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Studies on genetic of yield in okra

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ABSTRACT

The genetic of heterosis in okra were elucidated in this study. The parent genotypes Punjab Padmini was found as good general combiner followed by Parbhani Kranti and Arka Anamika. Based on overall specific combining ability, the cross combinations *viz.,* Parbhani Kranti × Punjab Padmini, MDU 1 × Mohanur Local and Arka Anamika x Mohanur Local were identified as good specific combiners. Standard heterosis upto a tune of 86.80% was recorded by the cross Punjab Padmini × Parbhani Kranti for fruit yield/plant. Most of the crosses which portrayed high standard heterosis, high per se and sca effects had both the parents with high gca effects or atleast one of the parents with high gca effects. The regression line of the V_r, W_r graph indicated the existence of complete dominance for trait like fruit yield per plant. It was found that combining ability is important for heterosis and not the gene distribution.

Key words: Epistasis, heterosis, specific combining ability, okra.

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is one of the important ancient and traditional vegetable crops. It has been reported that okra has an average nutritive value of 3.21, which is higher than tomato, eggplant and most of the cucurbits (Grubben, 7). A further increase in okra productivity needs intensive research and breeders need to examine whether productivity is enhanced mainly by genes favoured by heterozygosity or homozygosity okra. Mather (12) attributed differential expression of heterosis among crops to the type of genetic balance (heterozygous and homozygous balance) that a crop has acquired during the process of its evolution. Jinks (10) indicated the magnitude of diverse type of gene action, such as additive effect, dominance, non-allelic interaction, linkage, maternal effects and G × E interaction controlling quantitative traits for understanding the causes of heterosis. Non-allelic interactions are frequently observed to be associated with heterotic crosses but their contribution to net heterosis has not been found in general to be substantial (Chahal and Gosal, 2). Hence, knowledge of genetic causes of heterosis of experimental population is important to decide the breeding strategies for yield improvement in any crop, especially okra.

MATERIALS AND METHODS

Six okra genotypes *viz.*, Arka Anamika (AA), Parbhani Kranti (PK), Punjab Padmini (PP), MDU1, Pusa Sawani (PS) and Mohanur Local (ML) were crossed in full diallel fashion during first year in Plant Breeding Farm, Department of Genetics and Plant Breeding, Annamalai University. The resulting 30 hybrids (15 direct and 15 reciprocals) were sown in the field during January in second year following randomized block design with three replications. Each entry was sown in a single row plot of size of 3 m length. A row to row spacing of 45 cm and plant to plant spacing of 30 cm was adopted. Recommended agronomic practices and need-based plant protection measures were taken. All the parents and hybrids were selfed. Data were recorded on five randomly selected plants per entry per replication on yield and yield component characters namely, days to first flowering, plant height, number of nodes per plant, number of branches per plant, number of fruits per plant, fruit length, fruit weight, fruit yield per plant, green matter production, and harvest index. The data ware analysed for combining ability using standard procedure as outlined by Griffing (6), model I (fixed) and method 1. The graphic analysis as proposed by Jinks and Hayman (9) was followed. The combining ability of the parents and hybrids were scored as per the method outlined below. The parents/ cross combinations which showed significant gca / sca were given the score +1, if the was value positive and -1 for negative. For days to first flowering and plant height significant gca / sca were given the score +1 if the value negative and -1 if the value positive. Non-significant gca / sca effects were given the score 0. Total score more than +1 was considered as good combiner. Computation of heterosis and heterobeltiosis and its significance were carried out as per procedure suggested by Briggle (1), and Fonesca and Paterson (3). Standard heterosis was estimated by using standard check Parbhani Kranti.

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Six generations namely, P_1, P_2, F_1, F_2, B_1 and B_2 of three direct crosses *viz.*, AA x PK, PK x ML, AA x ML and their reciprocals were produced. These parental inbreds were selected based on duration and fruit yield per plant. The generations mean were subjected to scaling tests and joint scaling tests and the gene effects were partitioned following Mather and Jinks (11). The purpose of this part of the study is to estimate the hereditary variances for populations derived from crossing of the inbred lines of okra *viz.*, AA, PK and ML in full diallel fashion and to partition the epistasis.

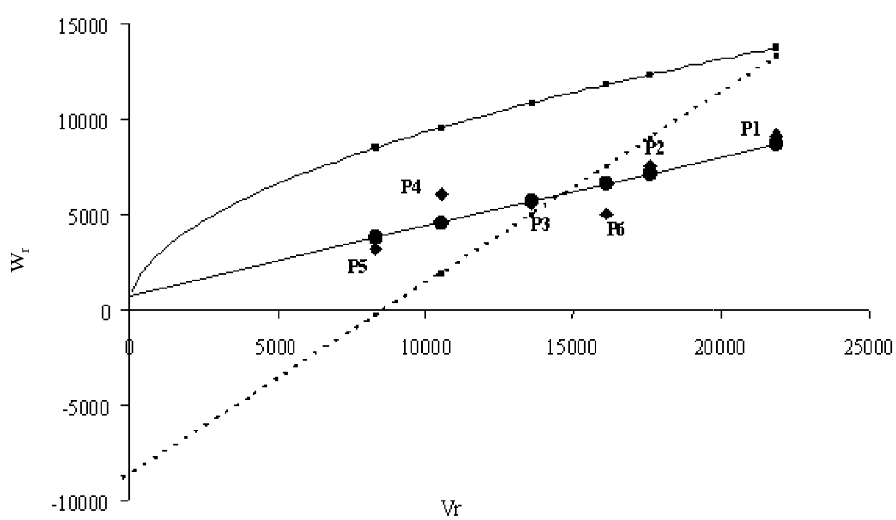
RESULTS AND DISCUSSION

Analysis of variance indicated that the parents and hybrids differed well among themselves for all the ten characters studied. The analysis of variance for combining ability revealed the importance of both additive and non-additive gene action in the inheritance and improvement of the traits (Table 1). The parents which recorded high fruit yield per plant *viz.*, AA and PP were found as good general combiners for five and eight traits including fruit yield per plant out of ten traits investigated, respectively (Table 2). This indicated that these parents have enormous amount of additive genetic variability. The result is in corroboration with the findings of Srivastava *et al.* (16), and Singh *et al.* (15). When the parents were assessed for their overall general combining ability, the parent PP(+6) was found as a high general combiner followed by PK(+4) and AA (+3) (Table 3). The hybrid which displayed high *per se* for fruit yield per plant *viz.*, PK × PP was found as a good specific combiner for many of the traits of interest. Based on the assessment of over all specific combining ability, the cross combinations *viz.*, PK × PP (+7); MDU 1 × ML (+7); AA × ML (+6); PK × PS (+6); MDU

Table 1. Estimates of variance for combining ability in okra.

Source	Mean sum of squares									
	Days to first flowering	Plant height	Number of nodes per plant	Number of branches per plant	Number of fruits per plant	Fruit length	Fruit weight	Fruit yield per plant	Green matter production	Harvest index
GCA	161.45**	2821.53**	49.87**	5.77**	45.77**	46.22**	70.36**	73009.60**	185200.00**	100.58**
SCA	4.57**	382.76**	23.25**	0.77**	16.29**	4.32**	5.02**	17170.40**	52131.74**	14.14**
GCA/SCA	35.33	7.37	2.14	7.49	2.81	10.70	14.02	4.25	3.55	7.11

*, ** Significant at 5 and 1% levels



Note: P1- Arka Anamika; P2 – Parbhani Kranti; P3 – Punjab Padmini; P4 – MDU 1; P5 – Pusa Sawani; P6 – Mohanur Local

Fig. 1. Vr, Wr graph for fruit yield per plant in okra.

1 × PS (+6); AA × PP (+5); PP × PS (+5); PK × MDU 1 (+4) and PK × ML (+4) were found as high specific combiners (Table 4). Standard heterosis for fruit yield per plant was maximum with the hybrids of the direct and reciprocal cross combinations *viz.*, AA × ML; PK × ML and PK × PP. Standard heterosis up to a tune of 86.80 per cent was recorded by PP × PK followed by ML × AA (86.50%) and ML × PK (85.21%). These cross combinations also portrayed high standard heterosis for all the traits studied except days to first flowering. The simple correlation coefficients between *per se* performance of parents and their gca effects were significant for all the traits, except days to first flowering (Table 2). This indicated that gca effect could well be utilized as a biometrical genetic marker for varietal breeding of okra. Such a relationship was

Table 2. Relationship between *per se* performance and gca effects in okra.

Character	Best *per se*	Best gca effects	Best *per se* and gca effects	Correlation coefficient (r)
Days to first flowering	PK	PK	PK	
	MDU 1	MDU 1	MDU 1	0.01
	AA	PP	-	
	ML	ML	ML	
Plant height	PS	PS	PS	0.97**
	AA	MDU 1	-	
No. of nodes per plant	AA	AA	AA	
	PP	PK	PP	0.84*
	PS	PP	-	
No. of branches per plant	ML	ML	ML	
	PS	PS	PS	0.99**
	PP	-	-	
No. of fruits per plant	AA	AA	AA	
	PP	PK	PP	0.84*
	PS	PP	-	
	ML	ML	ML	
Fruit length	PP	PP	PP	0.97**
	AA	-	-	
Fruit weight	ML	ML	ML	
	PP	PK	PK	0.96**
	PK	PP	PP	
Fruit yield per plant	AA	PK	PP	
	PP	ML	ML	0.84*
	ML	PP	-	
Green matter production	ML	ML	ML	
	AA	PK	PP	0.85*
	PP	PP	-	
	AA	AA	AA	
Harvest index	PP	PK	PK	0.86*
	PK	PP	PP	

*, ** Significant at 5 and 1% levels

AA = Arka Anamika PP = Punjab Padmini PS = Pusa Sawani

PK = Parbhani Kranti MDU1 = Madurai 1 ML = Mohanur Local

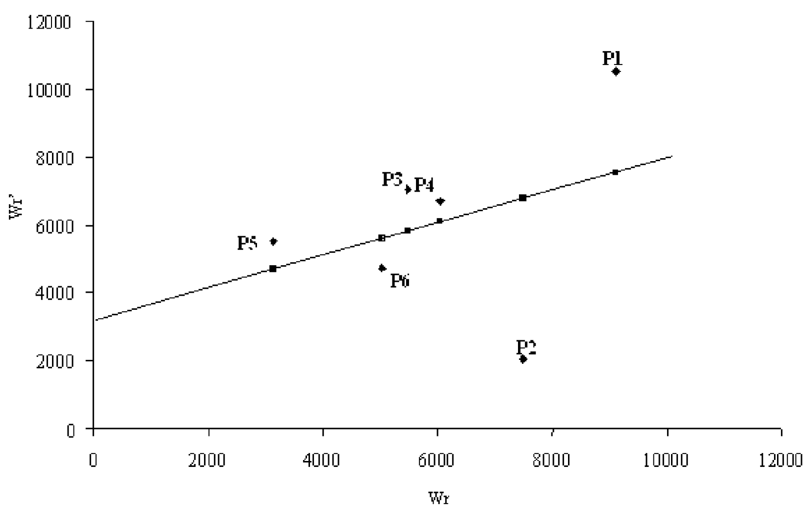
Table 3. Scoring based on gca effects for all the ten characters in okra.

Character	AA	PK	PP	MDU1	PS	ML
Days to first flowering	0	+1	+1	+1	-1	-1
Plant height	-1	-1	-1	+1	+1	+1
Number of nodes per plant	+1	+1	+1	-1	+1	-1
Number of branches per plant	0	-1	-1	-1	+1	+1
Number of fruits per plant	+1	+1	+1	-1	-1	-1
Fruit length	0	-1	+1	-1	-1	+1
Fruit weight	-1	+1	+1	-1	-1	+1
Fruit yield per plant	+1	+1	+1	-1	-1	+1
Green matter production	+1	+1	+1	-1	-1	+1
Harvest index	+1	+1	+1	-1	-1	0
Total score	+3	+4	+6	-6	-4	+3

AA = Arka Anamika; PP = Punjab Padmini; PS = Pusa Sawani
PK = Parbhani Kranti; MDU1 = Madurai 1; ML = Mohanur Local

also well evidenced from the correlation coefficients between *sca* effects and *per se* performance of hybrids (Table 5). Hence, *sca* effects could well be utilized as a biometrical genetic marker for hybrid breeding in okra. The cross combinations which showed high *sca* effects had both the parents with high gca effects or atleast one of the parent with high gca effect. Thus, there was good agreement between *per se* combining ability effects and standard heterosis. Similar trend was reported by Senthil Kumar and Anandan (13, 14).

For fruit yield per plant, the regression line of the V_r, W_r graph intersected the W_r axis nearer to the origin (Fig. 1). This indicated the existence of complete dominance in the inheritance of fruit yield. The relative value of V_r and W_r showed that the high yielding genotypes *viz*., AA had most recessive genes for fruit yield per plant (Fig. 1). The other high yielding genotype namely, PP had both dominant and recessive genes in equal frequencies for fruit yield per plant. The genotype namely, AA had more dominant genes for only one out of the eight characters plotted, namely, number of nodes per plant. The other high yielding genotype namely, PP was endowed with most dominant genes for flowering alone. The direct and reciprocal F_1 hybrids of the cross combinations *viz*., PK × PP, AA × ML and ML × PK recorded maximum fruit yield per plant. Among the parents involved in the above cross combinations the parents namely, PK and ML were endowed with most recessive genes for fruit yield per plant. The parent PK was endowed



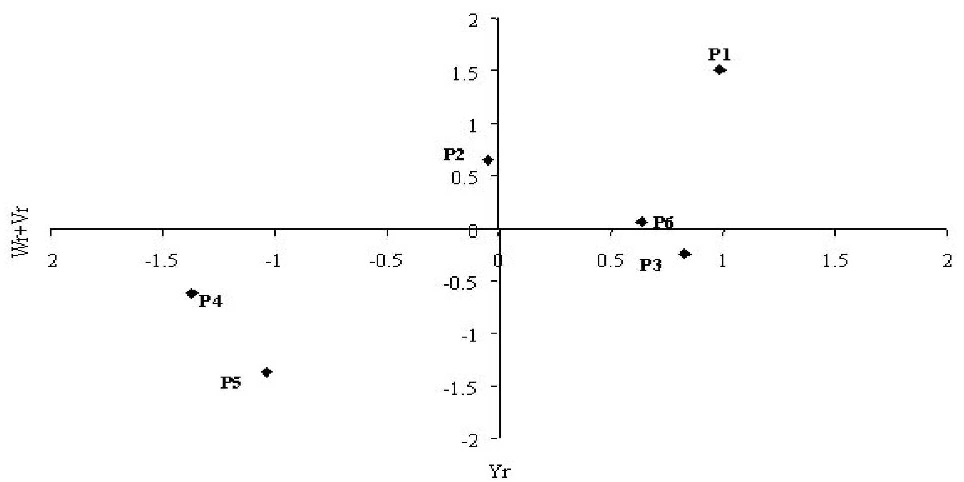
Note: P1- Arka Anamika; P2 – Parbhani Kranti; P3 – Punjab Padmini; P4 – MDU 1; P5 – Pusa Sawani; P6 – Mohanur Local

Fig. 2. W_r, W_r^1 graph for fruit yield per plant in okra.

Table 4. Scoring based on *sca* effects for ten characters in okra.

Cross	Days to first flowering	Plant height	No. of nodes per plant	No. of branches per plant	No. of fruits per plant	Fruit length	Fruit weight	Fruit yield per plant	Green matter production	Harvest index	Total score
AA × PK	0	-1	+1	0	+1	-1	+1	+1	+1	0	+3
AA × PP	0	-1	0	0	+1	+1	+1	+1	+1	+1	+5
AA × MDU 1	+1	+1	-1	0	-1	0	-1	-1	0	-1	-3
AA × PS	-1	-1	-1	0	-1	-1	0	-1	-1	-1	-8
AA × ML	0	-1	+1	+1	+1	+1	0	+1	+1	+1	+6
PK × PP	0	-1	+1	+1	+1	+1	+1	+1	+1	+1	+7
PK × MDU 1	-1	-1	+1	+1	0	+1	0	+1	+1	+1	+4
PK× PS	0	-1	+1	0	+1	+1	+1	+1	+1	+1	+6
PK × ML	+1	-1	+1	-1	+1	-1	+1	+1	+1	+1	+4
PP × MDU 1	0	0	-1	-1	-1	-1	0	-1	-1	0	-6
PP × PS	+1	0	+1	+1	+1	+1	-1	+1	+1	-1	+5
PP × ML	0	+1	+1	+1	-1	0	+1	0	+1	-1	+3
MDU 1 × PS	0	0	+1	+1	+1	0	0	+1	+1	+1	+6
MDU 1 × ML	+1	-1	+1	+1	+1	0	+1	+1	+1	+1	+7
PS × ML	-1	-1	-1	0	-1	0	-1	-1	-1	-1	-8

AA = Arka Anamika PP = Punjab Padmini PS = Pusa Sawani
PK = Parbhani Kranti MDU1 = Madurai 1 ML = Mohanur Local



Note: P1- Arka Anamika; P2 – Parbhani Kranti; P3 – Punjab Padmini; P4 – MDU 1; P5 – Pusa Sawani; P6 – Mohanur Local

Fig. 3. Y_r, W_r+V_r graph for fruit yield per plant in okra.

with most dominant genes for days to first flowering, plant height and harvest. The parent ML possessed most dominant genes for number of branches and fruit weight. The pattern of gene distribution for the parents' *viz.,* AA and PP revealed that they were mostly endowed with recessive genes. This indicated that the distribution of genes in these genotypes were asymmetrical. This asymmetry favours neither high

Table 5. Relationship between standard heterosis (d_{iii}), *per se* performance, gca effects and sca effects in okra.

Character	Best three crosses with high d_{iii}	*Per se* performance	sca effect	gca effect	Correlation coefficient (r)
Days to first flowering	-	-	-	-	0.15
	PS × ML	138.20	7.86**	-12.05** × -21.43**	
Plant height (cm)	ML × PS	141.80	7.86**	-21.43** × -12.05**	0.01
	ML × AA	147.47	3.98**	-21.43** × 1.34*	
No. of nodes per plant	AA × PK	38.47	2.07**	1.73** × 1.56**	
	PK × AA	38.47	2.07**	1.56** × 1.73**	0.38*
	PP × PS	38.20	3.37**	0.96** × 0.77**	
No. of branches per plant	AA × ML	6.87	0.96**	-0.02 × 1.13**	
	ML × AA	6.53	0.96**	1.13** × –0.02	0.23
	ML× PS	6.47	0.16	1.13** × 0.41**	
No. of fruits per plant	AA × PK	33.07	1.08**	2.14** × 1.78**	
	PP × PK	32.00	2.99**	0.96** × 1.78**	0.37*
	PK × PP	31.53	2.99**	1.78** × 0.96**	
	PP × ML	24.47	0.42	2.28** × 2.32**	
Fruit length (cm)	PP × PK	24.13	2.57*	2.28** × –0.50**	0.29
	ML × AA	23.60	1.98**	2.32** × –0.05	
Fruit weight (g)	ML × PK	26.80	1.02**	3.67** × 1.21**	
	ML × PP	26.53	0.73**	3.67** × 0.72**	-0.03
	ML × MDU1	26.33	2.07**	3.67** × –1.47**	
Fruit yield per plant (g)	PP × PK	748.44	88.16**	35.90** × 71.50**	
	ML × AA	747.24	115.69**	63.88** × 25.12**	0.40*
	ML × PK	742.11	64.40**	63.88** × 71.50**	
Green matter production (g)	ML × AA	1808.91	200.46**	170.51** × 13.82**	
	AA × ML	1780.40	200.46**	13.82** × 170.51**	0.26
	PP × PK	1665.87	181.12**	32.94** × 63.26**	
Harvest index	PP × AA	44.25	2.92*	1.91** × 1.38**	
	PK × ML	44.17	2.77*	3.28** × 0.03	0.42*
	AA × PK	44.08	0.14	1.38** × 3.28**	

*, ** Significant at 5 and 1% levels

AA = Arka Anamika; PP = Punjab Padmini; PS = Pusa Sawani

PK = Parbhani Kranti; MDU1 = Madurai 1; ML = Mohanur Local

nor low yields (Hayman, 8). The F_1 hybrids of the cross combination namely, PK × PP [recessive × (dominant + recessive)] could well be utilized for the exploitation of heterotic vigour for fruit yield per plant. The F_1 hybrids of this cross combination also recorded the maximum commercial heterosis. The other cross AA × ML involved recessive x recessive interaction. The cross ML × PK which recorded maximum standard heterosis also involved recessive x recessive interaction.

The standard deviation graph (Y_r, $W_r + V_r$ graph) almost confirmed the distribution pattern of genes, as inferred from V_r, W_r graph for fruit yield per plant (Fig. 3). The direct as well as the reciprocal cross combinations of the parents' *viz.*, AA and PS were the crosses which did not record significant heterosis for fruit yield per plant. The hybrids involving the cross combinations of these parents also failed to express significant heterosis for the characters *viz.*, days to first flowering, number of fruits, fruit weight and green matter production. This may be due to the fact that these parents carried all the dominant alleles for these traits and hence would not be expected to exhibit much heterosis on hybridization, as suggested by Young Jr. and Murray (17). On the other hand, the relative value of V_r, W_r showed that the parent

Table 6. Scaling and joint scaling test for okra fruit yield per plant.

Cross	Scale					
	A	B	C	D	$\chi^2_{(3)}$	P
AA × PK	8.68	-80.44**	-325.68**	-126.96**	167.99**	0.0001
	±11.01	±12.40	±28.46	±16.00		
PK × AA	-88.61**	-40.72**	-329.39**	-100.03**	177.85**	0.0001
	±14.33	±12.40	±26.45	±15.14		
AA × ML	-14.30	27.06	-296.95**	-154.85**	153.44**	0.0001
	±16.34	±17.46	±24.29	±16.80		
ML × AA	-18.90	-2.28	-227.53**	-103.17**	100.93**	0.0001
	±14.84	±13.72	±22.74	±14.93		
PK × ML	-58.49**	17.18	-187.13**	-72.91**	60.47**	0.0001
	±16.10	±15.18	±27.33	±17.11		
ML × PK	-32.86**	13.68	-360.72**	-170.77**	231.56**	0.0001
	±14.35	±20.35	±23.90	±16.82		

*, ** Significant at 5 and 1% levels

AA = Arka Anamika PP = Punjab Padmini PS = Pusa Sawani

PK = Parbhani Kranti MDU1 = Madurai 1 ML = Mohanur Local

Table 7. Genetic effects for okra fruit yield per plant.

Cross	Parameter					
	m	[d]	[h]	[i]	[j]	[l]
AA × PK	217.61**	47.25**	648.55**	253.92**	44.56**	-182.15**
	±32.03	±1.30	±73.37	±32.01	±8.05	±42.66
PK × AA	271.47**	-47.25**	449.55**	200.06**	-23.95**	-70.73
	±30.30	±1.30	±72.48	±30.28	±8.90	±44.04
AA × ML	197.93**	11.14**	800.71**	309.71**	-20.68	-322.47**
	±33.64	±1.42	±85.62	±33.61	±11.90	±53.14
ML × AA	301.28**	-11.14**	542.02**	206.35**	-8.31	-185.17**
	±29.89	±1.42	±74.55	±29.85	±10.03	±45.76
PK × ML	314.57**	-36.11**	473.72**	145.82**	-37.84**	-104.51*
	±34.27	±1.67	±83.90	±34.23	±10.90	±51.03
ML × PK	118.84**	36.11**	872.72**	341.54**	-23.27	-322.36**
	±33.69	±1.67	±86.84	±33.64	±12.33	±54.38

*, ** Significant at 5 and 1% levels

AA = Arka Anamika PP = Punjab Padmini PS = Pusa Sawani

PK = Parbhani Kranti MDU1 = Madurai 1 ML = Mohanur Local

AA had most recessive genes for fruit yield per plant and the parent PS had most dominant genes for fruit yield per plant. The standard deviation graph revealed that the parent namely, AA had recessive genes with positive effects and the parent PS had most dominant genes with negative effects. This may indicate that the dominant or recessive genes are not the cause for the heterosis. But, the combining ability may be the cause for heterosis. The scoring based on the overall gca effects of the parents namely, AA and PS showed less values. Their sca score were also negative. The parents of the cross combinations which recorded high heterosis, had highly significant gca effects and highly significant sca effects (mostly). The parents *viz.*, PK and PP were good general combiners and their cross combination *viz.*, PK × PP recorded high sca effects. Hence it may be pointed out that the combining ability of the parents could be the cause for the observed heterosis and may not be the gene distribution.

In V_r, W_r graph, the proximity of the points MDU 1 and PS from each other for fruit yield suggested that these parents have similar genotypes and that the differences among them might be due to genes with relatively small total influence on fruit yield per plant (Fig. 2). These genotypes formed a single group (say, group I). Similarly, the proximity of the points PK and ML from each other, for fruit yield per plant, suggested that these parents have similar genotypes (say, group II). The genotypes namely, PP and AA formed two separate single genotyped groups (says group III and group IV). The result revealed sufficient amount of genetic diversity among the parents used in the present inquiry. The cross combinations which recorded maximum mean fruit yield per plant *viz.*, PP × PK and ML × AA possessed parents from different groups, as inferred from the array points in V_r, W_r graph. This indicated that the observed heterosis may be partly due to genetic diversity among the parents used in the present investigation. Thus, the parents included in the present inquiry, offered a good scope for the inclusion in the hybridization programme.

From the generation mean analysis, scaling and joint scaling tests revealed the presence of epistatic interactions in almost all the cross combinations (Table 6). The different magnitude of positive and negative heterosis for the different characters in the F_1, over the parental means indicated the overall dominance of positively acting genes. On line with Francis Minvielle's (4) statement, the observed positive heterosis might be due to the random assortment of poorer and better alleles among the parents for a specific cross. The negative heterosis may be due to the more frequency of better alleles in only one parent of a particular cross. In the present study as inferred from generation mean and variance analysis, heterobeltiosis could well be attributed to the duplicate dominant epistasis, (Table 7) as reported by Senthil Kumar and Anandan (14). High specific combining ability may be due to epistasis. Hence, observed heterosis may be due to epistatic gene action. Whatever may be the hypothesis, heterosis is a result of complementation (Gallais, 5).

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