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Genetics and order effects of boll number per plant and boll weigh in upland cotton (*Gossypium hirsutum*)

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Abstract: Sixty, three-way crosses involving six parents were evaluated in a randomized block design. The mean data on boll number per plant and boll weight were analyzed as per the triallel analysis model. Predominance of epistatic gene effects (additive x dominance and dominance x dominance) was observed for both the characters. All the three-way crosses showed invariably order effect for both the characters. Parents SVPR 1 and Sharada were observed as good general combiners, being a grand parent and MCU 5 was considered as a good general combiner and immediate parent in three-way crosses for both the characters. Hence the population improvement programme i.e., recurrent selection with concurrent intermating before selection in early segregating generations can be adopted for the improvement of the above traits.

Key words : Triallel analysis, Epistasis, Three-way crosses, Boll number, Boll weight, Parent order effects.

Introduction

In cotton, boll number per plant and boll weight primarily influence the seed cotton yield, since they are the cardinal yield components showing direct and indirect association with seed cotton yield (Butany *et al.* 1968, Musande *et al.* 1981 and Ismail and Erani, 1986). Boll weight has an advantage of clean and easy picking besides better fibre qualities associated with high boll weight (Thombre *et al.* 1987). Hence the information on gene action for boll number per plant and boll weight is very essential for deciding effective selection method in segregating generations. The genetic investigation of boll number per plant and boll weight was carried out by several workers, indicating the importance of both additive and non-additive gene action in the expression of the characters (Gunaseelan and Krishnaswami, 1986; Pavasia *et al.* 1990; Tiwari *et al.* 1992). While additive and dominance gene effects may have great influence on variation of these characters like boll number per plant and boll weight, the information on epistatic gene effect would be of value for cotton workers (Thombre *et al.* 1987). The present study, therefore, was initiated to further analyse the gene action of boll number per plant and boll weight through triallel analysis proposed by Rawlings and Cockerham (1962) and further developed by Ponnusamy *et al.* (1974). Triallel analysis provides the information on all type of gene actions selection methods suitable in segregating generations and the order of the parents in cross combinations for maximum range to segregation and recombinations and to exploit the heterosis at the maximum possible.

Materials and Methods

All possible 60 three-way crosses involving six divergent upland cotton genotypes *viz.* MCU 5, MCU 7, TCH 1002, SVPR 1, Sharada and JR 36 were raised at Cotton Research Station, Srivilliputhur during summer 1999. The trial was laid out in a randomized block design with three replications. Data on boll number per plant and boll weight were recorded on ten randomly selected plants. Mean data were subjected to triallel analysis according to Ponnuswamy *et al.* (1974).

The following formula was used.

$$Y_{ijkl} = m + b_l + h_i + h_j + d_{ij} + g_k + S_{ik} + S_{jk} + t_{ijk} + e_{ijkl}$$

where,

Y_{ijkl} = phenotypic vaule in the l^{th} replication on ij^{th} cross (grand parents) mated to k^{th} parent

m = general mean

$_l$ = effects of l^{th} replication

Table 1. Analysis of variance of three-way crosses for boll number per plant and boll weight in upland cotton

Source of variation	d.f	Characters	
		Boll number per plant	Boll weight
General line effect of first kind (h_i)	5	54.856**	0.270**
General line effect of second kind (g_i)	5	44.936**	0.433**
2-line specific effect for first kind (d_{ij})	9	66.814**	0.371**
2-line specific effect of second kind (S_{ij})	19	59.336**	0.211**
3-line specific effect (t_{ijk})	21	42.417**	0.364**
Crosses	59	52.855**	0.314**
Replication	2	3.52	0.054
Error	118	0.622	0.013

* Significant at P=0.05
** Significant at P=0.01

Table 2. Estimates of general line effects (general combining ability effects) of first kind (h_i) and second kind (g_i) of six parents for boll number per plant and boll weight

Parents	General line effect of first kind (h_i)		General line effect of second kind (g_i)	
	Boll number per plant	Boll weight	Boll number per plant	Boll weight
MCU 5	0.164	-0.027	1.350**	0.080**
MCU 7	-1.319**	-0.142**	-1.933**	-0.203**
TCH 1002	0.331**	-0.066**	-0.496**	0.024
SVPR 1	0.497**	0.140**	1.240**	0.067**
Sharada	1.393**	0.066**	1.158**	0.104**
JR 36	-1.066**	0.029	-1.319**	-0.071

* Significant at P=0.05
** Significant at P=0.01

Table 3. Estimates of two-line specific effects (d_{ij}) (grand parents) for boll number per plant (upper half) and boll weight (lower half)

Parents	Parents					
	MCU 5	MCU 7	TCH 1002	SVPR 1	Sharada	JR 36
MCU 5	-	2.732**	-4.287**	3.085**	-1.115**	-0.415
MCU 7	0.123**	-	0.902**	-3.080**	-0.703**	0.150
TCH 1002	0.095**	-0.113**	-	0.222	2.808**	0.798**
SVPR 1	-0.172**	0.127**	0.025	-	-0.120	0.337
Sharada	-0.015	0.090**	0.112**	-0.272**	-	-0.870**
JR 36	-0.032	-0.227**	-0.118**	0.292**	0.085**	-

S.E for boll per plant = 0.193; S.E. for boll weight = 0.027
* Significant at P=0.05; ** Significant at P=0.01

Table 4. Estimates of two line specific effects of second kind (S_{ij}) their reciprocals (S_{ji}) (in parenthesis) for boll number per plant (upper half) and boll weight (lower half)

Parents	MCU 5	MCU 7	TCH 1002	SVPR 1	Sharada	JR 36
MCU 5	-	2.248** (4.448**)	0.176 (-1.720**)	-0.593** (-2.839**)	-3.052** (-1.180**)	1.220** (1.290**)
MCU 7	-0.108** (-0.121**)	-	-1.700** (1.060**)	0.813** (-3.555**)	0.113 (0.152)	-3.675** (0.095)
TCH 1002	-0.050 (0.083**)	0.038 (-0.103**)	-	-0.296 (2.154**)	0.466** (1.446**)	0.490** (-2.077**)
SVPR 1	0.106** (-0.156**)	0.220** (0.081**)	-0.189** (-0.041)	-	-0.264 (2.121**)	4.504** (-2.046**)
Sharada	0.096** (-0.114**)	0.134** (0.088**)	0.132** (0.018)	-0.191** (-0.176**)	-	2.539** (-2.737**)
JR 36	-0.045 (0.080**)	0.195** (0.042)	0.077 (0.112**)	0.307** (-0.062)	0.144** (-0.171**)	-

S.E for boll per plant = 0.170; S.E. for boll weight = 0.024
* Significant at P=0.05; ** Significant at P=0.01

where,
$_i$ and $_j$ are grand parents and k is the parent
g_{ij} = average effects of F_1 hybrids
h_i = general line effect of i^{th} parent as grand parent (first kind general line effect)
d_{ij} = two-line (ixj) specific effect of first kind (grand parents)
j_k = general line effect of k as parent (second kind effect)
s_{ik} = two line specific effect where, i is the half parent and k is the parent. Hence specific effect of second kind
t_{ijk} = three line specific effect
e_{ijkl} = error effect

The order effect is estimated as the difference between h_i and g_i, s_i and s_{ij} and between dij and $(S_{ij} + S_{ji})/2$. The presence of order effect does not affect the estimates of the parameters.

Results and Discussion

The analysis of variance for three-way crosses (Table 1) showed that the general line effect of first (h_i) and second kind (g_i), two line specific effect of both first (d_{ij}) and second kind (S_{ij}) and three line specific effect (t_{ij} were significant for both the characters indicatir the importance of both additive and non-additiv gene effects in the expression of these character

The general line effects of first and secor kind (h_i and g_i) were positive and significa for the lines SVPR 1 and Sharada for bo the characters suggested that these lines we good general combiners for boll number p plant and boll weight. Thus, from the gener line effects, SVPR 1 and Sharada were fou to be good general combiners and can be us as grand as well as immediate parents. T parent MCU 5 was found to be good for b weight alone and hence it would serve as good grand parent and also as immediate par for boll weight (Table 2).

The two line specific effects of fi kind (dij) for number of bolls per plant w positive and significant in the crosses MCU MCU 7, MCU 5/SVPR 1, MCU 7/TCH 10 TCH 1002/Sharada and TCH 1002/JR : indicating that these combinations were g specific combiners for boll number per pl

Table 5. Estimates of three line specific effect for boll number per plant and boll weight (in parenthesis)

Grand parental line	Grand parental line					
	MCU 5	MCU 7	TCH 1002	SVPR 1	Sharada	JR 36
MCU 5 / MCU 7	-	-	3.508** (-0.139**)	-2.906** (-0.297**)	1.269** (0.429**)	-1.873** (0.007)
MCU 5 / TCH 1002	-	2.881* (0.063)	-	1.438** (0.198**)	-0.217 (-0.249**)	-4.102** (0.012)
MCU 5 / SVPR 1	-	-1.508 (0.038)	-3.149**) (-0.291**)	-	0.577 (0.234**)	4.080** (0.018)
MCU 5 / Sharada	-	-1.878** (-0.117**)	1.897** (0.302**)	-1.912** (-0.171**)	-	1.893** (-0.014)
MCU 5 / JR 36	-	0.504 (0.016)	-2.256** (0.128**)	3.380** (0.269**)	-1.629** (-0.414**)	-
MCU 7 / TCH 1002	0.106 (-0.137**)	-	-	0.360 (0.141**)	-1.553** (-0.198**)	1.088** (0.195**)
MCU 7 / SVPR 1	-2.726** (0.077)	-	1.409** (0.547**)	-	0.327 (-0.355**)	0.990** (-0.115**)
MCU 7 / Sharada	0.509 (0.129**)	-	-5.589** (-0.367**)	5.287** (0.325**)	-	0.207 (-0.087)
MCU 7 / JR 36	2.111** (0.085)	-	0.672 (-0.041)	-2.741** (-0.168**)	-0.042 (0.124**)	-
TCH 1002 / SVPR 1	3.033** (-0.055)	-2.447** (0.009)	-	-	-0.042 (0.139**)	-0.184 (-0.094)
TCH 1002 / Sharada	-2.386** (0.362**)	1.453** (-0.076)	-	-2.267** (-0.196**)	-	3.199** (0.089)
TCH 1002 / JR 36	-0.753** (-0.169**)	-1.888** (0.004)	-	0.469 (-0.143**)	2.172** (0.308**)	-
SVPR 1 / Sharada	1.463** (0.222**)	1.498** (0.083)	1.924** (-0.052)	-	-	-4.886** (0.191)
SVPR 1 / JR 36	-1.771** (0.354**)	2.457** (-0.131**)	-0.184 (-0.205**)	-	-0.501 (-0.018)	-
Sharada / JR 36	0.413 (0.269**)	-1.073** (0.111**)	1.768** (0.117**)	-1.108** (0.042)	-	-

S.E (t_{ijk}) for bolls per plant = 0.269; S.E. (t_{ijk}) for bolls per weight = 0.038

** Significant at 1 per cent level

Table 6. Related magnitude of components genetic variation for boll number per plant and boll weight

Component of genetic variation	Boll number per plant	Boll weight
Additive	23.080	0.166
Dominance	-79.080	-0.299
Additive x additive	-47.145	-0.288
Additive x dominance	242.974	1.276
Dominance x dominance	82.022	0.580

as grand parent in three-way crosses. The crosses MCU 5/MCU 7, MCU 5/TCH 1002, MCU 7/SVPR 1, MCU7/Sharada, TCH 1002/Sharada, SVPR 1/JR 36 and Sharada/JR 36 were observed as good specific combiners for boll weight, as they have exhibited positive and significant "d_{ij}" effects (Table 3). The crosses showing good specific combining ability (d_{ij}) were having the parental combinations of either good x good or good x poor general combiners, as reported by Ram *et al.* (1994) in rice. The crosses showing high two line specific effect (d_{ij}), involving one good and one poor general combiners, could produce desirable transgressive segregants if fixable gene complexes (additive) in good combiners and complementary epistatic effect in poor combiners acted in the same direction to maximize the desirable attributes.

The estimates of two line specific effect of second kind (s_{ij}) for number of bolls per plant were positive and significant in the crosses MCU 5//MCU 7, MCU 5//JR 36, MCU 7//SVPR 1, TCH 1002//Sharada, TCH 1002//JR 36 and Sharada//JR 36 indicating them as good specific combiners (Table 4). Whereas, the reciprocal effect (S_{ji}) was positive and significant in crosses like MCU 5//MCU 7, MCU 5//JR 36, MCU 7//TCH 1002, TCH 1002//SVPR 1, TCH 1002//Sharada and SVPR 1//Sharada. In respect of boll weight, the "S_{ij}" effect was positive and significant in crosses like MCU 5//SVPR 1, MCU 5//Sharada, MCU 7//SVPR 1, MCU 7//Sharada, MCU 7//JR 36, TCH 1002//Sharada and Sharada//JR 36. The reciprocal effect (S_{ji}) was found positive and significant in the cross combinations MCU 5//TCH 1002, MCU 5//JR 36, MCU 7//SVPR 1, MCU 7//Sharada and TCH 1002//JR 36. Thus, the high positive 'S_{ij}' estimates were recorded for both boll number per plant and boll weight in the crosses *viz.* MCU 7//SVPR 1, TCH 1002//Sharada, TCH 1002//JR 36 and Sharada//JR 36 indicated that the crosses were good specific combiners in three-way crosses for both characters. The higher positive "S_{ij}" estimates for boll number per plant in many crosses have negative (or) lesser "S_{ij}" value for boll weight and vice versa. This has proved that the crosses, which are specific combiners for boll number per plant are poor combiners for boll weight. Further the predominance of reciprocal effects (Sij) for both characters furnished the information on the importance of order of the parents in three-way crosses. Similar results have also been reported by Chaudhry and Singh (1976) in Barley, Joshi (1990) in wheat and Ram *et al.* (1994) in rice.

The three line specific effect (t_{ijk}) was positive and significant in 22 triplet combinations of which the superior triplets for boll number per plant are MCU 7/Sharada//SVPR 1, MCU 5/SVPR 1//JR 36, MCU 5/MCU 7//TCH 1002 and MCU 5/JR 36//SVPR 1 (Table 5). Positive and significant three line effects (t_{ijk}) were observed in 19 combinations of which the superior triplets for boll weight are MCU 7/SVPR 1//TCH 1002, MCU 7/Sharada//SVPR 1 and TCH 1002/JR 36//Sharada (Table 5). Most of the triplets having positive and significant "t_{ijk}" for boll number per plant had negative or low "t_{ijk}" effect for boll weight. The triplet combinations showing positive and significant "t_{ijk}" effect for both characters are MCU 5/MCU 7//Sharada, MCU 5/TCH 1002//SVPR 1, MCU 5/Sharada//TCH 1002, MCU 5/JR 36//SVPR 1, MCU 7/Sharada//SVPR 1, TCH 1002/JR 36//Sharada and Sharada/JR 36//TCH 1002 (Table 5). These combinations showed high per se performance also and hence they would deserve consideration in heterosis breeding.

Change of order of the parents had its impact on the performance of the hybrid. A case study of the triplet MCU 7/Sharada//SVPR 1 for boll number/plant showed that the tijk effect varied with the order of parents. The triplet in the above order had significant tijk effects and also high mean. The alternate forms of the triplet had low mean and low tijk effects (Table 5). Similar observations had been noticed in other triplets also, which implies the importance of order effects for boll number/plant. Similarly change of order of the parents had its impact on the performance of hybrid for boll weight. The triplet in the order of MCU 5/SVPR 1//Sharada and MCU/JR 36//TCH 1002 had significant three line effect and high per se performance. When this order was changed, the three-line effect has been highly altered. This shows that the order effect had to be decided well before attempting the multiple crosses.

The triallel analysis indicated that the boll number per plant and boll weight were governed by additive and epistatic gene effects (Table 6). Partitioning of the component variances through triallel analysis showed predominance of additive x dominance followed by dominance x dominance type of gene action. Hence the population improvement programme i.e., recurrent selection with concurrent intermating before selection in early segregating generations can be adopted for improvement of the above traits.

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