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Genetic variability and character association in tulip (*Tulipa gesneriana*) for various quantitative traits

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ABSTRACT

A study was conducted during 2009-11 to estimate the genetic variability, heritability, genetic advance and correlation in twenty one genotypes of tulip (*Tulipa gesneriana* L.). Tulip germplasm were evaluated for various vegetative, floral and bulb quality related traits. Blushing Apeldoorn was earliest to flower and Golden melody took maximum days to flower. The maximum scape length and flower size was recorded in Ganders Rhapsody and Montecarlo respectively. Golden Melody produced the maximum number of bulbs and bulblets. Ali Bi, Blushing Apeldoorn, Ganders Rhapsody, Pretty Women, Strong Gold and Tulip Hb were promising genotypes for cut flower production. The study revealed wide variation for all the characters indicating sufficient genetic variability to be exploited in breeding programme. The maximum value of PCV and GCV was recorded for number of bulbs per plant. High heritability coupled with high genetic advance was observed for spike length, plant height, and wrapper leaf area. Selection on the basis of these characters would be more effective for the improvement of tulip. Scape length, the economically important trait in tulip, revealed a highly significant and positive correlation with plant height and bulb size. Highly significant and positive correlation of number of bulbs was observed with number of leaves per plant and wrapper leaf area. Hence, direct selection from germplasm lines may be effective for improvement in closely associated traits.

Key words: Correlation, Genetic variability, Heritability, Tulip

Tulip (*Tulipa gesneriana* L.), the queen of bulbous flowers, belongs to the family Liliaceae. It ranks third in the international cut flower trade (Flower Council of Holland 2008). It has a great commercial value either as forced cut flower/potted plant or for garden and landscape. Tulips are highly valued for their attractive, coloured, upright flowers, mainly produced in springs. The flowers may be single or double and vary in shape from simple cup, bowls or goblets to more complex forms produced by twisted or rounded tepals. In, India tulip has been recently introduced at the Kashmir valley. It is gaining great popularity there over the last few years (Jhon and Khan 2003). There is tremendous scope for its commercial cultivation in Himachal Pradesh, Jammu & Kashmir, Uttarakhand and similar other hilly terrains of India (Jhon *et al.* 2007). The main strength of tulip cultivation in these areas lies in the suitability of climate for cut flower production and bulb multiplication, availability of manpower, lesser cost of production compared to major temperate bulb growing countries (Jhon 2006). However, this crop has never been opted as commercial crop in India due to lack of adaptive genotypes, agro-techniques and planting material (Jhon *et al.* 2007). Hence, there is a need to standardize the agro-techniques for production and bulb multiplication and to breed cultivars suitable for growing under Indian condition.

The performance of any crop or variety largely depends on genotypic and environmental interactions. As a result, cultivars which perform well at one region may not show same performance in other region of varying climatic condition. Therefore, it is necessary to evaluate the available germplasm to find out the most promising genotypes suitable for cut flower and bulb multiplication (Punam *et al.* 2009). The extent of genetic variability is of paramount importance for the improvement of a crop as greater is the genetic variability in the existing germplasm better would be the chances of selecting superior genotypes (Vavilov 1951). Improvement through selection depends upon the variability existing in the available cultivars, which may be due to the difference either in genetic constitution of cultivars or in the environments in which they grow (Sestra *et al.* 2007). Genotypic and phenotypic coefficients of variation are useful in detecting the amount of variability present in the genotypes

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(Kumar et al. 2012). Tulip is a vegetative propagated crop and selection is an easy method for improvement programme. Selection is effective only when the observed variability in the population is heritable in nature (Jhon *et al*. 2006). As the breeders are always interested in the improvement of several economic characters and hence, the knowledge of correlation among the traits is important to have the idea of concurrent changes which would be brought about in other traits while making selection for one trait (Bhatia 2004). The nature and the extent of association among the traits is of great importance for planning an efficient breeding programme (Panwar *et al*. 2012). Hence, the present study was conducted with the aim to identify the promising genotypes suitable for commercial cultivation under Kullu Valley condition and to ascertain the extent of genetic variability, heritability, genetic advance and to establish correlation among different traits.

MATERIALS AND METHODS

The present study was carried out at the research farm of Indian Agricultural Research Institute, Regional Station, Katrain, Kullu, Himachal Pradesh during 2009-11. The tulip was introduced for the first time at this station. The experimental material comprised 21 genotypes of tulip introduced from Holland and collected from various parts of Jammu & Kashmir. Healthy and uniform sized bulbs weighing about 10-15 g were planted 8-10 cm deep at a distance of 20 cm × 15 cm. Eighteen bulbs were planted per treatment per replication in randomized block design with three replications. After planting of bulbs the crop was mulched with grass in order to maintain the soil temperature and moisture. The recommended package of practices along with plant protection measures was followed to raise the successful crop. The data were recorded on five randomly selected plants in each genotype in each replication. The observations were recorded for sixteen quantitative characters namely days to sprouting, percentage sprouting, number of leaves/plant, wrapper leaf area, days to flower, plant height, scape length, scape thickness, flower diameter, percentage flowering, duration of flowering, number of bulbs per plant, bulb weight (g), bulb size (cm), number of bulblets per plant and bulblet weight. Data of both years were pooled and subjected to analysis of variance using statistical software SPSS 12. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variability (PCV) were calculated by using formulae suggested by Singh and Choudhary (1985). Heritability in broad sense and expected genetic advance (GA) as percent of mean was calculated according to the formula suggested by Allard (1960). The Pearson's correlation coefficient was estimated from analysis of variance and covariance for all the characters as suggested by Al-Jibouri *et al*. (1958).

RESULTS AND DISCUSSION

Tulip is recently introduced flower in India and information regarding adaptive genotypes suitable for cut flower and bulb multiplication is scanty. Therefore, tulip genotypes were evaluated at our station to identify the promising genotypes suitable for cut flower and bulb multiplication under mid-Himalayan region. The analysis of variance (ANOVA) showed highly significant differences among genotypes for all traits (Table 1 and 2). Among all the cultivars Blushing Apeldoorn was the earliest to sprout (30.33 days), whereas Oxford Wonder took the maximum (72.33 days) to sprout. The tulip genotypes under study took 104.67 to 146.33 days to flowering from date of planting (Table 3). The earliest flowering was observed in Blushing Apeldoorn (104.67 days) while Golden melody (146.33 day) took maximum days to flower. Based on days taken to flower the tulip genotypes were classified as early (=115 days), mid (>115 to =130) and late (>130 days) flowering types. Blushing Apeldoorn, Ganders Rhapsody, Golden Apeldoorn, Lle de France, Oxford Wonder and Tulip Hb were categorized as early type. Fourteen genotypes were mid season flowering type and only one genotype, i e Golden Melody was classified as late flowering type. Accordingly, genotypes may be utilized for prolonging the blooming period. Early, mid and late flowering in tulip is genetically controlled as reported by Jhon and Khan (2003).

Scape length is the most important parameter determining the quality of cut tuips. The scape length was maximum in Ganders Rhapsody (38.44 cm) and minimum in Christmas Dream (9.38cm). The scape thickness varied from 3.57 mm (Leen Vander Mark) to 7.97 mm (Strong Gold). Good marketable grade scapes (>25 cm) were obtained in Pretty Women, Strong Gold, Tulip Hb, Oxford Wonder and Ali Bi. Flower size in tulip ranged from 4.37cm to 12.56cm. Double flowered Montecarlo (12.56 cm) exhibited the maximum flower size. Significantly large florets were recorded in Oxford Wonder (7.73 cm), Tulip Hb (7.21cm) and Strong Gold (6.79 cm). The duration of flowering was longest in Blushing Apeldoorn (25.00 days) and shortest in Christmas Dream (13.67 days). Ali Bi, Blushing Apeldoorn, Ganders Rhapsody, Pretty Women, Strong Gold and Tulip Hb had luxuriant vegetative growth and flowering. Thus, these genotypes are highly promising for cut flower production. However, Cassini, Character, Christmas Dream, Hamilton and Horizon exhibited poor vegetative growth (as evident from wrapper leaf area and plant height) and flowering (Scape length, thickness and flower size) hence, not suitable for commercial cultivation. Wide range of variability for vegetative and floral traits in tulip has also been reported earlier by Jhon and Khan (2002) and Ahmed and Khurshid (2004). Variability for various vegetative and floral traits is attributed to genetic background of the genotypes. Such information can help in selection of genotypes for direct introduction and their utilization in further breeding programmes in developing superior genotypes.

Tulip genotypes varied significantly for vegetative and bulb production traits (Table 2&3). The maximum number

Table 1 Mean Performance of tulip genotypes for different floral related traits.

Genotypes	Days to sprout	Per cent sprouting	Days to flower	Scape length (cm)	Scape thickness (mm)	Flower diameter (cm)	Percent flowering	Flowering duration (days)
Ali bi	52.33	80.00	120.82	26.32	5.55	6.14	86.67	17.67
American Dream	45.67	93.33	129.67	22.07	5.37	5.11	96.67	19.33
Apeldoorn	38.33	100.00	118.67	22.69	5.35	6.31	100.00	22.33
Apeldoorn Elite	44.67	95.83	124.33	21.34	4.91	5.55	76.67	18.67
Blushing Apeldoorn	30.33	100.00	104.67	25.40	6.01	5.83	100.00	25.00
Cassini	69.67	76.67	126.00	15.81	5.18	4.50	90.00	16.00
Character	62.67	53.33	125.67	20.20	5.39	5.49	56.67	15.67
Christmas Dream	40.33	44.44	116.67	9.38	4.15	4.37	11.67	13.67
Ganders Rhapsody	33.33	100.00	114.00	38.44	6.83	5.41	97.62	21.33
Golden Apeldoorn	41.67	100.00	114.33	22.97	6.19	5.85	90.00	19.00
Golden Melody	48.67	100.00	146.33	22.20	4.85	5.62	96.67	15.00
Golden Oxford	42.33	76.67	123.00	18.84	6.37	5.74	70.00	18.67
Hamilton	60.67	46.67	121.33	20.82	5.95	6.05	56.67	17.00
Horizon	53.33	43.33	124.33	11.73	5.34	5.29	56.67	18.33
Leen Vander Mark	39.33	93.33	123.00	18.70	3.57	4.83	76.67	16.33
Lle De France	45.33	93.33	110.33	25.07	5.26	6.27	96.67	21.33
Montecarlo	42.33	93.33	115.33	20.52	5.48	12.56	76.67	21.33
Oxford Wonder	72.33	76.67	114.67	26.68	5.27	7.73	90.00	17.00
Pretty Women	36.33	100.00	120.33	32.33	6.90	5.99	86.54	21.33
Strong Gold	35.33	100.00	122.67	29.03	7.97	6.79	97.44	22.67
Tulip Hb	39.33	100.00	110.67	27.33	5.75	7.21	96.67	21.00
CD at (P=0.05)	6.01	11.72	4.09	1.44	0.43	0.87	11.25	2.60

Table 2 Mean Performance of tulip genotypes for different vegetative and bulbs traits.

Genotypes	Number of leaves/ plant	Wrapper leaf area (cm^2)	Plant height (cm)	No of bulbs/ plant	Bulb weight (g)	Bulb size (cm)	No. of bulblets/ plant	Bulblets/ weight (g)
Ali bi	4.67	112.16	31.40	2.08	15.28	10.90	2.72	3.27
American Dream	4.44	107.03	26.78	2.10	19.02	10.55	2.87	3.51
Apeldoorn	4.01	119.17	31.87	2.56	21.26	11.09	1.40	3.13
Apeldoorn Elite	4.29	106.89	30.27	2.89	18.03	11.51	2.51	2.76
Blushing Apeldoorn	5.15	119.67	35.47	3.07	21.13	12.25	2.07	3.70
Cassini	3.11	78.83	18.03	1.33	10.73	9.37	2.55	1.43
Character	3.68	66.75	23.48	1.33	9.00	9.62	2.00	1.35
Christmas Dream	2.58	43.77	15.11	1.60	7.74	8.37	1.56	1.18
Ganders Rhapsody	5.07	110.08	44.33	3.21	16.44	13.61	1.54	2.05
Golden Apeldoorn	4.11	109.77	27.70	2.33	15.87	11.37	2.77	2.11
Golden Melody	4.93	113.04	30.20	3.78	14.19	9.94	3.41	2.69
Golden Oxford	4.44	117.69	24.73	2.32	10.30	11.30	2.56	2.52
Hamilton	3.13	72.40	25.69	1.44	9.39	9.20	1.22	1.52
Horizon	3.35	54.67	14.47	1.08	10.64	7.93	1.09	1.29
Leen Vander Mark	3.44	79.50	23.50	1.75	10.89	9.32	2.45	2.22
Lle De France	3.67	80.38	28.97	2.33	12.18	10.47	1.67	2.85
Montecarlo	4.33	85.47	25.71	1.99	15.95	11.31	3.10	3.01
Oxford Wonder	3.56	85.54	32.67	1.00	16.67	11.30	1.54	3.36
Pretty Women	5.18	125.00	41.40	3.67	20.82	13.08	2.56	3.57
Strong Gold	5.29	122.52	39.53	2.87	24.30	14.03	1.60	4.17
Tulip Hb	5.62	150.47	35.60	3.22	25.88	13.50	1.22	3.68
CD at (P=0.05)	0.67	10.22	3.25	0.98	1.45	1.49	0.73	0.56

Table 3 Mean, minimum, maximum, range and standard deviations for different traits in tulip

Character	Mean	Minimum	Maximum	Range	Standard deviation
Days to sprouting	46.22	30.33	72.33	42.00	11.69
Percent sprouting	84.14	43.33	100.00	56.67	20.33
Number of leaves/ plant	3.82	2.58	5.50	2.92	0.76
Wrapper leaf area (cm^2)	97.12	43.77	150.47	106.70	26.10
Days to flower	120.32	104.67	146.33	41.66	8.56
Plant height (cm)	28.90	14.47	44.33	29.86	7.90
Spike length (cm)	22.79	9.38	38.44	29.06	6.46
Scape thickness (mm)	5.60	3.57	7.97	4.40	0.95
Flower diameter (cm)	6.13	4.37	12.56	8.19	1.68
Percent flowering	81.27	11.67	100.00	88.33	21.58
Flowering duration (days)	18.98	13.67	25.00	11.33	2.90
No of bulbs/plant	2.28	1.00	3.78	2.78	0.83
Bulb weight (g)	15.51	7.74	25.88	18.14	5.23
Bulb size (cm)	10.95	7.93	14.03	6.10	1.69
No of bulblets/plant	2.11	1.09	3.41	2.32	0.69
Bulblet weight (g)	2.64	1.18	4.17	2.99	0.91

Table 4 Estimates of Genotypic and phenotypic coefficient of variation, broad sense heritability and genetic advance for different traits in tulip

Character	GV	PV	GCV (%)	PCV (%)	Broad Sense heritability (%)	GA	GA as percentage of mean
Days to sprouting	11.39	11.96	24.56	25.78	90.73	22.36	48.19
Percent sprouting	19.91	21.14	23.66	25.13	88.71	38.63	45.91
Number of leaves/ plant	0.72	0.83	18.94	21.74	75.92	1.30	34.00
Wrapper leaf area (cm^2)	25.86	26.59	26.62	27.38	94.57	51.80	53.34
Days to flower	8.44	8.79	7.01	7.31	92.07	16.68	13.86
Plant height (cm)	7.81	8.06	27.04	27.89	94.03	15.61	54.01
Spike length (cm)	6.45	6.51	28.35	28.61	98.20	13.17	57.87
Scape thickness (mm)	0.94	0.97	16.70	17.34	92.69	1.85	33.12
Flower diameter (cm)	1.66	1.74	27.01	28.36	90.75	3.25	53.01
Percent flowering	20.41	21.48	25.11	26.43	90.64	40.10	49.34
Flowering duration (days)	2.76	3.17	14.52	16.72	75.44	4.93	25.99
No of bulbs/plant	0.66	0.88	35.24	38.62	83.27	1.51	66.25
Bulb weight (g)	5.30	5.46	32.94	35.20	87.58	9.85	63.51
Bulb size (cm)	1.61	1.85	14.71	16.85	76.13	2.90	26.43
No of bulblets/ plant	0.64	0.78	30.19	36.77	67.42	1.08	51.07
Bulblet weight (g)	0.89	0.95	33.81	36.20	87.24	1.72	65.05

GV, Genotypic variance; PV, phenotypic variance; GCV, genotypic coefficient of variation; PCV, phenotypic coefficient of variation; GA, genetic advance

of leaves (5.50) was recorded in Golden Apeldoorn, wrapper leaf area in Tulip Hb (150.47 cm^2) and plant height in Ganders Rhapsody (44.33 cm). Good quality bulbs are basic and most important input for cut flower production, as the growth and flowering of tulips largely depends upon bulb quality. Other inputs are rendered ineffective if the bulbs are of poor quality (Jhon *et al.* 2007). The number of bulbs ranged from 1.00 in Oxford Wonder to 3.78 in Golden Melody. Pretty Women, Tulip Hb, Ganders Rhapsody, Blushing Apeldoorn, Strong Gold and Apeldoorn Elite produced significantly higher number of bulbs and were at par with each other. The maximum (25.88 g) and minimum (7.74 g) bulb weight was recorded in Tulip Hb and Christmas Dream, respectively. Bulb size ranged from 7.93cm (Horizon) to 14.03 cm (Strong Gold). Mother bulb size has great impact on vegetative, flowering and bulb related traits in tulip (Jhon

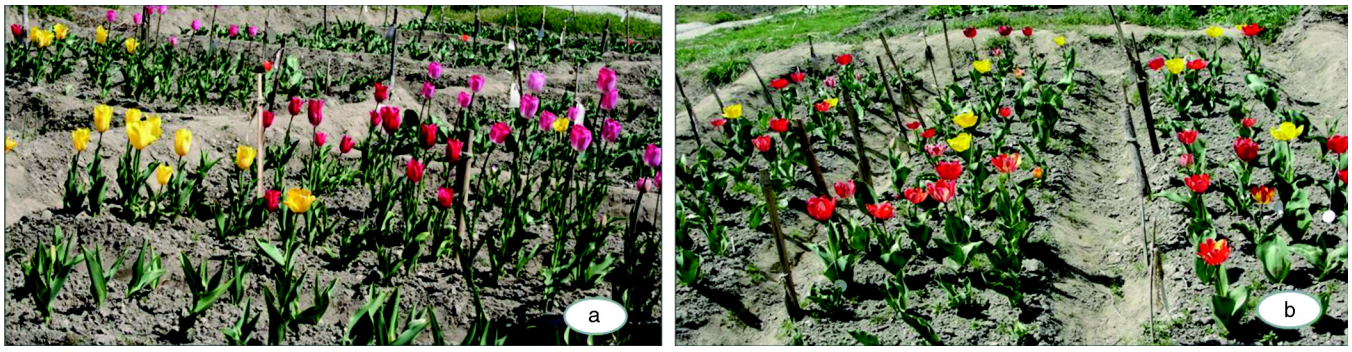

Fig 1 Field performance of tulip germplasm in Kullu valley. a) 2009-10; b) 2010-11

et al. 2007). High percent flowering grade bulbs (10-12 cm) were obtained in Pretty Women, Tulip Hb, Blushing Apeldoorn and Ganders Rhapsody, Strong Gold and Apeldoorn Elite. This was attributed to either number of leaves or large wrapper leaf area that might have resulted in more production and translocation of photosynthates to the storage organs, i e bulbs in these genotypes (Ahmed and Khurshid 2004). These genotypes can be successfully opted for large scale bulb production. Cassini, Character, Christmas Dream, Hamilton and Horizon, and Oxford Wonder were shy bulb multipliers and most of the bulbs produced by them were non-flowering grade. Variation in bulb and bulblets characters in tulip can be attributed to genetic and environmental factors as reported earlier by Jhon *et al*. (2005); Jhon *et al*. (2007) and Ahmed and Khurshid (2004).

Most of the characters under study exhibited moderate to high phenotypic and genotypic coefficient of variation (Fig 1 and Table 4). The maximum value of PCV (38.62) and GCV (35.24) was recorded in number of bulbs per plant. High (>30 %) PCV and GCV estimates were recorded for bulblet weight, bulb weight and number of bulblets per plant. Most of the traits showed moderate (15-30%) estimates of PCV and GCV. Days to flower exhibited the lowest estimates of PCV (7.31) and GCV (7.01). Phenotypic coefficient of variation was higher than their respective genotypic coefficient of variation for all the character indicating the influence of the environment. Jhon *et al.* (2006) have also reported similar results for genotypic and phenotypic coefficient of variation in tulip. The difference between phenotypic and genotypic coefficient of variance was high for number of leaves per plant, duration of flowering and most of the bulb related traits indicating greater genotypic × environment interaction. Hence, there is lesser scope for improvement of these characters through selection. Earlier Kumar *et al.* (2012) have also obtained high differences between PCV and GCV for many traits in gerbera. The estimates of phenotypic and genotypic coefficient of variance showed narrow difference for plant height, spike length, scape thickness and days to flower indicating that these traits were least influenced by environment. Specifically for scape length PCV and GCV were 28.61and 28.35, respectively indicating that phenotypic variability could be a reliable measure of genotypic variability. This facilitates for direct selection for improving the performance of specific trait. Similar results for GCV and PCV have been reported earlier by Jhon *et al*. (2006) in tulip and Balamurugan *et al*. (2002) in gladiolus.

GCV helps in measurement of the range of genetic diversity in a character and provide means to compare the genetic variability in the quantitative characters. The GCV along with heritability estimates provides a better picture of the amount of genetic advance to be expected by phenotypic selection (Burton 1952). The heritability of characters determine how much the phenotype of a plant is a guideline to the genotype and thus, help the breeder to base his selection on the phenotypic performance of the plant (Kumar *et al.* 2012). The heritable portion of variability was thus determined with the help of broad sense heritability. The broad sense heritability estimates were recorded high for almost all the characters and it ranged from 67.42% (number of bulblets produced per plant) to 98.20 % (Scape length). Heritability estimates were very high (>90 %) for days to sprout, wrapper leaf area, days to flower, plant height, scape length and thickness, flower diameter and per cent flowering were recorded for traits. Such high estimates of heritability have been found useful in making selection of superior genotypes on the phenotypic performance with respect to quantitative traits. These results on broad sense heritability corroborate the findings of Sestra *et al*. (2007) and Jhon *et al.* (2006). Number of leaves per plant, duration of flowering, bulb size and number of bulblets per plant, exhibited moderate to low heritability. The low heritability estimates for this character might be due to the predominance of genotype × environment interaction.

GCV and heritability (broad sense) are not sufficient to determine the amount of variations which are heritable and heritable variations could be determined with greater accuracy when heritability along with genetic advance is studied (Burton 1952). Most of the characters exhibited moderate to high genetic advance as a per cent of mean (Table 4). The

Table 5 Pearson's correlation (r) among different quantitative traits in tulip

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
X_1		–0.206	–0.526**	–0.464**	0.294*	–0.416**	–0.310*	–0.267*	–0.046	–0.195	–0.522**	–0.612**	–0.461**	–0.431**	–0.048	–0.380**
X_2			0.406**	0.542**	0.071	0.281*	0.182	0.035	0.180	0.606**	0.292*	0.422**	0.497**	0.327**	0.417**	0.571**
X_3				0.836**	–0.057	0.759**	0.687**	0.563**	0.217	0.594**	0.578**	0.761**	0.736**	0.745**	0.182	0.680**
X_4					–0.089	0.736**	0.661**	0.511**	0.133	0.694**	0.558**	0.728**	0.787**	0.757**	0.184	0.713**
X_5						–0.237	–0.260*	–0.188	–0.265*	–0.043	–0.493**	0.042	–0.226	–0.322*	0.358**	–0.176
X_6							0.942**	0.601**	0.184	0.641**	0.591**	0.671**	0.716**	0.823**	–0.052	0.683**
X_7								0.612**	0.187	0.660**	0.528**	0.572**	0.611**	0.784**	–0.031	0.570**
X_8									0.173	0.366**	0.540**	0.383**	0.451**	0.649**	–0.124	0.368**
X_9										0.158	0.349**	0.005	0.277*	0.272*	0.112	0.372**
X_{10}											0.515**	0.483**	0.620**	0.568**	0.177	0.635**
X_{11}												0.460**	0.635**	0.595**	–0.132	0.571**
X_{12}													0.570**	0.626**	0.205	0.479**
X_{13}														0.718**	–0.012	0.786**
X_{14}															–0.040	0.646**
X_{15}																0.112
X_{16}																

** Correlation is significant at the 0.01 level; * correlation is significant at the 0.05 level

X_1, Days to sprout; X_2, per cent sprouting; X_3, number of leaves per plant; X_4, wrapper leaf area (cm^2); X_5, days to flower; X_6, plant height (cm); X_7, scape length (cm); X_8, flower diameter (cm); X_9, scape thickness (mm); X_{10}, percent flowering; X_{11}, duration of flowering (days); X_{12}, number of bulbs per plant; X_{13}, bulb weight (g); X_{14}, bulb size (cm); X_{15}, number of bulblets per plant; X_{16}, bulblet weight (g)

genetic advance (GA) as a per cent of mean varied from 13.86 for days to flower to 66.25 for number of bulbs per plant. The high (>50%) estimates of GA were observed for wrapper leaf area, spike length, plant height, flower diameter, number and weight of bulb and bulblet. Most of these traits also exhibited high heritability. High heritability coupled with high genetic advance for these traits may be because of additive gene effect (Bhatia 2004). Selection on the basis of these characters would be more effective for the improvement of tulip. Days to sprout, per cent sprouting, scape thickness and per cent flowering exhibited high heritability with moderate genetic advance indicating presence of dominant and epistatic genes and these traits can be improved through hybridization (Kumar *et al*. 2012). Similar results for heritability and genetic advance were obtained earlier in tulip by Jhon *et al*. (2006) and Balamurugan *et al*. (2002) in gladiolus. High heritability along with low genetic advance was observed only for days to flower indicating the influence of non-additive gene effect on this trait. It demands selection with adequate progeny testing for improvement.

Correlation studies were carried out to reveal the nature and extent association between growths, flowering and bulb related traits (Table 5). Scape length, scape thickness and flower size are the economically important traits that determine the quality of cut tulips. Improvements in these traits are the prime objectives of tulip breeding programme. Scape length revealed a highly significant and positive correlation with, plant height (0.942), and bulb size (0.784). Earlier, Bhatia *et al.* (2004) also observed highly significant correlation of spike length with plant height and corm size in gladiolus. Significant positive correlation of scape length was also recorded for number of leaves/plant, wrapper leaf area, flower size, number of bulbs/plant and bulb weight. Therefore, it was evident that scape length, an important character for cut flower production, could be increased with the increase in any of these characters, especially plant height and bulb size as they exhibited a high degree of significant positive correlation with scape length, so a direct selection from germplasm lines may be effective for improvement (Panwar *et al.* 2012). Scape length exhibited negatively associated with days to sprout, days to flower and number of bulblets/plant. Similar trends for stalk length have been earlier reported in gerbera by Anuradha and Gowda (2002) and Kumar *et al.* (2012).

Flower size showed highly significant and positive correlation with bulb size (0.649), scape length (0.612) and plant height (0.601). Number of leaves/plant, wrapper leaf area duration of flowering, number of bulbs and bulb weight also positively associated with flower size. It is evident from this association that cut flower quality parameters of tulip such as scape length and flower durability can be improved simultaneously with the improvement in flower size. Similar trends of association of flower size have been earlier reported in gladiolus (Bhatia 2004, Jhon *et al.* 2002).

Tulips are commercially multiplied via bulbs. However, multiplication rate in tulip is quite poor. So there is a need to improve the multiplication potential either by selecting the genotypes with high bulb production coefficient or via indirect improvement in the traits contributing for number of bulbs per plant. Number of bulbs showed highly significant and positive correlation with number of leaves/plant (0.761), wrapper leaf area (0.728). Further, traits like plant height, scape length and thickness, bulb weight and size were also positively associated with number of bulbs. It indicated that improvement in these characters could lead to an increase number of bulbs/plant. However, negative correlation between bulbs/plant and days to sprout indicated that with the increase in one parameter there would be decrease in another parameter as observed earlier in gladiolus (Bhatia 2004, John *et al.* 2002).

This study revealed wide variation for majority of traits indicating sufficient genetic variability to be exploited in breeding program. The commercially important traits like spike length, flower diameter, number and weight of bulb exhibited high heritability coupled with high genetic advance signifying additive gene action. Hence, selection would be more effective for the improvement of these traits. Plant height and bulb size exhibited a high degree of significant positive correlation with scape length and flower size, so a direct selection from germplasm lines may be effective for improvement for improving the cut flower quality.

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