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Research Note

Gene effects for seed yield and its components in chickpea (*Cicer arietinum* L.)

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Abstract

An investigation was carried out to detect the gene effects for seed yield and its components by using Generation mean analysis, involving five generations (P_1, P_2, F_1, F_2 and F_3) in four crosses of chickpea. The analysis of variance between families (crosses) revealed that the mean squares due to crosses were significant for all the characters studied. The analysis of variance among progenies within each family indicated significant differences among five generation means for all the characters in all the crosses except for reproductive phase duration in crosses GAG 0419 x JCP 245 and GJG 0727 x SAKI 9516 and harvest index in cross GJG 0727 x SAKI 9516. Dominance type of gene effect along with dominance x dominance type of epistasis was of immense importance for seed yield per plant in cross GAG 0419 x JCP 245. While additive gene effect as well as additive x additive type of interaction were observed in cross GJG 0719 x SAKI 9516 for the traits reproductive phase, number of pods per plant and seed yield per plant. But only additive type of main effect controlled the expression of seed yield in crosses GJG 0727 x SAKI 9516 and Dahod Yellow x IPC 2009-52. It was noticed that both additive and non-additive type of gene effects played vital role in the inheritance of days to flowering, days to maturity, reproductive phase duration, 100-seed weight and harvest index in majority of crosses. Additive gene effects can be exploited by selection method like pedigree method of selection. While non-additive may be exploited by using cyclic method of breeding. Reciprocal recurrent selection can take care of additive as well as non-additive type of gene effects.

Key words
Chickpea, Generation mean analysis, gene action, yield

Chickpea is the third most important pulse crop, after dry bean and peas, produced in the world. It accounts for 20% of the world pulses production. Major producers of chickpea include India, Pakistan and Mexico. India accounts about 9.93 million hectares area with total production and productivity of 9.53 million tons and 929 kg/ha, respectively. Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Karnataka are the major chickpea producing states. The area, production and productivity of chickpea crop in Gujarat, accounts for about 0.25 million hectares, 0.31 million tons and 1251 kg/ha, respectively (Singh, 2014).

The information on the nature of gene action would be helpful in predicting the effectiveness of selection for different traits in a population. A distinct knowledge of the type of gene action, its magnitude and composition of genetic variance are of fundamental importance to a plant breeder, which help in formulating an effective breeding programme. Information on nature and relative magnitude of genetic component of variation (additive and dominance) have been generated by diallel analysis or line x tester analysis in chickpea which unlike generation mean analysis does not provide information on non-allelic gene actions operating in the inheritance. It is therefore, important to estimate the components of epistasis along with the additive and dominance components. Such information is limited in chickpea especially under irrigated conditions. Estimation of gene effects responsible for seed yield and its components is very useful in selecting appropriate breeding methodology as per the preponderance of genetic components especially for above said sowing conditions.

Generation mean analysis of four crosses *viz*., GAG 0419 X JCP 245 (C_1), GJG 0719 X SAKI 9516 (C_2), GJG 0727 X SAKI 9516 (C_3) and Dahod Yellow X IPC 2009-52 (C_4) involving seven genotypes of chickpea was carried out during *Rabi* 2013-14. Five generation *viz*., P_1, P_2, F_1, F_2 and F_3 in each of these crosses were separately grown in compact family block design with three replications. Experiment was conducted under irrigated condition. Observations on days to flowering, days to maturity, reproductive phase duration, plant height (cm), number of branches per plant, biological yield per plant (g), 100 seed weight (g), seed yield per plant (g) and harvest index (%) were recorded in five randomly selected plants from P_1, P_2, F_1s and twenty plants of F_2 and F_3 generation from each plot. Five parameter model using P_1, P_2, F_1, F_2 and F_3 was used to calculate various gene effects i.e. additive, dominance and their interactions (additive x additive and dominance x dominance) as described by Hayman and Mather (1955). The scaling tests C and D were computed for all the ten characters in four crosses to test the adequacy of additive dominance model as described by Mather (1949). While, joint scaling test of Cavalli (1952) was also performed.

The analysis of variance between families (crosses) revealed that the mean squares due to crosses were significant for all the characters under study (Table 1). The analysis of variance among progenies within each family indicated significant differences among five generation means for all the characters studied in all the crosses except for reproductive phase duration in GAG 0419 x JCP 245 and GJG 0727 x SAKI 9516 and harvest index in GJG 0727 x SAKI 9516. The results thus suggested the presence of wide differences among the crosses as well as progenies within family. These characters were therefore, dropped from further analysis.

On the basis of individual scaling test, it was observed that both or any one the individual scaling tests C and D were significant for all the four crosses for days to flowering and days to maturity. While D scaling test was significant for crosses GJG 0719 x SAKI 9516 and Dahod Yellow x IPC 2009-52 for reproductive phase duration. In case of plant height, either C or D or both C and D scaling tests were significant for all the crosses except GJG 0719 x SAKI 9516. Adequacy of five parameter model proved by significant D scaling test for number of branches per plant in GJG 0727 x SAKI 9516. Again scaling tests were significant for all the crosses except Dahod Yellow x IPC 2009-52 in case of number of pods per plant. Significance of C scaling test indicated the suitability of five parameter model for biological yield per plant in GAG 0419 x JCP 245 and GJG 0727 x SAKI 9516. Both C and D scaling tests were found significant for cross GAG 0419 x JCP 245 as well as GJG 0719 x SAKI 9516 for 100-seed weight. Significance of either C or D test pin pointed the adequacy of five parameter model for all the crosses except Dahod Yellow x IPC 2009-52 in case of seed yield per plant. In the cross GAG 0419 x JCP 245, C scaling test was significant for harvest index. The application of joint scaling test expressed significant chi-square values for these traits further confirmed involvement of digenic interaction parameters in the inheritance of all these characters. When the simple additive-dominance model failed to explain the variation among generation means, a five parameter model involving two digenic interaction parameters as proposed by Hayman (1958) was applied.

The gene effects from three parameter model revealed that the mean (m) effect was found significant for all the characters. Additive and dominance effect were found highly significant for plant height in cross GJG 0719 x SAKI 9516. Additive gene effect and dominance gene effect played significant role in the inheritance of number of branches per plant in cross Dahod Yellow x IPC 2009-52 and GJG 0719 x SAKI 9516, respectively. While additive as well as dominance type of gene effects played vital role in the inheritance of number of pods per plant in cross Dahod Yellow x IPC 2009-52. Both the type of gene effect were found significant for biological yield per plant in crosses GJG 0719 x SAKI 9516 and Dahod Yellow x IPC 2009-52. Equal importance of additive and dominance gene effects was noticed in the inheritance of 100-seed weight in cross GJG 0727 x SAKI 9516. But only dominance gene effect played vital role in cross Dahod Yellow x IPC 2009-52 for 100-seed weight. Additive gene effect was significant in cross Dahod Yellow x IPC 2009-52 for the important trait seed yield per plant. However both additive and dominance type of gene effect found responsible for harvest index in crosses namely GJG 0719 x SAKI 9516 and Dahod Yellow x IPC 2009-52.

The results obtained from the five parameter model (Table 2) revealed that in addition to the significance of m, (d) and (h) effects, both the digenic interactions (i) and (l) were significant for days to maturity, plant height and harvest index in the cross GAG 0419 x JCP 245; reproductive phase duration in the cross GJG 0719 x SAKI 9516, plant height in the crosses *viz.*, GJG 0727 x SAKI 9516 and Dahod Yellow x IPC 2009-52. Similar results were reported by Pandey and Tiwari (1989). The goodness of fit for five parameter model could not be tested in the present study owing to no degrees of freedom left for testing chi-square estimates for various characters.

In case of first cross i.e. GAG 0419 x JCP 245 all the components of gene effects *viz.*, additive (d) dominance (h), additive x additive (i) and dominance x dominance (l) were significant for days to maturity, plant height and harvest index. Magnitude of dominance type of main effect and dominance x dominance type of epistasis was higher in the inheritance of above said traits. All the type of gene effects were found significant for reproductive phase duration and number of pods per plant in cross GJG 0719 x SAKI 9516. Importance of additive and dominance x dominance type of epistasis was observed for days to flowering and 100-seed weight. Only additive and dominance type of main effects played vital role in the inheritance of developmental trait days to maturity. While only additive component which includes additive and additive x additive type of digenic interaction was of immense importance in the expression of seed yield per plant. Most important yield contributing trait number of pods per plant had significant role of two types of main effects (additive and dominance) with additive x additive type of epistasis. In cross GJG 0727 x SAKI 9516, all type of components of gene effects played important role in the inheritance of plant height. While additive and additive x additive type of gene effects found responsible for days to flowering and number of pods per plant. Only dominance type of main effects was of great importance for days to maturity. Contrary to this, only additive type was of vital significance in biological yield per plant and seed yield per plant. Both type of digenic interactions *viz.,* additive x additive and dominance x dominance were significant for number of branches per plant.

While examining the results on gene effects, the role of both type of main effects and interaction effects was found in plant height in cross Dahod Yellow x IPC 2009-52. In case of days to flowering, additive components looked vital in the expression of this trait as additive, additive x additive and dominance x dominance gene effects were significant. But reproductive phase duration character had significant additive and dominance gene effects along with dominance x dominance type of epistasis. In a nut shell, both additive and dominance type of gene effects played an important role in the inheritance of traits under study. The dominance components, in general, was more than the additive component in majority of cases, presence of fixable interaction i.e. additive x additive in several traits suggested the scope of improvement through selection. In chickpea, where lodging is not a problem as in rainfed areas, increase in height may result in higher seed yield provided podding starts from the lower node. As reported earlier during cross wise discussion, additive, dominance and epistatic gene effects controlled this trait in chickpea. Singh and Ramanujam (1981) and Pandey and Tiwari (1989) also reported additive and non-additive gene effects in the inheritance of this character.

In majority of crosses, both additive and additive x additive components were important in the expression of pods per plant. Malhotra *et al.* (1983) and Bhardwaj and Sandhu (2007) also reported the similar results. This suggested the importance of straight selection from early segregating generation for the improvement of this trait. Duplicate type of epistasis was prevalent in majority of crosses.

Both additive and non-additive type of gene effects were important in the expression of days to flowering, days to maturity, reproductive phase duration, 100-seed weight and harvest index in majority of crosses. This suggested that selection for these characters would be more fruitful if the selection is delayed till dominance component is reduced due to selfing. Complementary type of epistatis played vital role in all above traits. These results corroborated earlier findings of Karami (2011), Kumar *et al.* (2012) and Kumhar *et al.* (2013). Additive type of gene effects found of immense importance in the control of biological yield per plant with duplicate type of epistatic interaction. Direct selection is recommended for the improvement of this trait.

For seed yield per plant, dominance type of main effect and dominance x dominance type of interaction effect were played vital role in cross GAG 0419 x JCP 245. While additive gene effect with additive x additive epistasis interaction was of greater importance in the inheritance of this trait in cross GJG 0719 x SAKI 9516. Only additive type of gene effect controlled the inheritance in cross GJG 0727 x SAKI 9516. For cross Dahod Yellow x IPC 2009-52, three parameter model found adequate with importance of additive gene effect. In all crosses, complementary type of epistasis was observed for this trait. Singh and Ramanujam (1981), Jaiswal and Singh (1989), Singh *et al.* (1993) and Kumhar *et al.* (2013) explained the role of additive and non-additive type of gene action in the inheritance of seed yield per plant. While Malhotra and Singh (1989) showed the role of additive gene action.

The findings of this study demonstrated that dominance gene effect and dominance x dominance type of epistasis played vital role for seed yield per plant in cross GAG 0419 x JCP 245. In remaining three crosses (GJG 0719 x SAKI 9516, GJG 0727 x SAKI 9516 and Dahod Yellow x IPC 2009-52), fixable components of gene effect (additive/ additive x additive) were observed important in the inheritance of seed yield per plant. In case of yield contributing characters number of pods per plant, biological yield per plant, 100-seed weight and harvest index, the role of both components i.e. additive and non-additive was prevalent in majority cases. Importance of epistasis was also observed in many cases along with main effect. When additive as well non-additive effects are involved, reciprocal recurrent selection would be an ideal method. Under a situation like duplicate type of gene action, breeding procedures involving multiple crosses, biparental crosses may be restored to get transgressive segregants. The additive gene effects may be exploited by fixing these traits through selection method of plant breeding, while non-additive gene effects may be exploited by using cyclic method of breeding involving selection and hybridization of desirable segregants from concerned crosses.

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Table 1. Analysis of variance (mean square) between crosses and between generations within cross of five generations for different characters in chickpea

Source of variation	d. f.	Days to flowering	Days to maturity	Reproductive phase duration	Plant height (cm)	Number of branches per plant	Number of pods per plant	Biological yield per plant (gm)	100-seed weight (gm)	Seed yield per plant (gm)	Harvest index (%)
Analysis of variance between crosses											
Replication	2	0.04	11.54	10.48	0.57	0.004	11.00	4.17	0.64	0.62	4.40
Crosses	3	3.26**	0.62**	2.76**	0.01**	0.20**	38.16**	3.02**	3.53**	9.36**	66.53**
Error	6	0.21	6.04	6.80	0.35	0.009	8.50	4.05	1.42	1.03	4.47
χ^2 test		S	S	S	NS	NS	S	S	NS	S	NS
Analysis of variance between generations within cross											
GAG 0419 x JCP 245 (Cross 1)											
Replication	2	0.02	2.15	1.94	3.59	0.004	5.09*	53.07*	1.45	17.39*	61.40
Generations	4	18.02**	15.70**	2.65	10.89**	0.067**	99.09**	92.50**	20.08**	34.21**	197.10*
Error	8	0.17	1.15	0.88	1.34	0.006	0.83	11.81	1.09	2.47	33.79
GJG 0719 x SAKI 9516 (Cross 2)											
Replication	2	1.03	55.94**	67.66**	1.65	0.04	115.22	8.45	5.51	0.99	12.26
Generations	4	25.81**	67.73**	45.96**	5.22*	0.17**	338.76*	56.00*	33.08*	14.49*	57.43*
Error	8	0.44	4.51	3.79	0.75	0.01	64.29	8.78	7.11	2.40	9.18
GJG 0727 x SAKI 9516 (Cross 3)											
Replication	2	0.55*	10.99	20.26	0.39	0.0012	52.64	6.21	5.16	0.03	8.57
Generations	4	24.31**	59.52*	8.12	12.72**	0.11**	212.28*	46.56**	54.79**	5.68*	40.75
Error	8	0.08	14.70	16.48	0.68	0.014	48.84	2.73	6.59	1.11	19.26
Dahod Yellow x IPC 2009-52 (Cross 4)											
Replication	2	1.79	79.27**	64.60**	2.52	0.02	9.72	14.05**	12.47	0.18	6.90
Generations	4	54.73**	39.32**	41.22*	5.44*	0.134*	250.03**	16.30**	52.17**	1.17*	18.55*
Error	8	1.15	2.61	5.96	1.01	0.032	5.57	0.57	6.57	0.18	4.77

* and ** Significant at 5 and 1 per cent levels, respectively
Chi-square for Bartlett's test of homogeneity of error variance, S = Significant, NS = Non-significant

Table 2. Genetic component of generation means in four chickpea crosses for seed yield and its components

Cross	Genetic Components					Types of Interaction
	m	d	h	i	l	
Days to flowering						
GJG 0419 x JCP 245	48.55** ± 0.65	-1.53** ± 0.15	-0.68 ± 1.97	-3.81* ± 1.94	-16.04** ± 06.05	C
GJG 0719 x SAKI 9516	50.65** ± 0.55	2.26** ± 0.28	-3.19 ± 2.25	2.21 ± 2.05	-13.82* ± 06.20	C
GJG 0727 x SAKI 9516	43.67** ± 0.56	-1.10* ± 0.44	-6.53** ± 2.09	-9.17** ± 1.97	-2.40 ± 05.93	C
D. Yellow x IPC 2009-52	50.93** ± 0.54	-5.13** ± 0.26	1.51 ± 2.17	-9.16** ± 1.97	-21.16** ± 05.91	D
Days to maturity						
GJG 0419 x JCP 245	90.30** ± 0.28	-0.83** ± 0.25	-2.38** ±0.81	-5.81** ± 0.88	-5.24* ± 02.56	C
GJG 0719 x SAKI 9516	92.32** ± 1.18	-1.97* ± 0.94	-10.07** ±3.62	0.22 ± 3.84	-16.51 ± 11.23	C
GJG 0727 x SAKI 9516	91.40** ± 1.01	0.13 ± 0.90	-13.78** ± 3.47	-15.44 ± 3.65	10.76 ± 10.22	D
D. Yellow x IPC 2009-52	90.93** ± 0.97	-0.73 ± 0.93	-5.29 ±3.43	-10.42 ± 9.98	-0.62 ± 03.60	C
Reproductive phase duration						
GJG 0419 x JCP 245	-	-	-	-	-	-
GJG 0719 x SAKI 9516	41.67** ± 0.64	-4.23** ± 0.86	-6.89** ± 2.09	-18.72** ± 2.53	14.04* ± 07.01	D
GJG 0727 x SAKI 9516	-	-	-	-	-	-
D. Yellow x IPC 2009-52	40.00** ± 0.56	4.40** ± 0.88	-6.76** ± 2.23	-1.29 ± 2.47	20.71** ± 06.10	D
Plant height						
GJG 0419 x JCP 245	34.83** ± 0.30	-1.37** ± 0.38	-6.64** ± 0.91	-10.87** ± 1.24	13.15** ± 03.17	D
GJG 0719 x SAKI 9516	33.83** ± 0.25	-1.45** ± 0.35	2.10** ± 0.57	-	-	-
GJG 0727 x SAKI 9516	35.43** ± 0.21	-1.36** ± 0.24	10.91** ± 0.79	6.48** ± 0.92	-17.68** ± 02.53	D
D. Yellow x IPC 2009-52	36.11** ± 0.36	1.20** ± 0.40	6.72** ± 1.29	4.65** ± 1.44	-20.04** ± 03.84	D
No. of Branches/ plant						
GJG 0419 x JCP 245	3.56** ± 0.09	0.04 ± 0.10	0.31 ± 0.19	-	-	-
GJG 0719 x SAKI 9516	3.32** ± 0.10	0.16 ± 0.13	0.46* ± 0.22	-	-	-
GJG 0727 x SAKI 9516	2.90** ± 0.13	0.03 ± 0.12	-0.64 ± 0.46	-0.94* ± 0.47	3.02* ± 01.31	D
D. Yellow x IPC 2009-52	3.27** ± 0.10	-0.26* ± 0.11	-0.19 ± 0.24	-	-	-
No. of Pods/ plant						
GJG 0419 x JCP 245	42.26** ± 2.24	-4.96** ± 1.47	12.71 ± 7.49	-4.72 ± 7.37	13.78 ± 22.35	C
GJG 0719 x SAKI 9516	35.25** ± 1.80	13.83**± 2.80	15.47** ± 6.68	-16.62* ± 7.74	-1.82 ± 20.67	D
GJG 0727 x SAKI 9516	33.32** ± 1.81	-11.17** ± 3.17	-8.30 ± 7.92	-32.80** ± 9.06	47.87* ± 22.29	D
D. Yellow x IPC 2009-52	38.56** ± 0.87	11.59**± 0.89	10.39** ± 2.77	-	-	-
Biological yield / plant						
GJG 0419 x JCP 245	24.46** ± 1.39	4.10** ± 1.34	8.51 ± 5.08	7.51 ± 5.34	27.74 ± 15.06	C
GJG 0719 x SAKI 9516	26.40** ± 0.46	-5.74** ± 0.49	-4.75** ± 1.85	-	-	-
GJG 0727 x SAKI 9516	22.38** ± 1.07	-2.30** ± 0.65	4.80 ± 3.03	-4.35 ± 3.21	25.73 ± 19.8	C
D. Yellow x IPC 2009-52	23.78** ± 0.55	1.74*± 0.66	4.31** ± 1.07	-	-	-
100 - seed weight						
GJG 0419 x JCP 245	17.37** ± 1.02	-2.35** ± 0.55	6.98** ± 2.68	0.77 ± 2.92	-0.49 ± 08.98	D
GJG 0719 x SAKI 9516	16.46** ± 0.79	2.57** ± 0.95	0.35 ± 2.87	-1.18 ± 3.14	28.88** ± 08.30	C
GJG 0727 x SAKI 9516	18.97** ± 0.87	4.61** ± 0.96	4.76* ± 2.26	-	-	-
D. Yellow x IPC 2009-52	22.58** ± 1.14	-1.46± 1.62	-9.68** ± 2.03	-	-	-
Seed yield / plant						
GJG 0419 x JCP 245	8.04** ± 0.62	0.15 ± 0.98	6.89** ± 2.35	1.98 ± 2.78	17.98* ± 07.02	C
GJG 0719 x SAKI 9516	6.65** ± 0.55	-2.74** ± 0.44	2.33 ± 1.73	-4.08* ± 1.75	4.11 ± 05.23	C
GJG 0727 x SAKI 9516	6.94** ± 0.51	-0.99** ± 0.35	2.67 ± 1.75	-0.28 ± 1.79	4.56 ± 05.17	C
D. Yellow x IPC 2009-52	6.49** ± 0.23	0.64* ± 0.28	-0.07 ± 0.49	-	-	-
Harvest index						
GJG 0419 x JCP 245	33.83** ± 0.50	-8.03** ± 1.01	11.50** ± 2.15	-8.49** ± 2.86	25.35** ± 6.93	C
GJG 0719 x SAKI 9516	27.29** ± 0.95	-3.59** ± 1.00	7.41** ± 1.74	-	-	-
GJG 0727 x SAKI 9516	-	-	-	-	-	-
D. Yellow x IPC 2009-52	30.36** ± 0.68	-1.45*± 0.73	-4.50* ± 2.01	-	-	-

* and ** significant at 5 and 1 per cent levels, respectively

(-) dropped from genetic analysis due to non-significant differences among generation means