Electronic Journal of Plant Breeding, 9 (1) : 18 - 24 (Mar 2018) DOI: 10.5958/0975-928X.2018.00003.0
ISSN 0975-928X

Research Article

Spectrum of variation and transgressive segregation in F_2 generation of desi chickpea

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(Received: 10 Dec 2017; Revised: 28 Feb 2018; Accepted: 23 Mar 2018)

Abstract
The studies on genetic variability, heritability and genetic advance was carried out with 720 plants of each F_2 populations of four chickpea crosses. High mean performance, wider range of variation, high heritability coupled with moderate to high expected genetic advance as per cent of mean was observed for number of branches per plant, number of pods per plant and seed yield per plant in GJG 0315 x ICCV 96029, GJG 0107 x GCP 105 and GJG 0719 x SAKI 9516 of F_2 populations, which indicated the predominant role of additive gene action in the expression of these three traits. Moderate heritability and low genetic advance was recorded for number of branches per plant, number of pods per plant and seed yield per plant in GAG 0419 x JCP 245. Greater number of transgressive segregants was found for number of branches per plant followed by days to flowering and days to maturity, number of pods per plant and seed yield per plant. A track on these transgressive segregants should be maintained and forwarded to further generations till they reach nearly homozygous condition. Most promising one can be used in further breeding programme.

Key words
Variability, transgressive segregation, F_2 generation, chickpea

Introduction

India is one of the major pulses growing country of the world, accounting roughly for one third of total world area under pulse cultivation and one fourth of total world production. Pulses occupy a key position in Indian diet and meet about 30 per cent of the daily protein requirement (Singh, 2011). Chickpea is an excellent source of the essential nutrients, protein, minerals (calcium, potassium, phosphorus, magnesium, iron and zine), fiber, unsaturated fatty acids and β-carotene (Jukanti *et al.*, 2012). Upgrading of genetic potential of cultivars for higher economic yield requires development and execution of a very sound breeding programme. The breeding strategy for varietal development generally involves selection of potential genotypes from the existing germplasm, utilizing them in the hybridization programme and isolation of superior genotypes in the segregating generations. This could be done through knowledge of genetic variability, heritability and genetic advance under selection. The objective of this study is to evaluate F_2 generation for genetic variability, heritability, genetic advance and identification of superior/transgressive segregants in four desi chickpea crosses.

Material and Methods

Four F_2 populations *viz*., GJG 0315 x ICCV 96029(cross 1), GAG 0419 x JCP 245 (cross 2), GJG 0107 x GCP 105 (cross 3) and GJG 0719 x SAKI 9516 (cross 4) were grown in 3.0 m long block accommodating 24 rows with a spacing 45 cm between rows and 10 cm between plants within row. The size of F_2 population was 720 plants for each cross. Two rows each of the eight parents were grown next to F_2 populations in 3.0 m row length plots. Observations were recorded for number of branches per plant, number of pods per plant, seed yield per plant on 250 plants in each of the F_2 populations and 10 plants in each of the parents. Measurement of days to flowering and days to maturity were noted on early flowered 100 plants in each of the F_2 populations.

Data recorded on individual plant basis in each cross were used to calculate means, variances, standard error of mean and coefficient of variation by standard procedure (Snedecor and Cochran, 1967).

In F_2 generation, phenotypic variance, genotypic variance, experimental error variance, genotypic co-efficient of variation, phenotypic coefficient of variation and heritability in broad sense was estimated according to formula proposed by Mahmud and Kramer (1951).

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ISSN 0975-928X

Phenotypic variance σ_p^2 = $^2_{F2}$

Genotypic variance $\sigma_g^2 = \sigma^2_{F_2} - \sqrt{\sigma^2_{p_1} . \sigma^2_{p_2}}$

Experimental error variance $\sigma_e^2 = \sqrt{\sigma^2_{p_1} . \sigma^2_{p_2}}$

Genotypic coefficient of variation

$$GCV\ (\%) = \frac{\sqrt{\sigma_g^2}}{\bar{X}} \text{ X } 100$$

Phenotypic coefficient of variation

$$PCV\ (\%) = \frac{\sqrt{\sigma_p^2}}{\bar{X}} \text{ X } 100$$

$$\text{Heritability } (h^2\%) = \frac{\sigma^2_{F_2} - \sqrt{\sigma^2_{p_1} . \sigma^2_{p_2}}}{\sigma^2_{F_2}} \times 100$$

Where, $\sigma^2_{F_2}$ $\sigma^2_{p_1}$ and $\sigma^2_{p_2}$ indicated observed variance of F_2 generation, first parent and second parent, respectively.

Transgressive segregation

The limiting value of standard variates corresponding to range of parental means at 5% probability level was calculated so that the segregants beyond this limiting value should be transgresants. Transgressive segregants showing significant deviation only in the desirable direction were considered for drawing inferences about transgression. The limiting normal deviation (ND) value calculated as under.

$$\text{ND value} = \frac{\text{Threshold value} - \overline{F_2}}{\sigma_{F_2}}$$

$$\text{Threshold value} = P(+) + 1.96\ \sigma_{P(+)}$$

Where, P(+), $\sigma_{P(+)}$, σ_{F_2} and $\overline{F_2}$ indicated mean of increasing parent, standard deviation of increasing parent, standard deviation of F_2 and Mean of F_2 generation, respectively.

Results and Discussion

Variability parameters, heritability and expected genetic advance estimated for days to flowering and days to maturity as well as number of branches per plant, number of pods per plant and seed yield per plant in F_2 generation of four desi chickpea crosses are presented in Table 1 and 2, respectively along with mean values of parents.

Among all the F_2s, GJG 0315 x ICCV 96029 recorded minimum number of days to flowering and days to maturity, while remaining three crosses were found late by 6 to 8 days in flowering. Maximum phenotypic range of variation was recorded in GJG 0315 x ICCV 96029 as depicted by coefficient of range, followed by GAG 0419 x JCP 245 and GJG 0719 x SAKI 9516. The parent GJG 0107 had taken minimum number of days to flowering and maturity followed by ICCV 96029. There was desirable shift towards early flowering and maturity from parents to F_2 population in GJG 0315 x ICCV 96029 and GJG 0719 x SAKI 9516. Genotypic variance, phenotypic variance, GCV and PCV were observed maximum in GJG 0315 x ICCV 96029 followed by GAG 0419 x JCP 245 and GJG 0719 x SAKI 9516. On the other hand, least variation (GCV and PCV) were recorded in GJG 0107 x GCP 105 for both traits. High heritability coupled with high genetic advance expressed per cent of mean was noticed in GJG 0315 x ICCV 96029 and GJG 0719 x SAKI 9516 for days to flowering. Heritability values were found moderate with low genetic advance in case of all the F_2 populations for days to maturity. Vekariya (2006) also reported the low value of heritability and genetic advance in segregating materials of chickpea crosses for earliness.

Results indicated that F_2 of GJG 0315 x ICCV 96029 recorded highest number of branches per plant followed by GJG 0719 x SAKI 9516. Maximum phenotypic range of variation was recorded in GJG 0315 x ICCV 96029 and GJG 0107 x GCP 105 (coefficient of range 100 %) followed by GAG 0419 x JCP 245. The parent GCP 105 recorded maximum number of branches per plant followed by GJG 0315. While comparing mean values of parents with F_2 populations, there was desirable shift towards higher number of branches per plant in GJG 0315 x ICCV 96029, GAG 0419 x JCP 245 and GJG 0719 x SAKI 9516. Genotypic variance, phenotypic variance as well as its coefficient of variation i.e. GCV and PCV were observed maximum in GJG 0107 x GCP 105 followed by GJG 0315 x ICCV 96029. High heritability (61.833 %) coupled with medium genetic advance as per cent of mean (24.517) was observed in F_2 of GJG 0315 x ICCV 96029 for number of branches per plant. In remaining F_2s, heritability was high, but genetic advance found to be low. Kumar *et al.* (2003) and Vekariya (2006) also reported same results in segregating populations.

The highest number of pods per plant was recorded in GAG 0419 x JCP 245 (74.07) followed by GJG 0719 x SAKI 9516 (48.94) in F_2 populations. Likewise, the highest phenotypic range of variation was also observed in GAG 0419 x JCP 245 (coefficient of range 98.347 %) followed by GJG 0315 x ICCV 96029 and GJG 0719 x SAKI 9516. Maximum number of pods per plant was found in parent JCP 245 followed by GCP 105, but parent GJG 0107 had minimum number of pods per plant (24.50). There was desirable shift towards higher number of pods per plant from better parent to F_2 population in GJG 0719 x SAKI 9516 only. Out of the four F_2 populations, maximum genotypic variance and phenotypic variance were noticed in F_2 of GAG 0419 x JCP 245 followed by GJG 0107 x GCP 105. Phenotypic and genotypic coefficient of variation were found maximum in GJG 0107 x GCP 105 followed by GJG 0315 x ICCV 96029. High heritability with high to medium genetic advance as per cent of mean were found in GJG 0315 x ICCV 96029, GJG 0107 x GCP 105 and GJG 0719 x SAKI 9516. These results are akin with the findings of Kumar *et al.* (2003) and Vekariya (2006).

Among the F_2 populations of four crosses, maximum seed yield per plant was recorded in cross 2 (15.50 g) followed by cross 4 (13.49 g) and cross 3 (13.23 g), while cross 1 had minimum seed yield per plant (9.39 g). All the four crosses recorded high phenotypic range with coefficient of range varied from 99.498 % in GJG 0315 x ICCV 96029 to 98.872 % in GJG 0719 x SAKI 9516. Maximum seed yield per plant was found in parent GCP 105 (18.54 g) followed by JCP 245 (14.02 g), but parent ICCV 96029 had minimum seed yield per plant (5.30 g). There was desirable shift towards high seed yield per plant from better parent to F_2 population in GAG 0419 x JCP 245 and GJG 0719 x SAKI 9516. Genotypic variance and phenotypic variance were observed to be maximum in GAG 0419 x JCP 245 followed by GJG 0719 x SAKI 9516. On the other hand, phenotypic and genotypic coefficient of variation were recorded maximum in GJG 0315 x ICCV 96029followed by GJG 0719 x SAKI 9516. All the four F_2 populations showed high heritability estimates for seed yield per plant. The highest was registered by cross 1 (93.893 %), followed by cross 4 (82.068 %), cross 2 (76.020 %) and cross 3 (70.697 %). Genetic advance expressed in per cent of mean was found of high magnitude in cross 3 (73.158 %) and cross 4 (69.366 %). It was moderate and low in GJG 0315 x ICCV 96029 and GAG 0419 x JCP 245, respectively. It indicated that gain achieved in all the crosses except GAG 0419 x JCP 245. Vekariya (2006) and Neelu Kumari *et al.* (2013) also reported high heritability with high genetic advance as per cent of mean for seed yield per plant in chickpea.

In the present study, high mean performance, wider range of variation as well as genotypic and phenotypic coefficient of variation displayed relatively higher amount of genetic variability for number of branches per plant, number of pods per plant and seed yield per plant in all the four F_2 crosses, while comparatively less variability were found for days to flowering and days to maturity. The extent to which genetic segregation is expected in later generation of a cross is largely a reflection of the heritability of the characters in question (Mahmud and Kramer, 1951). The heritability was calculated by utilizing the variability among spaced F_2 plants in relation to the variability among spaced plants of the non-segregating parents. High heritability coupled with moderate to high expected genetic advance as per cent of mean was observed for number of branches per plant, number of pods per plant and seed yield per plant for GJG 0315 x ICCV 96029, GJG 0107 x GCP 105 and GJG 0719 x SAKI 9516, which indicated the predominant role of additive gene action in the expression of these three traits. These results are in accordance with those of Kumar *et al.* (2003), Vekariya (2006) and Neelu Kumari *et al.* (2013).

There was sufficient diversity among the parents for seed yield and its contributing characters, hence good amount of transgression might be observed. Cox and Frey (1985) also observed that the frequency of transgression was positively correlated to genetic divergence of the parental lines. The transgressive segregation observed for various characters in F_2 generation of each of the cross GJG 0315 x ICCV 96029 (Cross 1), GAG 0419 x JCP 245 (Cross 2), GJG 0107 x GCP 105 (Cross 3) and GJG 0719 x SAKI 9516 (Cross 4) is given in Table 3.

High percentage of transgressive segregants were observed for number of branches per plant (58.25 and 41.25 %) followed by days to flowering (37.00 and 33.00 %) and days to maturity (34.00 and 32.00 %) in GJG 0315 x ICCV 96029 and GJG 0107 x GCP 105, respectively. Good amount of transgression percentage was observed for days to flowering and days to maturity followed by number of branches per plant in GAG 0419 x JCP 245 and GJG 0719 x SAKI 9516. On the other hand, number of pods per plant and seed yield per plant had low transgressive segregants as

compared to these three characters in all the four crosses. Singh *et al.* (1996) and Ajay *et al.* (2014) in different pulse crops also reported variable transgressive segregation for number of branches per plant, number of pods per plant and seed yield per plant. A track on these transgressive segregants should be maintained and forwarded to further generations till they reach nearly homozygous condition. Most promising one can be used in further breeding programme.

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Electronic Journal of Plant Breeding, 9 (1) : 18 - 24 (Mar 2018) DOI: 10.5958/0975-928X.2018.00003.0
ISSN 0975-928X

Table 1. Variability parameters for days to flowering and days to maturity in F_2 generation of four crosses in chickpea

Parameters	Days to flowering				Days to maturity			
	GJG 0315 x ICCV 96029 (Cross 1)	GAG 0419 x JCP 245 (Cross 2)	GJG 0107 x GCP 105 (Cross 3)	GJG 0719 x SAKI 9516 (Cross 4)	GJG 0315 x ICCV 96029 (Cross 1)	GAG 0419 x JCP 245 (Cross 2)	GJG 0107 x GCP 105 (Cross 3)	GJG 0719 x SAKI 9516 (Cross 4)
Range	22.00 - 42.00	32.00 - 46.00	31.00 - 42.00	32.00 - 46.00	82.00 - 104.00	91.00 - 105.00	90.00 - 103.00	92.00 - 106.00
F_2 Mean ± S. E.	30.16 ± 0.14	38.46 ± 0.14	36.18 ± 0.98	38.64 ± 0.96	90.35 ± 0.16	98.44 ± 0.15	96.48 ± 0.27	99.24 ± 0.22
Coefficient of Range	31.25	17.95	15.07	17.95	11.83	7.14	6.74	7.07
σ_p^2	14.88	8.87	6.48	7.20	17.24	9.61	7.17	7.88
σ_g^2	9.96	3.73	1.07	5.10	10.72	4.07	2.10	2.46
σ_e^2	4.92	5.14	5.41	2.10	6.52	5.54	5.07	5.41
PCV (%)	12.79	7.74	7.04	6.95	4.60	3.15	2.78	2.83
GCV (%)	10.46	5.02	2.86	5.84	3.62	2.05	1.50	1.58
h^2 (%)	66.95	42.09	16.52	70.82	62.16	42.35	29.24	31.26
GA	2.25	0.15	3.17	3.09	2.42	0.16	3.33	3.23
GA (% mean)	7.45	0.40	8.75	7.99	2.68	0.16	3.45	3.25
P_1 Mean ± S. E.	52.00 ± 0.70	46.10 ± 0.43	37.90 ± 0.88	43.60 ± 0.62	112.40 ± 0.87	103.70 ± 0.63	98.80 ± 0.63	106.20 ± 1.00
P_2 Mean ± S. E.	39.50 ± 0.70	44.40 ± 1.19	53.40 ± 0.62	52.40 ± 0.34	100.40 ± 0.75	105.10 ± 0.88	112.50 ± 0.81	113.50 ± 0.54

The P_1 and P_2 are first and second parent, respectively in all the four crosses

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ISSN 0975-928X

Table 2. Variability parameters for number of branches per plant, number of pods per plant and seed yield per plant in F_2 generation of four crosses in chickpea

Parameters	Number of branches per plant				Number of pods per plant				Seed yield per plant (g)			
	GJG 0315 x ICCV 96029 (Cross 1)	GAG 0419 x JCP 245 (Cross 2)	GJG 0107 x GCP 105 (Cross 3)	GJG 0719 x SAKI 9516 (Cross 4)	GJG 0315 x ICCV 96029 (Cross 1)	GAG 0419 x JCP 245 (Cross 2)	GJG 0107 x GCP 105 (Cross 3)	GJG 0719 x SAKI 9516 (Cross 4)	GJG 0315 x ICCV 96029 (Cross 1)	GAG 0419 x JCP 245 (Cross 2)	GJG 0107 x GCP 105 (Cross 3)	GJG 0719 x SAKI 9516 (Cross 4)
Range	0.00 - 7.00	1.00 - 5.00	0.00 - 6.00	1.00 - 4.00	2.00 - 159.00	2.00 - 240.00	4.00 - 181.00	3.00 - 206.00	0.10 - 9.72	0.64 - 54.15	0.45 - 54.16	0.40 - 70.50
F_2 Mean ± S. E.	2.93 ± 0.04	2.45 ± 0.03	2.43 ± 0.15	2.48 ± 0.09	46.02 ± 0.53	74.07 ± 1.34	46.96 ± 0.14	48.94 ± 0.15	9.39 ± 0.10	15.50 ± 0.30	13.23 ± 0.03	13.49 ± 0.02
Coefficient of Range	100.00	66.67	100.00	60.00	97.52	98.35	95.68	97.13	99.50	97.66	98.35	98.87
σ_p^2	0.85	0.57	0.98	0.46	717.01	1426.46	802.10	686.42	37.99	90.84	60.51	66.19
σ_g^2	0.53	0.32	0.68	0.33	646.05	979.92	563.93	456.29	35.67	69.05	42.78	54.32
σ_e^2	0.33	0.25	0.30	0.13	70.96	446.53	238.17	230.14	2.32	21.78	17.73	11.87
PCV (%)	31.57	30.94	40.70	27.37	58.19	50.99	60.31	53.53	65.62	61.50	58.80	60.31
GCV (%)	24.82	23.18	34.01	23.06	55.24	42.26	50.57	43.64	63.59	53.62	49.44	54.64
h^2 (%)	61.83	56.10	69.82	70.97	90.10	68.70	70.31	66.47	93.89	76.02	70.70	82.07
GA	0.72	0.04	1.21	0.34	9.71	1.95	35.05	11.65	3.59	0.49	9.68	9.36
GA (% mean)	24.52	1.60	50.02	13.60	21.10	2.63	74.63	23.80	38.23	3.17	73.16	69.37
P_1 Mean ± S. E.	2.30 ± 0.15	1.40 ± 0.16	1.20 ± 0.13	1.20 ± 0.13	50.50 ± 2.02	44.70 ± 5.96	24.50 ± 3.82	28.00 ± 4.09	11.32 ± 0.58	10.89 ± 1.55	7.85 ± 1.10	8.82 ± 1.17
P_2 Mean ± S. E.	1.30 ± 0.21	1.70 ± 0.15	2.60 ± 0.22	1.90 ± 0.10	32.10 ± 3.52	75.30 ± 7.49	59.70 ± 6.24	41.40 ± 5.63	5.30 ± 0.40	14.02 ± 1.41	18.54 ± 1.61	8.07 ± 1.02

The P_1 and P_2 are first and second parent, respectively in all the four crosses

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ISSN 0975-928X

Table 3. Transgressive segregants for days to flowering, days to maturity, number of branches per plant, number of pods per plant and seed yield per plant (g) in four crosses of chickpea

Progeny	ND value	T. S. (%)	Threshold value	ND value	T. S. (%)	Threshold value	ND value	T. S. (%)	Threshold value	ND value	T. S. (%)	Threshold value
	Cross 1 (GJG 0315 x ICCV 96029)			Cross 2 (GAG 0419 x JCP 245)			Cross 3 (GJG 0107 x GCP 105)			Cross 4 (GJG 0719 x SAKI 9516)		
Days to flowering												
P_1	-	-	-	-	-	-	-	-	-	-	-	-
P_2	-	-	-	-	-	-	-	-	-	-	-	-
F_2	4.58	37.00	43.86	5.50	48.00	51.75	6.21	33.00	43.32	3.60	21.00	47.43
Days to maturity												
P_1	-	-	-	-	-	-	-	-	-	-	-	-
P_2	-	-	-	-	-	-	-	-	-	-	-	-
F_2	4.83	34.00	105.04	5.01	57.00	110.52	4.01	32.00	102.70	4.26	25.00	112.38
Number of branches per plant												
P_1	-	-	-	-	-	-	-	-	-	-	-	-
P_2	-	-	-	-	-	-	-	-	-	-	-	-
F_2	0.47	58.25	3.25	0.54	32.00	2.65	1.64	41.25	3.97	0.16	21.00	2.52
Number of pods per plant												
P_1	-	-	-	-	-	-	-	-	-	-	-	-
P_2	-	-	-	-	-	-	-	-	-	-	-	-
F_2	0.96	12.75	63.01	1.67	15.75	121.73	2.38	35.75	98.39	1.49	11.25	76.29
Seed yield per plant (g)												
P_1	-	-	-	-	-	-	-	-	-	-	-	-
P_2	-	-	-	-	-	-	-	-	-	-	-	-
F_2	1.34	11.25	14.92	1.21	3.25	22.73	2.57	13.25	28.52	0.68	9.75	16.07