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Genetics of pod yield and yield contributing characters in okra [*Abelmoschus esculentus* (L). Moench]

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SUMMARY

The nature and magnitude of gene action was analyzed by six generation mean for pod yield and yield contributing characters in six inter varietals crosses of okra. The results revealed that both additive and dominance gene effects were significant for majority of the traits in all the six crosses studied, however the magnitude of dominance gene effects was much higher than the additive effects in all the crosses for majority of the traits which indicated pre-dominant role of dominance gene effects in the inheritance of yield/plant and its related traits. Study indicated that dominance gene effects for pod yield and yield contributing characters were of prime importance. All the characters recorded significant additive and dominance gene effect but the magnitude of dominance gene effect was higher. Among the non-allelic interactions, additive x additive and dominance x dominance were found significant, the opposite sign of (h) and (l) indicated that both the characters are controlled by duplicate type of epistasis. So, further improvement could be expected through bi-parental mating or reciprocal recurrent selection.

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Key words : Dominance gene effects, Additive effects, Six generation mean, *Abelmoschus esculentus* (L). Moench, *Okra*

Okra [*Abelmoschus esculentus* (L). Moench] is one of the important vegetables grown for its immature non-fibrous edible pods in tropical and sub-tropical parts of the world. Study of nature and magnitude of gene effects governing the inheritance of quantitative characters is of prime importance in formulating breeding methods used for crop improvement programme. In self pollinated crops an approach based on generation mean analysis has particular suitability as in addition to additive and dominance gene effect, it also estimate the types of epistasis present. In present investigation, an attempt has been made to estimate gene effects operative for control of pod yield and yield contributing characters by using six generation means in six inter varietals crosses of okra.

MATERIALS AND METHODS

The experimental material in present investigation comprised of six inter varietal crosses of okra *viz.*, Parbhani Kranti x Pusa Sawani, Parbhani Kranti x GO_2, Arka Anamika x Pusa Sawani, Arka Anamika x VRO_5, Arka Abhay x HRB-55 and Arka Abhay x VRO_6, their respective parents, F_2's, BC_1 and BC_2 populations. The material was grown in compact family block design with three replications on Agriculture Experimental Station, Navsari Agricultural University, Paria, Ta. Pardi, Dist. Valsad during summer-2007. The parents and F_1's consisted of one line of 3.0 m, BC_1 and BC_2 consisted of two lines of 3.0m and F_2's consisted of four lines of 3.0 m in each replication. The distance between two rows was 45 cm and within plants 30 cm. Recommended agronomical practices were followed for okra.

Five random competitive plants in each treatment in P_1, P_2 and F_1, ten plants in BC_1 and BC_2 and 20 plants in F_2 generation were selected for recording the observation.

Simple scaling test A, B, C and D of Mather (1949) was used to detect presence of the epistasis. Six parameter model given by Hayman (1958) used to obtained estimate of m, d, h, i, j and l parameters.

RESULTS AND DISCUSSION

Before any model is fitted to estimate gene actions involved in yield and its components, scaling tests were performed as given by Mather (1949). The scaling tests

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Table 1 : Generation mean for pod yield and yield contributing characters per plant

Characters	Cross	Generation					
		P_1	P_2	F_1	F_2	BC_1	BC_2
Days to first fruit set	C_1	49.20	46.73	42.73	51.13	46.07	47.33
	C_2	48.47	47.93	45.13	50.90	46.80	47.70
	C_3	49.60	47.00	45.50	51.10	48.93	48.70
	C_4	49.47	51.13	47.47	53.47	49.07	50.20
	C_5	47.07	49.93	45.00	51.53	46.67	49.03
	C_6	46.93	48.53	45.13	50.63	46.47	48.00
Plant height (cm)	C_1	155.07	146.40	141.53	145.27	148.93	145.70
	C_2	151.40	154.20	160.93	144.97	155.30	153.90
	C_3	142.40	145.53	149.53	138.60	147.63	147.30
	C_4	144.20	108.80	146.77	136.83	145.47	121.83
	C_5	160.53	136.20	164.93	127.13	162.43	157.33
	C_6	168.60	127.13	156.60	116.83	158.90	145.40
Branches/ plant	C_1	4.13	3.40	4.73	3.50	4.40	4.10
	C_2	4.20	3.80	4.80	3.10	4.30	4.13
	C_3	4.07	3.47	4.80	3.10	4.40	3.70
	C_4	4.00	3.60	4.47	3.47	4.17	3.67
	C_5	4.13	4.00	4.80	3.83	4.30	4.10
	C_6	4.57	3.40	4.77	3.13	4.57	4.23
Pod length (cm)	C_1	9.46	11.39	14.39	10.91	11.04	11.66
	C_2	9.97	11.83	13.37	10.01	10.41	11.93
	C_3	12.84	11.28	10.51	11.86	11.94	10.77
	C_4	12.87	12.41	13.60	10.07	13.10	12.65
	C_5	11.98	11.11	14.71	10.24	12.10	11.70
	C_6	11.69	12.19	13.59	9.91	12.28	11.50
Pod girth (cm)	C_1	1.62	1.71	1.86	1.53	1.66	1.72
	C_2	1.64	1.59	1.77	1.56	1.65	1.60
	C_3	1.64	1.68	1.75	1.47	1.67	1.70
	C_4	1.65	1.73	1.57	1.51	1.59	1.62
	C_5	1.53	1.58	1.82	1.54	1.60	1.63
	C_6	1.57	1.64	1.74	1.44	1.62	1.67
Number of pods/plant	C_1	22.73	20.27	28.00	17.93	22.77	21.10
	C_2	22.13	21.93	26.93	19.02	22.77	22.13
	C_3	19.48	20.97	18.73	14.80	19.27	18.90
	C_4	19.67	17.00	22.73	16.17	19.93	19.57
	C_5	28.07	21.37	30.13	19.87	29.67	23.47
	C_6	27.67	23.67	28.07	20.75	27.73	26.47
Pod yield (g/ plant)	C_1	327.80	325.27	434.57	278.23	328.93	341.73
	C_2	320.43	292.53	376.30	281.10	326.93	327.07
	C_3	246.07	290.40	265.47	190.92	254.33	269.63
	C_4	278.07	303.73	356.42	218.60	295.30	313.67
	C_5	430.90	289.45	436.53	281.17	431.02	330.50
	C_6	403.20	360.73	412.93	275.03	412.30	407.93

C_1: Parbhani Kranti x Pusa Sawani C_2: Parbhani Kranti x GO_2, C_3: Arka Anamika x Pusa Sawani
C_4: Arka Anamika x VRO_5 C_5: Arka Abhay x HRB-55 C_6: Arka Abhay x VRO_6

A, B, C and D (Table 2) indicated presence of appreciable amount of epistasis in different characters, except in cross Parbhani Kranti x Pusa Sawani for days to first fruit set, plant height and branches/plant; in Parbhani Kranti x GO_2 for days to first fruit set, plant height and branches/plant; in cross Arka Anamika x Pusa Sawani for plant height, branches/plant, pod length, pods/plant and yield/plant; in cross Arka Anamika x VRO_5 for plant height, branches/

Table 2 : Estimate of scaling test for pod yield and yield contributing characters

Characters	Cross	Scaling test			
		A	B	C	D
Days to first fruit set	C_1	0.20	5.20**	23.13**	8.86**
	C_2	0.00	2.33**	16.93**	7.30**
	C_3	2.77**	4.90**	16.80**	4.57**
	C_4	1.20**	1.80**	18.33**	7.67**
	C_5	1.27**	3.13**	19.13**	7.37**
	C_6	0.87**	2.33**	16.80**	6.80**
Plant height (cm)	C_1	1.26	3.46*	-3.46	-4.11**
	C_2	-1.73	-7.33**	-47.60**	-19.27**
	C_3	3.33	-0.47	-32.60**	-17.73**
	C_4	-0.03	-11.90**	0.80	6.36**
	C_5	-0.60	13.53**	-118.06	-65.50**
	C_6	-7.40**	7.07*	-141.60**	-70.63**
Branches/ plant	C_1	-0.07	0.07	-3.00**	-1.50**
	C_2	-0.40*	-0.33	-5.20**	-2.23**
	C_3	-0.07	-0.87**	-4.73**	-1.90**
	C_4	-0.13	-0.70**	-2.67**	-0.90**
	C_5	-0.33	-0.60**	-2.40**	-0.73**
	C_6	-0.20	0.30	-4.97**	-2.53**
Pod length (cm)	C_1	-1.78**	-2.45**	-6.00**	-0.88**
	C_2	-2.52**	-1.34**	-8.50**	-2.31**
	C_3	0.52	-0.25	2.32**	1.02**
	C_4	-0.27	-0.71**	-12.20**	-5.62**
	C_5	-2.49**	-2.42**	-11.54**	-3.31**
	C_6	-0.71**	-2.77**	-11.42**	-3.97**
Pod girth (cm)	C_1	-0.17**	-0.13**	-0.93**	-0.31**
	C_2	-0.10**	-0.17**	-0.53**	-0.13**
	C_3	-0.04*	-0.03*	-0.92**	-0.42**
	C_4	-0.03**	-0.05*	-0.47**	-0.19**
	C_5	-0.16**	-0.14**	-0.62**	-0.16**
	C_6	-0.06**	-0.03*	-0.91**	-0.41**
Number of pods/plant	C_1	-5.20**	-6.07**	-27.26**	-8.00**
	C_2	-3.53**	-4.60**	-21.86**	-6.87**
	C_3	0.32	-1.90**	-18.72**	-8.56**
	C_4	-2.53**	-0.60*	-17.47**	-7.17**
	C_5	1.13**	-4.57**	-30.23**	-13.40**
	C_6	-0.26	1.20**	-24.47**	-12.70**
Pod yield/ plant	C_1	-104.50**	-76.37**	-409.27**	-114.20**
	C_2	-42.87**	-14.70**	-241.17**	-91.80**
	C_3	-2.87	-16.60**	-303.73**	-142.13**
	C_4	-43.88**	-33.42**	-420.23**	-171.47**
	C_5	-5.40	-64.98**	-468.75**	-199.18**
	C_6	8.47**	42.20**	-489.67**	-270.17**

* and ** indicate significance of values at P=0.05 and 0.01, respectively

plant and pod length; in cross Arka Abhay x HRB-55 for plant height, branches/plant and yield/plant and in cross Arka Abhay x VRO_6 for branches/plant and pods/plant. Presence of epistatic gene action for pod yield and its related traits have been reported earlier by Pullaiah *et al.* (1996), Aher *et al* (2003), Ghai and Mahajan (2004) and Kumar *et al* (2005) which supported the present results.

Based upon the present findings the gene actions involved in the inheritance of various characters affecting pod yield and its components are discussed below

Yield/plant:

Digenic epistatic model, based on six generations, showed that (Table 3) on an average dominance gene effect contributed maximum towards yield. Additive gene effects were negative in four crosses and small in two crosses in relation to dominance for yield. However, cross combination Arka Abhay x HRB-55 and Arka Abhay x VRO_6 exhibited significant positive additive effect. Results also indicated that magnitude of additive effect was generally dependent upon the magnitude of differences between the two parental lines while signs depend on the magnitude of P_1 and P_2 parents.

Among digenic epistasis, major role in the inheritance of yield/plant was showed by additive x additive and dominance x dominance gene interactions. The additive x additive gene effects were positive and significant in all the six crosses, while dominance x dominance gene effects had significant diminishing effect in all the crosses. Among three types of epistasis, sign attached to dominance x dominance effects was of more importance. Gamble (1962) suggested that negative effects of dominance x dominance was undesirable. Duplicate type of epistasis played significant role in the inheritance of yield/plant in all the crosses. Both additive and non additive gene action were important in the inheritance of yield/ plant in okra as reported by several workers *viz.,* Liou *et al.* (2002), Mitra and Das (2003), Singh and Singh (2003), Deo *et al.* (2004), Kumar *et al.* (2004), Jindal and Ghai (2005), Sarvanan *et al.* (2005) and Dahake and Bangar (2006). Role of dominance and dominance x dominance gene action in the expression of yield/plant have been reported by Ghai and Mahajan (2004) and Kumar *et al.* (2005). In all crosses in addition to dominance effect additive x additive type of epistasis was also important. Duplicate epistasis was present in all the six crosses.

Days to first fruit set:

For days to first fruit set non-additive gene effects played a major role in all the crosses (Table 3). The dominance gene effects were highly significant in all the

Table 3 : Estimate of gene effects for number of pods and pod yield per plant

Characters	Cross	Gene action					
		m	d	h	i	j	l
Days to first fruit set	C_1	51.13**	-1.27**	-22.97**	-17.73**	-2.50	12.33**
	C_2	50.90**	-0.90**	-17.67**	-14.60**	-1.17	12.27**
	C_3	50.77**	0.23**	-10.60**	-7.80**	-1.07	0.13
	C_4	53.47**	-1.13**	-18.17**	-15.33**	-0.30	12.33**
	C_5	51.53**	-2.37**	-18.23**	-14.73**	-0.93	10.33**
	C_6	50.63**	-1.53**	-16.20**	-13.60**	-0.73	10.40**
Plant height (cm)	C_1	145.27**	3.23**	-1.00	8.20**	-1.10	-12.93**
	C_2	144.97**	1.40	46.67**	38.53**	2.80	-29.47**
	C_3	138.60**	0.33	41.03**	35.47**	1.90	-38.33**
	C_4	136.83**	23.63**	7.53**	-12.73**	5.93	24.67**
	C_5	127.13**	5.10**	147.57**	131.00**	-7.07	-143.93**
	C_6	116.83**	13.50**	150.00**	141.27**	-7.23	-140.93**
Branches/ plant	C_1	3.50**	0.30**	3.97**	3.00**	-0.07	-3.00**
	C_2	3.10**	0.17*	5.27**	4.47**	-0.03	-3.73**
	C_3	3.10**	0.70**	4.83**	3.80**	0.40	-2.87**
	C_4	3.47**	0.50**	2.47**	1.80**	0.30	-0.93*
	C_5	3.83**	0.20	2.20**	1.47**	0.13	-0.53
	C_6	3.13**	0.33**	5.85**	5.07**	-0.25	-5.17**
Pod length (cm)	C_1	10.91**	-0.63**	5.74**	1.77**	0.34	2.45**
	C_2	10.01**	-1.52**	7.10**	4.63**	-0.59	-0.77
	C_3	11.86**	1.17**	-3.60**	-2.05**	0.39	1.77*
	C_4	10.07**	0.45**	12.20**	11.23**	0.22	-10.26**
	C_5	10.24**	0.40**	9.80**	6.63**	-0.03	-1.73**
	C_6	9.91**	0.78**	9.60**	7.95**	1.03	-4.47**
Pod girth (cm)	C_1	1.53**	-0.07**	0.82**	0.63**	-0.02	-0.33**
	C_2	1.56**	0.06**	0.41**	0.26**	0.03	0.02
	C_3	1.47**	-0.03**	0.93**	0.85**	-0.00	-0.77**
	C_4	1.51**	-0.05**	0.23**	0.35**	-0.01	-0.23**
	C_5	1.53**	-0.04**	0.58**	0.32**	-0.01	-0.02
	C_6	1.44**	-0.05**	0.95**	0.82**	-0.02	-0.73**
Number of pods/ plant	C_1	17.93**	1.67**	22.50**	16.00**	0.43	-4.73**
	C_2	19.02**	0.63**	18.63**	13.73**	0.53	-5.60**
	C_3	14.80**	0.37**	15.64**	17.13**	1.11	-15.55**
	C_4	16.17**	0.37*	18.73**	14.33**	-0.97	-11.20**
	C_5	19.87**	6.20**	32.22**	26.80**	2.85	-23.37**
	C_6	20.75**	1.27**	27.80**	25.40**	-0.73	-26.33**
Pod yield/ plant	C_1	278.23**	-12.80**	336.43**	228.40**	-14.07	-47.53**
	C_2	281.10**	-0.13	253.42**	183.60**	-14.08	-126.03**
	C_3	190.92**	-15.30**	281.50**	284.27**	6.87	-264.80**
	C_4	218.60**	-18.07**	408.45**	342.93**	-5.23	-265.63**
	C_5	281.17**	100.52**	474.73**	398.37**	29.79	-327.98**
	C_6	275.03**	4.37**	571.73**	540.33**	-16.87	-591.00**

* and ** indicate significance of values at P=0.05 and 0.01, resepctively

crosses. Among epistasis the magnitude of dominance x dominance effect was high, significant and positive in crosses all the crosses except cross Arka Anamika x Pusa Sawani. Additive x additive effects were significant and negative in all the crosses. Duplicate epistasis was present in all the crosses except cross Arka Anamika x Pusa Sawani.

Predominant role of non-additive gene action in the expression of days to first fruit set have been reported by Ahmed *et al.* (2004), Jindal and Ghai (2005) and Dahake and Bangar (2006).

Plant height:

The dominance effect was positive and significant in five crosses. Additive x additive and dominance x dominance type of non-allelic gene actions were useful for the inheritance of plant height. Additive gene effects also contributed in four crosses *viz.,* Parbhani Kranti x Pusa Sawani, Arka Anamika x VRO_5, Arka Abhay x HRB-55 and Arka Abhay x VRO_6. Thus further change in plant height could be possible through selection in this population. Duplicate gene action was present for plant height in four crosses having significant magnitude for dominance x dominance gene effects, while one cross exhibited complementary epistasis.

Dhankhar and Dhankhar (2001), Rewale *et al.* (2003), Dahake and Bangar (2006) and Kumar *et al.* (2006) observed non-additive gene action for this trait. Kumar *et al.* (2005) and Sarvanan *et al.* (2005) reported role of dominance effects whereas role of dominance x dominance have been reported by Ghai and Mahajan (2004) and Kumar *et al.* (2005). While, duplicate type of epistasis was reported by Pullaiah *et al.* (1996) and Tripathi *et al.* (2002).

Branches/plant:

For this trait dominance effects were highly significant in all the crosses, while additive gene effects were highly significant for four crosses but the magnitude of dominance effect was higher compared to additive in all the crosses which suggested its greater role in the expression of this trait. In all the crosses dominant tend to increase the branches per plant while dominance x dominance seemed to appear as the retardant. Duplicate type of epistasis was present in all the crosses, except cross Arka Abhay x HRB-55, where the dominance x dominance gene effects exhibited significant magnitude.

Involvement of non-additive gene effect (including epistasis) in the expression of this trait has been reported by Rewale *et al.* (2003), Mitra and Das (2003), Kumar *et al.* (2004) and Kumar *et al.* (2006).

Pod length:

The magnitude of dominance effect was significant, positive and high compared to additive in five crosses indicating its major role in inheritance of this trait.

Additive x additive gene effects were highly significant and positive for four crosses while it was negative for two crosses. Dominance x dominance gene effects were found highly significant for five crosses and had diminishing effects in three crosses while two crosses exhibited enhancing effects. Dominance gene effect tended to increase the magnitude of pod length. Duplicate type of epistasis was present in four crosses while one cross exhibit complementary type epistasis.

Kumar *et al.* (2005) and Sarvanan *et al.* (2005) reported dominance gene effects for this trait. While, Rewale *et al.* (2003), Kumar *et al.* (2004), Dahake and Bangar (2006) and Kumar *et al.* (2006) also reported preponderance of non-additive gene action (including epistasis) in the expression of pod length in okra.

Pod girth:

The dominance gene effects were highly significant and positive in magnitude in all the crosses while additive effects were significant and negative in all the crosses and had diminishing effects in all the crosses except cross Parbhani Kranti x GO_2 (Table 3). For this trait additive x additive gene effects were found highly significant and positive for all the crosses while, dominance x dominance were highly significant and negative in four crosses. Additive x additive effect caused beneficial role in all the crosses. Duplicate epistasis made major contribution in four crosses for this trait. Preponderance of non-additive gene effects was observed by Deo *et al.* (2004) and Dahake and Bangar (2006) while predominant role of dominance effect was reported by Saravanan *et al.* (2005). Duplicate type epistasis was reported by Pullaiah *et al.* (1996) and Tripathi *et al.* (2002).

Pods/plant:

All the crosses showed highly significant and positive additive and dominance gene effect for pods/plant; however, the magnitude of dominance type gene effects were higher in magnitude for all the crosses indicating that the non-additive type of gene action contributing maximum for inheritance of this trait. Among epistasis, additive x additive type gene effects were highly significant and positive for all the crosses, while the dominance x dominance type of gene effects were highly significant and had diminishing effects for all the crosses. Duplicate type of epistasis was made major contribution for all the crosses.

Aher *et al.* (2003) and Kumar *et al.* (2005) also reported importance of dominance effect in the inheritance of this trait. While the non-additive type of gene action (including epistasis) was reported by Dhankhar and Dhankhar (2002), Rewale *et al.* (2003), Mitra and Das (2003), Kumar *et al.* (2004), Saravanan *et al.* (2005), Dahake and Bangar (2006) and Kumar *et al.* (2006). While duplicate type of epistasis was reported by Kumar *et al.* (2005).

In the present investigation magnitude of non-fixable components was high for yield/plant as well as its components. Exploiting this type of variability, population improvement approach is generally suggested. Some forms of recurrent selection like diallel selective mating (Jensen, 1970) or bi-parental mating in early segregating generation as suggested by Joshi and Dhawan (1966) might prove to be effective alternative approach. These methods utilize both additive and non-additive genetic variance during selection of genotypes and permit the release of conceal variability. Such populations may be composed of numerous parental lines. The constant recombination's increases the probability of desire gene combinations. However, since okra is an often cross pollinated crop and in absence of cytoplasmic genetic male sterility it would not be feasible. Hence, till it become feasible, cyclic method of breeding would be the alternative approach to conserve the frequency of desirable genes influencing yield contributing traits. Therefore, directional selection would be preferable as a method for increasing frequency of desirable homozygotes.

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