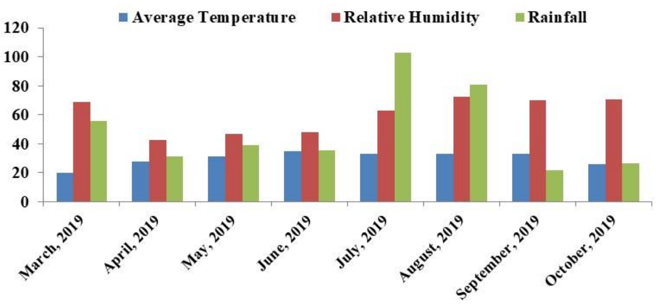

Figure 1. Temperature (°C), relative humidity (%) and rain fall (mm) during study period.

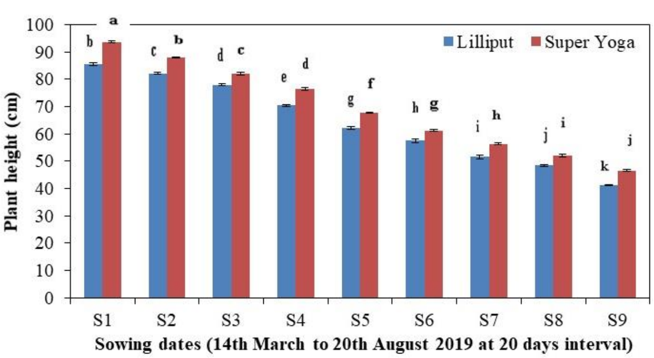

Figure 2. Height of plant (cm) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 2.273)

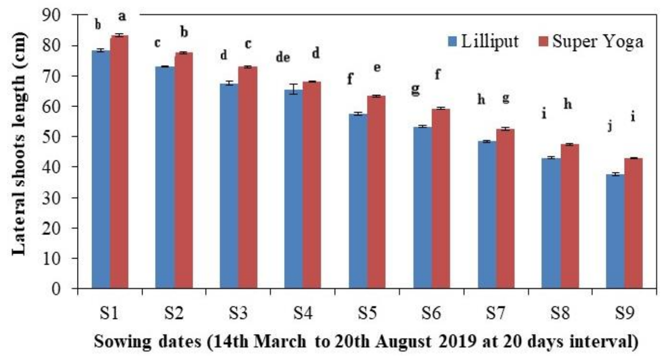

Figure 3. Length of the lateral shoots (cm) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 2.946)

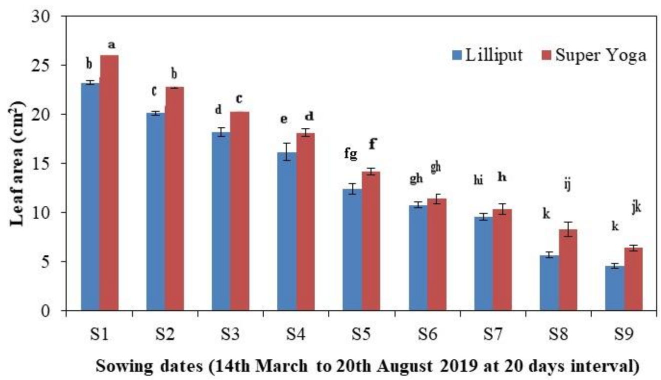

Figure 4. Leaf area (cm^2) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 1.922)

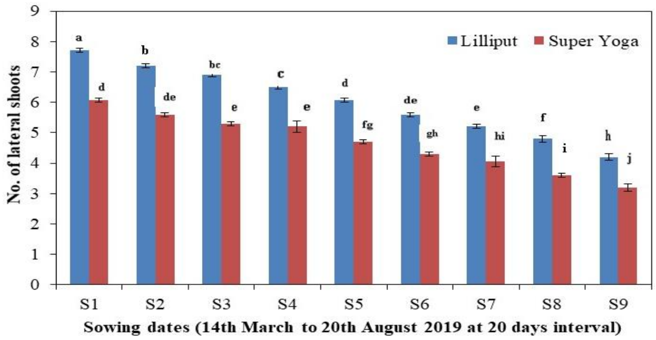

Figure 5. Number of lateral shoots per plant of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 0.459)

***Flowering Traits*: Time from transplanting to flowering, blooming period and flower diameter was more for 'Super Yoga' compared to 'Lilliput'. While, pollen viability, number of flowers per plant and un-opened flower buds per plant were higher in 'Lilliput' than 'Super Yoga'. Seed sown on March 14 gave highest values for all flower related traits except number of un-opened flower buds which were highest for sowing on 23rd April and 12th May. Moreover, flower diameter and pollen viability of sowing on March 14 and April 03 were statistically similar (Table 2&3). Interactive effect of sowing dates and Zinnia cultivars indicated that 'Super Yoga' sown on March 14 took more time from transplanting to flowering (53.2 days) compared to 'Lilliput' (46.6 days). 'Super Yoga' sown on April 03 was statistically similar to 'Lilliput' sown on March 14 for this parameter

Table 2. Effect of cultivars and sowing time on flowering traits of *Zinnia elegans*.

Factor	Period from transplanting to flowering (days)	Blooming period (days)	Number of flowers per plant	Flower diameter (mm)	Pollen viability (%)	Number of un-opened flower buds
Cultivars						
Lilliput	34.0^B	32.9^B	13.0^A	29.6^B	58.7^A	8.3^A
Super Yoga	39.4^A	38.4^A	6.9^B	37.8^A	55.0^B	6.0^B
P- value	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**
Sowing time						
14th March	49.9^A	55.5^A	19.3^A	46.2^A	78.0^A	8.7^{AB}
3rd April	45.6^B	50.4^B	16.5^B	47.5^A	74.8^A	8.9^{AB}
23rd April	40.2^C	45.4^C	13.8^C	41.8^B	69.0^B	9.5^A
12th May	34.8^D	40.6^D	11.3^D	38.4^C	63.3^C	9.3^A
31st May	31.4^E	36.0^E	9.7^E	33.7^D	58.5^D	7.8^{BC}
20th June	27.8^F	30.7^F	7.3^F	28.7^E	52.0^E	7.1^{CD}
10th July	26.8^F	25.9^G	5.7^G	24.9^F	44.0^F	6.1^D
30th July	35.2^D	20.5^H	3.8^H	22.4^G	38.3^G	4.5^E
20th August	38.7^C	15.8^I	2.3^I	19.8^H	34.0^H	2.4^F
P-value	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**

**=Highly Significant

Table 3. Effect of cultivars and sowing time on seed traits of *Zinnia elegans.*

Factor	Days to seed setting (from transplanting)	Seed weight per flower (mg)	Seed yield per plant (g)	100-seed weight (mg)	Seed viability (%age)
Cultivars					
Lilliput	20.8^B	154.03^B	2.6^A	431.9^B	50.4^B
Super Yoga	24.1^A	164.80^A	1.5^B	468.0^A	53.0^A
P- value	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**
Sowing time (2019)					
14th March	36.7^B	244.8^B	4.7^A	685.8^B	89.0^A
3rd April	34.7^C	250.1^A	4.0^B	689.7^A	84.6^B
23rd April	30.7^E	242.0^C	3.3^C	678.8^C	80.5^C
12th May	28.7^F	237.6^D	2.6^D	670.9^D	75.3^D
31st May	32.6^D	231.7^E	2.5^D	665.0^E	70.5^E
20th June	38.9^A	228.2^F	1.6^E	659.5^F	65.6^F
10th July	0.0^G	0.0^G	0.0^F	0.0^G	0.0^G
30th July	0.0^G	0.0^G	0.0^F	0.0^G	0.0^G
20th August	0.0^G	0.0^G	0.0^F	0.0^G	0.0^G
P-value	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**

**=Highly significant

(Fig. 6). Although statistically non-significant, yet minimum, blooming period was recorded in both cultivars for August 20 sowing, i.e., 37.1 and 40.3 days in 'Lilliput' and 'Super Yoga', respectively (Fig. 7). Same trend was recorded for total blooming period in both cultivars. Total blooming period ranged 51.8-13.2 and 59.2-18.5 days in 'Lilliput' and 'Super Yoga', respectively.

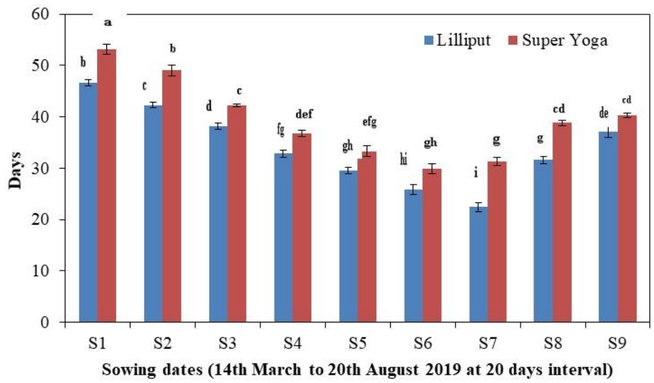

Figure 6. Time taken from transplanting to flowering (days) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 4.198)

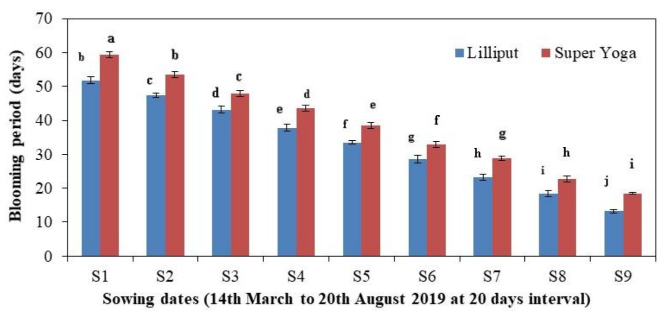

Figure 7. Total period of blooming (days) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 2.667)

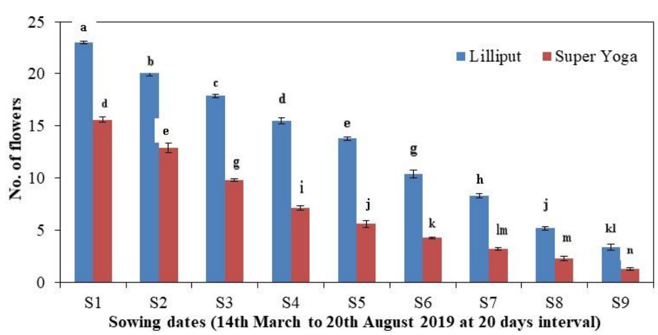

Figure 8. Number of flowers per plant of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 0.929)

'Lilliput' produced more flowers for all sowing dates compared to 'Super Yoga', being the maximum for plants grown on 14th March (Fig. 8). 'Lilliput' sown on March 14 had almost seven times more flowers per plant compared to those sown on 20th August. Similarly, 'Super Yoga' sown March 14 produced 13 times more flowers per plant compared to those sown on 20th August. Sowing on May 12 produced half number of flowers compared to March 14 sowing in 'Super Yoga'. While number of flowers per plant were almost halved for June 20 sowing in 'Lilliput' (Fig. 8). 'Lilliput' and 'Super Yoga' sown on April 23 showed highest total number of un-opened flower buds (10.6 and 8.4) and minimum (3.1 and 1.6) when sown on 20th August (Fig. 9). Flower diameter was the highest in 'Super Yoga' when sown on March 14 and April 03, i.e., 51.8 mm and 55.7 mm, respectively (Fig. 10). Flower diameter declined gradually in both cultivars for sowing from March 14 to August 20, range being 55.7-19.71 mm and 40.7-19.9 mm in 'Super Yoga' and 'Lilliput', respectively. Results indicated that flower diameter reduced by three and two times in 'Super Yoga' and 'Lilliput', respectively; with more decline in 'Super Yoga' compared to 'Lilliput'.

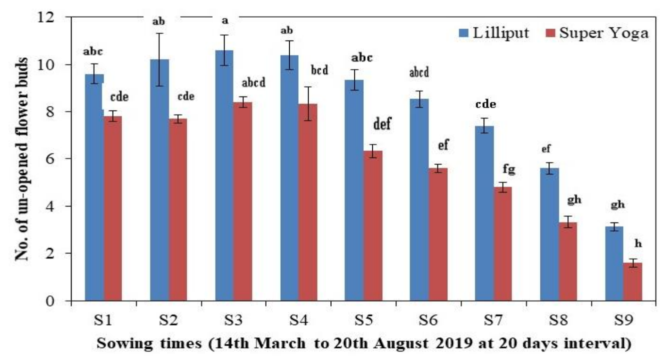

Figure 9. Total number of un-opened flower buds of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 2.296)

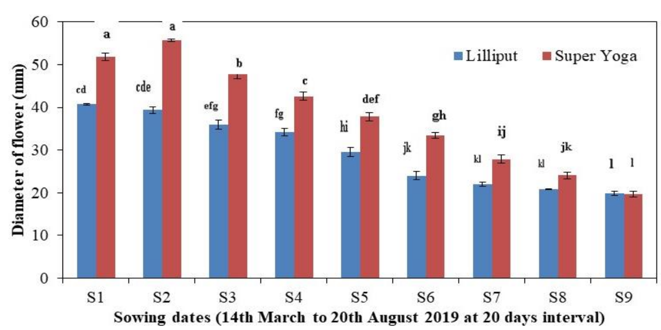

Figure 10. Diameter of flower (mm) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 3.946)

***Pollen Viability and Seed Related Traits*:** 'Super Yoga' took more days from transplanting to seed setting, had higher seed weight per flower, 100-seed weight and seed viability (%) compared to 'Lilliput' (Table 3). However, seed yield per plant was higher in 'Lilliput' than 'Super Yoga' (Table 3). Seed sown on March 14 gave the highest seed yield and seed viability (%) but days to seed setting, seed weight per flower, 100-seed weight were highest for sowing on 3rd April (Table 3). Combined effect of sowing date and cultivar, although statistically non-significant, revealed highest pollen viability in 'Lilliput' and 'Super Yoga' sown on March 14, i.e., 80.6% and 75.3%, respectively (Fig. 11). 'Super Yoga' sown on 14th March was statistically at par with 'Lilliput' sown on 3rd April. Pollen viability gradually declined in both cultivars from 14th March to 20th August, ranging from 80.6 to 36.3% and 75.3 to 31.6% in 'Lilliput' and 'Super Yoga', respectively (Fig. 11). It is also evident from results (Fig. 12) that pollen production and number of pollen grains, declined from 14th March to 20th August.

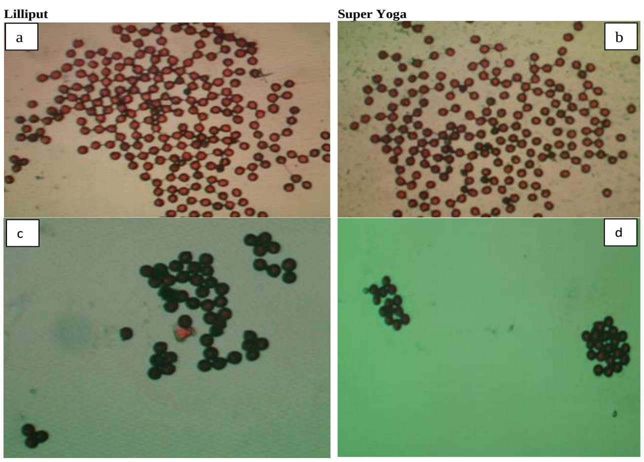

Figure 12. Pollen viability test indicating number of pollen grains and their viability for cultivar Lilliput and Super Yoga sown on March 14 (a & b) and August 20 (c & d).

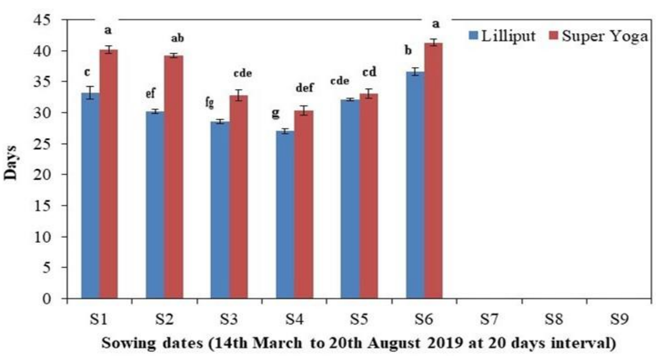

Figure 13. Days to seed setting (from transplanting) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 2.738).

Days to seed setting ranged from 27.0 to 36.6 in 'Lilliput' while from 30.3 to 41.3 in 'Super Yoga' (Fig. 13). Maximum days to seed setting were recorded in cultivar 'Super Yoga' (41.3 days) and 'Lilliput' (36.6 days) sown on 20th June. No seed setting was recorded in both cultivars for plants grown from 10th July to 20th August. Maximum seed weight per flower was recorded in cultivar 'Super Yoga' (255.0 mg) and 'Lilliput' (245.2 mg) sown on 3rd April while, minimum seed weight per flower was observed in these cultivar when sown on 20th June, i.e., 218.3 mg and 218.3 mg, respectively (Fig. 14). Maximum seed yield per plant was recorded in cultivar 'Lilliput' (5.4 g) and 'Super Yoga' (3.9 g) sown on 14th March while, minimum seed yield per plant in these cultivar was recorded when sown on 20th June, i.e., 2.3 g and 0.9 g, respectively (Fig. 15). 'Super Yoga' sown on 3rd April produced highest value of 100-seed weight (715.8 mg) and minimum when grown on 20th June. Same trend was noted for 'Lilliput' ranging from 663.6 to 632.6 mg (Fig. 16). Seed viability was the highest in both cultivars for March 14 sowing, i.e., 87.3% and 90.6% in 'Super Yoga' and 'Lilliput', respectively. Minimum germination percentage was observed in cultivar 'Lilliput' (62.6%) and 'Super Yoga' (68.6%) sown on 20th June (Fig. 17).

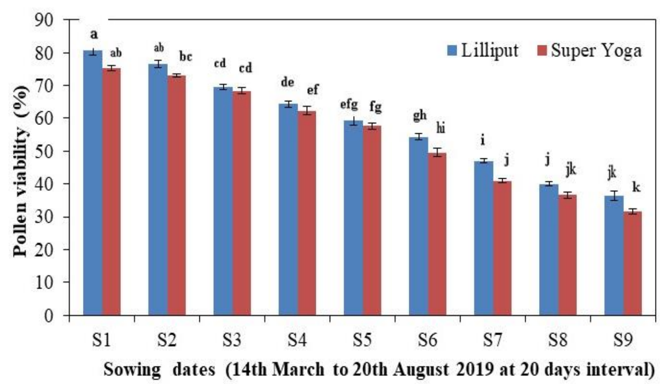

Figure 11. Pollen viability of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 5.388)

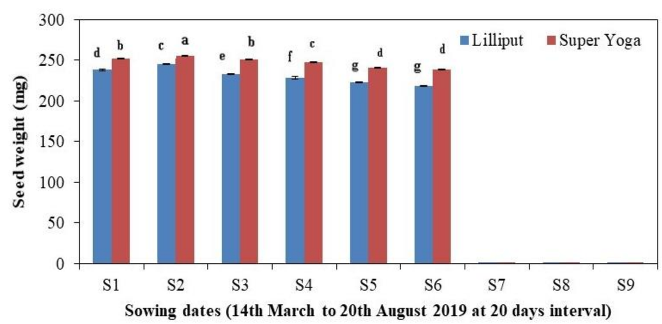

Figure 14. Seed weight per flower (mg) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 2.889).

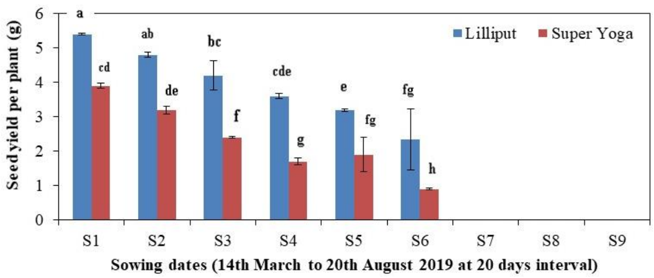

Figure 15. Seed yield per plant (g) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 0.695).

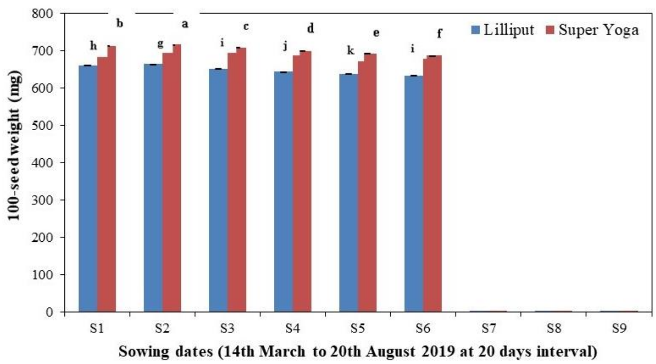

Figure 16. 100-seed weight (mg) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 3.275).

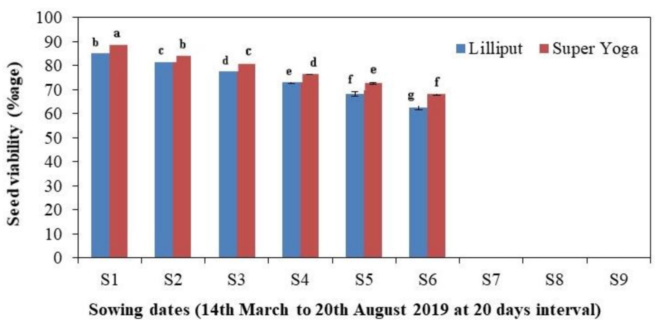

Figure 17. Germination of seeds (%age) of two Zinnia cultivars as influenced by different sowing times. Vertical bars represent ± SE of means (LSD = 2.989).

DISCUSSION

Zinnia is considered as summer annual flowering plant (Sharif *et al*., 2019) that can flower in response to any day length but will flower earlier under short-day conditions (Baloch *et al*., 2010). It is tender with regard to frost tolerance, therefore grown during spring and summer months, from May to October, in plains of Punjab. After seedling establishment, it can tolerate hot summers and flowers. However, vegetative growth phase of summer grown plants increases during long days (Baloch *et al*., 2010) and high light irradiance (Baloch *et al*., 2013). This increase in vegetative growth period was evident in this study in the form of increased plant height, more number of lateral shoots, length of lateral shoots, and leaf area. Size of plant (33.7-43.9%), number of lateral shoots (21-45%), length of lateral shoots (30-43.8%), and leaf area (55-71%), decreased in late (June-July) sown Zinnia plants of both cultivars compared to March 14 sowing (percent reduction mentioned in parenthesis for each parameter), although these late sown plants flowered earlier than those sown during March-May. These results are in agreement with the findings of Blanchard and Runkle (2011) who stated that stem elongation was affected by difference in day and night temperature and stem length was more due to higher day temperature than night temperature. Zhao *et al*. (2014) examined the effect of two planting dates (12th March and 2nd April, 2010) on the yield of Zinnia in Mississippi state and found that Zinnia yield was higher from first planting date than second planting date. One possible reason of small leaf area and less vegetative growth of late grown plants of both cultivars may be the high temperature and monsoon rainfall that causes disease problem and thus limit its production.

Because Zinnia bear flower on shoot terminals and number of lateral shoots were more in early sown plants of both cultivars, therefore number of flowers were more in early sowing dates and then gradually decreased. Time from transplanting to flowering decreased till July 10 and then started increasing. This change may be due to increase in mean daily temperature till July 10, after which mean temperature was slightly decreased due to rainfall. Blanchard and Runkle (2011) also reported that more time was required by Zinnia cultivars to flower when mean daily temperature was from 18.2-18.6 °C compared to plants provided with 22.1-22.3 °C.

Early grown plants of both cultivars had larger leaf area because of which, these early sown plants of both cultivars, produced large sized flowers. Previously, Rasool *et al*. (2020) reported increase in flower diameter with increase plant size and leaf area, which affirms the findings of present study. Moreover, exposure to high irradiance might be helpful to prolong the blooming period as reported earlier by Baloch *et al*. (2013). Difference in number and size of flowers between the two cultivars was a genetic response as mentioned by Dorgham (2019) who evaluated four cultivars of Zinnia.

High temperature possibly reduced number of flowers per plant as well as their diameter; flower diameter was almost half in late sowing treatments than that of flowers borne on plants sown from 14th March to 23rd April. Oren-Shamir *et al*. (2000) reported that the temperature had striking effect on the period of flowering, flower diameter and number of florets per flower head in *Aster*. Carvalho *et al*. (2005) also observed that number of flowers per plant reduced when *Chrysanthemum morifolium* cv. 'Reagan Improved' was exposed to high temperature at visible terminal flower bud formation. Moreover, earlier transplanted plants had flower of greater diameter than late sown plants possibly because of more photosynthates accumulation. These outcomes were supported by the results of Mohanty *et al*. (2015) who observed significant improvement in diameter of flower due to early sowing in African marigold. Carvalho *et al*. (2005) also reported reduction in flower diameter of Chrysanthemum due to high temperature which supported findings of this study.

Pollen grains of Zinnia remain viable for about 18 hours while stigma remains receptive for about seven days, receptivity range from 79.9% to 37.0% (Yao-mei *et al*., 2007). Pollen viability also decreased with the delay in sowing time, i.e., from 14th March to 20th August, possibly because of high temperature prevailing during the flowering of late sown plants of both cultivars. Pollen of flowers from plants grown from 10th July to 20th August was non-viable. Negative effects on high temperature on pollen viability has been reported in several crop plants such as, tomato (Pressman *et al*., 2002), sorghum (Prasad *et al*., 2006), *Phaseolus vulgaris* (da Silva *et al*., 2019), sunflower (Astiz *et al*., 2013) and quinoa (Hinojosa *et al*., 2018). This high temperature possibly has decreased sugar concentration in mature pollen grains as reported earlier (Pressman *et al*., 2002). Another reason of this reduced pollen viability can be high humidity (>70%) coupled with high temperature (>37°C) during late in the season as also reported by Aronne (1999) in two Mediterranean species, viz. *Cistus incanus* and *Myrtus communis*.

Optimum temperature range for Zinnia is 23-28 °C. Slight increase in temperature above the optimum (1-4 °C) has been reported to cause moderate decrease in yield of various crops. But if temperature rise 4 °C above optimum, particularly during pollen development period, then it severely affects yield (Hatfield and Prueger, 2015). Same reason can be ascribed to decline in seed yield per flower and per plant due to decline in pollen viability and number of flowers per plant with delay in sowing. Razzaq *et al*. (2015) also recorded more seed setting in spring sown sunflower compared to the autumn sown crop. Previously, Hatfield *at el*. (2011) stated that temperature rise reduced yield by 2.5-10% in several crops. Seed produced early in the season had higher 100-seed weight as compared to that maturing late in the season, possibly because of reduced leaf area, ultimately less photosynthates for developing seeds. Moreover, some of the developing seeds on late sown plants possibly have not attained complete maturity. Therefore, high temperature coupled with high humidity might have affected quality of seeds from late sown plants, a possible reason of low germination percentage (Rao *et al*., 2017). Furthermore, drying of maturing seeds at high temperature, particularly around 40 °C, can also be the reason of seed quality deterioration (Rao *et al*., 2017).

***Conclusion*:** Zinnia is considered as a promising summer annual flower. Results revealed that seed yield declined progressively with sowing date; 17.5% and 29.7% less seed was produced in April 03 and 23 sowing, respectively, compared with March 14 sowing. Sowing on 20th June produced three times less seed compared to March 14 sowing. Seed yield decreased in plants grown late in the season (mid-May to August) because of low pollen viability possibly due to high temperature coupled with high humidity. ‘Lilliput’ has more branching compared to ‘Super Yoga’, therefore produced more flowers that resulted in higher seed yield. It was concluded that Zinnia should be sown early in the season (March 14) to produce high seed yield of good quality.

***Conflict of Interest*:** There is no conflict of interest among authors.

***Author’s contribution*:** Rimsha Asghar: Conducted experiment, collected data and tabulated it.
Khurram Ziaf: Perceived the idea and prepared first draft of the manuscript.
Iftikhar Ahmad: Helped in designing the study, layout in field, crop management, and guided in data collection.
Muhammad Awais Ghani: Analyzed the data and presented the results in readable form, helped in result interpretations.
Umbreen Shahzad: Proof read the paper for final submission and helped in incorporating the suggestions of the reviewers.

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