Plant Archives Vol. 16 No. 2, 2016 pp. 705-714 ***ISSN 0972-5210***

GRIFFING AND HAYMAN'S DIALLEL ANALYSES OF VARIANCE FOR SHOOT FLY RESISTANCE TRAITS IN SORGHUM

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Abstract

Diallel analysis involving nine divergent parents were used to study the inheritance of shoot fly resistance in sorghum at sorghum research unit, Dr. P.P.D.K.V., Akola (A.P.), India. Observations were recorded on grain yield, number of eggs per plant at 14 and 21 DAE, seedling vigour, leaf glossiness, dead heart at 14 and 28 DAE, trichomes density chlorophyll content index and recovery percent. Data were analysed as per Griffing and Hayman model. The mean squares due to genotypes were significant, which indicated presence of substantial degree of diversity for all the characters studied. It is seen from general combining ability effects that the parents IS 18551, IS 2312, SPV 504, Ringni and AKSV 13R showed desirable *gca* effect for most of the shoot fly resistance traits in F_1 diallel progenies. Crosses exhibiting highest positive significant *sca* effects for almost all the shoot fly resistance traits included CSV 18R × IS 18551, Ringni a × AKR MS45B and IS 2312 × IS 18551. So, these crosses may be forwarded further to develop genotypes with shoot fly resistance. Lower magnitude of variance due to *gca* than *sca* revealed that non-additive gene action was predominant for all the characters studied. Hayman's graphical approach showed over dominance for yield and most of the traits contributing to shoot fly resistance. Ringni was identified as the parent having most of the dominant genes for almost all the characters contributing to shoot fly resistance. Thus, heterosis breeding would be rewarding due to the presence of non additive gene action as per Griffing's approach and predominance of overdominance as per Hayman's approach.

Key words : Diallel analysis, F_1 generation, gene action, shoot fly resistance.

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is an important staple food for the rural poor in the semi-arid tropics. Sorghum is the third most important cereal after wheat and rice in the country and is being grown in both the *kharif* and *rabi* seasons. Although, *rabi* sorghum is preferred over *kharif* sorghum due to its superior grain quality, but its productivity is not high compared to that of *kharif* sorghum. Several constraints affect the grain yield and among these, shoot fly and drought are the most important. As *rabi* sorghum is normally grown on stored soil moisture from the post monsoon rains and the receding soil moisture, the crop yields suffer from occurrence of post-flowering moisture stress. Although *rabi* sorghum is characterized by good grain quality, but the introduction of *kharif* sorghum in breeding programme with the objective of increasing yield levels, noticed increase in susceptibility to shoot fly and decrease in grain quality. Therefore, breeding for shoot fly resistance is one of the main objectives of *rabi* sorghum crop improvement programme.

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The combining ability analysis provides information on estimates of general and specific combining ability effects and variances, which have a direct bearing on deciding the next phase of breeding programme.

During the past few years, several reports have appeared which indicated that diallel analysis is the quickest method of understanding the genetic nature of quantitatively inherited traits and to ascertain the prepotency of parents. Out of various methods to analyse the diallel crosses, the combining ability analysis (Griffing, 1956b) and the graphical analysis (Jinks and Hayman, 1953; Hayman, 1954) are most frequently used. The approaches of Griffing (1956a) and Hayman (1954a, 1954b) are statistically similar, in their analyses of variance. Griffing's general combining ability (*GCA*) component is mathematically identical to Hayman's additive component. Griffing employs one specific combining ability (*SCA*) and one reciprocal effect

Table 1 : Analysis of variance of parents and F_1 crosses in 9 × 9 diallel set of sorghum.

S. no.	Characters/Degrees of freedom	Sources					
		Replication	Treatments	Parents	F_1 Crosses	Parents vs. F_1 crosses	Error
		2	44	8	35	1	88
1	Grain yield per plant	0.77	1064.32**	66.56**	977.66	12079.66**	4.49
2	Numbers of eggs per plant at 14 DAE	0.04	0.87**	2.64**	0.49**	0.004	0.03
3	Numbers of eggs per plant at 21 DAE	0.09*	1.55**	6.55**	0.34**	3.93**	0.01
4	Dead heart percentage at 14 DAE	1.24	143.07**	258.46**	119.29**	52.46*	11.39
5	Dead heart percentage at 28 DAE	7.91	164.08**	294.14**	116.88**	775.68**	8.97
6	Trichomes density	0.001	5.50**	9.79**	4.29**	13.28**	0.002
7	Seedling vigour	0.01	0.31**	0.53**	0.27**	0.0001	0.023
8	Leaf glossiness	0.113**	0.39**	0.58**	0.35**	0.002	0.020
9	Recovery percentage	10.83	215.17**	280.34**	200.34**	210.19**	5.44
10	Chlorophyll content index	8.83**	20.47**	22.50**	16.72*	135.591*	2.673

** Significant at 1% level, * Significant at 5% level.

Table 2 : Analysis of variance for the combining ability of F_1 crosses in 9 x 9 diallel set.

S. no.	Characters/Degrees of freedom	Sources					
		GCA 8	SCA 36	Error 88	σ^2 gca	σ^2 sca	σ^2 gca / σ^2 sca
1	Grain yield per plant	208.17**	387.35**	1.496	18.789	385.857	0.049
2	Seedling vigour at 14 DAE	0.17**	0.09**	0.008	0.015	0.082	0.183
3	Leaf glossiness at 14 DAE	0.20**	0.11**	0.007	0.018	0.105	0.17
4	Trichomes density	2.75**	1.63**	0.001	0.25	1.624	0.154
5	Chlorophyll content index	10.11**	6.09**	0.891	0.838	5.202	0.161
6	Numbers of eggs per plant at14 DAE	0.60**	0.22**	0.009	0.054	0.212	0.252
7	Numbers of eggs per plant at 21 DAE	1.12**	0.38**	0.004	0.102	0.379	0.268
8	Dead heart percentage at 14 DAE	129.24**	29.57**	3.78	11.404	25.773	0.442
9	Dead heart percentage at 28 DAE	137.30**	36.34**	2.988	12.21	33.349	0.366
10	Recovery percentage	90.70**	67.51**	1.813	8.081	65.692	0.123

** Significant at 1% level.

component, while Hayman subdivides these into three dominance components (b1, b2 and b3) and two reciprocal effect components (c and d). They differ, however, in the genetic assumptions and interpretations which are associated with them. Griffing's analysis is a strict statistical treatment of main effects (*GCA*) and interactions (*SCA*) whereas Hayman's analysis incorporates genetic assumptions. Griffing's method involves only ANOVA and estimation of *GCA* and *SCA* effects. Hayman's method, on the other hand, may include statistical and graphical analyses of array variances and covariance, and the estimation of a number of genetic parameters. Hence, in the present study, diallel analysis was adopted broadly to undertand the inheritan of traits contributing to shoot fly resistance.

Materials and Methods

The experimental material consisted of nine diverse genotypes crossed in diallel fashion to secure 36 F_1's. These F_1's along with parents were sown in randomized complete block design, replicated thrice during *rabi* 2011-2012. Data were recorded for grain yield plant^{-1} (g) seedling vigour at 14 DAE, leaf glossiness at 14 DAE, trichome density on 14 DAE, chlorophyll content index

Table 3 . Estimates of general combining ability effects of parents from F_1 crosses.

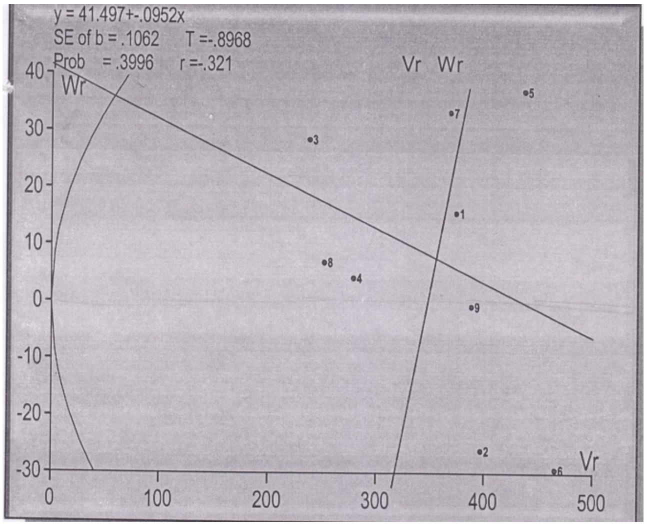
S. no.	Parents	Grain yield per plant	Seedling vigour	Leaf glossiness	Trichome density	Chlorophyll content index	Number of eggs/plant at 14 DAE	Number of eggs/plant at 21 DAE	Dead heart percentage at 14 DAE	Dead heart percentage at 28 DAE	Recovery percentage
1.	Ringni	6.854 **	-0.013	-0.009	-0.032 **	-0.492	-0.075 **	-0.084 **	-0.522	0.150	0.832 *
2.	M-35-1	4.598 **	0.045	0.023	-0.131 **	0.219	0.002	-0.103 **	-0.909	1.032 *	-1.091 **
3.	SPV 504	1.631 **	0.028	-0.040	-0.084 **	-0.268	-0.087 **	-0.101 **	-0.862	-1.267 *	0.952 *
4.	AKSV 13R	1.692 *	-0.004	0.042	0.137 **	-0.268	-0.039	-0.112 **	-0.168	-1.358 **	0.359
5.	MS 104-B	-0.176	.086 **	0.133 **	-0.193 **	0.729 **	0.155 **	0.217 **	3.210 **	2.576 **	-0.205
6.	MS 45-B	-4.685 **	0.120 **	0.137 **	-0.787 **	1.792 **	0.461 **	0.721 **	4.672 **	3.189 **	-5.515 **
7.	CSV 18R	-4.178 **	0.140 **	0.136 **	-0.344 **	0.635 *	0.151 **	0.095 **	3.923 **	5.416 **	-2.402 **
8.	IS 2312	2.962 **	-0.210 **	-0.221 **	0.439 **	-1.275 **	-0.283 **	-0.304 **	-5.362 **	-5.809 **	4.492 **
9.	IS 18551	-5.436 **	-0.192 **	-0.201 **	0.996 **	-1.073 **	-0.285 **	-0.330 **	-3.982 **	-3.930 **	2.578 **
SE (m) (gi)		**0.348**	**0.025**	**0.023**	**0.008**	**0.268**	**0.027**	**0.002**	**0.554**	**0.491**	**0.383**
CD 5% (gi)		**0.691**	**0.049**	**0.046**	**0.016**	**0.533**	**0.054**	**0.036**	**1.100**	**0.976**	**0.761**
CD 1% (gi)		**0.916**	**0.066**	**0.061**	**0.021**	**0.706**	**0.072**	**0.047**	**1.459**	**1.293**	**1.008**
SE (m) (gi-gj)		**0.522**	**0.037**	**0.035**	**0.011**	**0.402**	**0.041**	**0.027**	**0.831**	**0.737**	**0.574**
CD 5% (gi-gj)		**1.037**	**0.074**	**0.069**	**0.022**	**0.799**	**0.107**	**0.054**	**1.651**	**1.464**	**1.14**
CD 1% (gi-gj)		**1.374**	**0.097**	**0.092**	**0.029**	**1.058**	**0.081**	**0.071**	**2.188**	**1.94**	**1.511**

at 21 DAE, number of eggs per plant at 14 and 21 DAE, dead heart percentage at 14 and 28 DAE and recovery percentage for five randomly selected plants in each F_1 and parents. Seedling vigour and leaf glossiness were measured on scale 1-5 as suggested by Sharma *et al*. (1997). Trichome density was calculated as per the procedure outlined by Sharma *et al*. (1997). Chlorophyll content index was recorded using SPAD 502 chlorophyll meter. All the recommended cultural operations were carried out to raise a good crop. All the necessary data transformations were done for seedling vigour, leaf glossiness, dead heart percentage and recovery percentage. Data were subjected to statistical analyses as per Griffing (1956b), method-2, model-1 and Hayman (1954b).

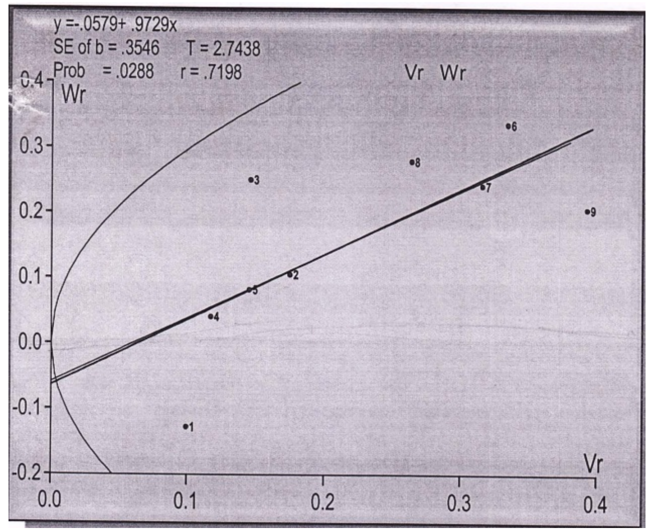
Results and Discussion

The analysis of variance (table 1) also exhibited significant variation for all the characters under study which is indicative of their genetic diversity. Sufficient range of variation has been observed in all characters under study. Nimbalkar and Bapat (1987) also found similar results who also observed a wide diversity among parents as indicated by highly significant variances due to parents, F_1's and segregating generations.

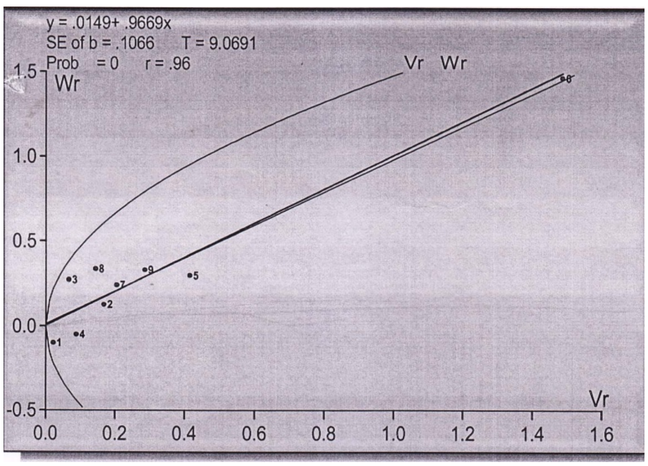
It is seen from the table 2 that four parents proved to be best general combiner for all the shoot fly resistance related traits under study. The parent IS 18551 has been found to possess desirable gca for all the shoot fly resistance characters such as number of eggs per plant at 14 and 21 DAE, dead heart percentage at 14 and 28 DAE, trichome density, seedling vigour, leaf glossiness, recovery percentage and chlorophyll content index in F_1 diallel progenies. Another parent IS 2312, transmitted favourable genes for almost all the shoot fly resistance related characters in F_1 diallel set. This parent IS 2312 has been found to possess desirable gca for all the shoot fly resistance characters such as number of eggs per plant at 14 and 21 DAE, dead heart percentage at 14 and 28 DAE, trichome density, seedling vigour, leaf glossiness, recovery percentage and



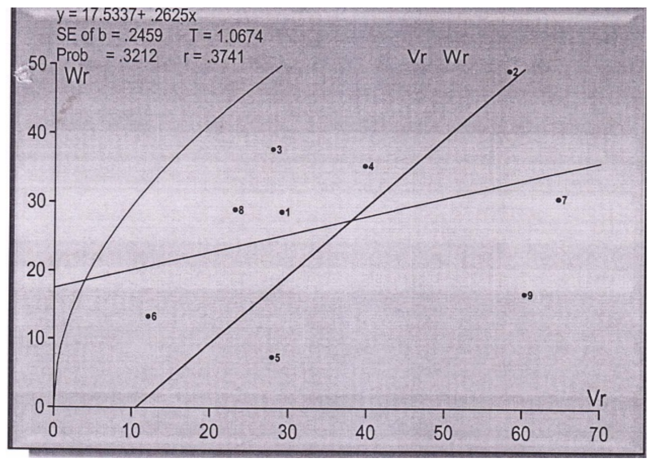
Grain yield



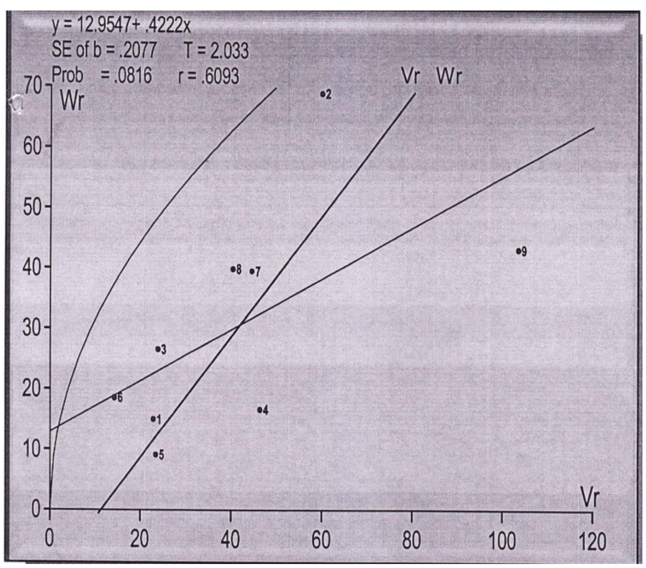
Number of eggs per plant 14 DAE



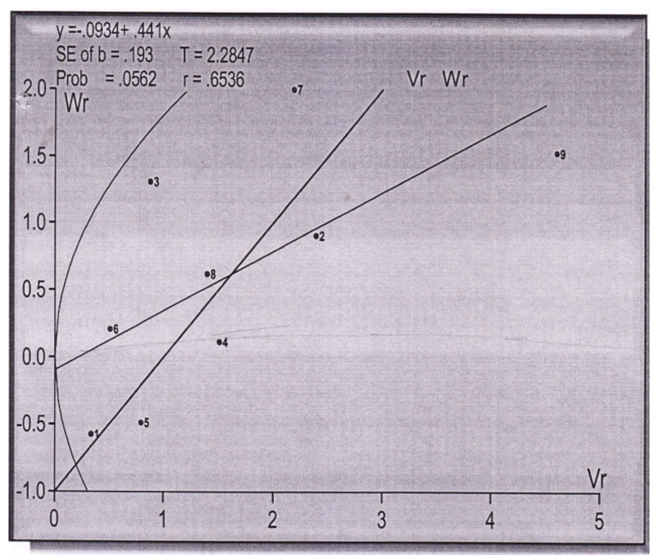
Number of eggs per plant 21 DAE



Dead heart percentage at 14 DAE

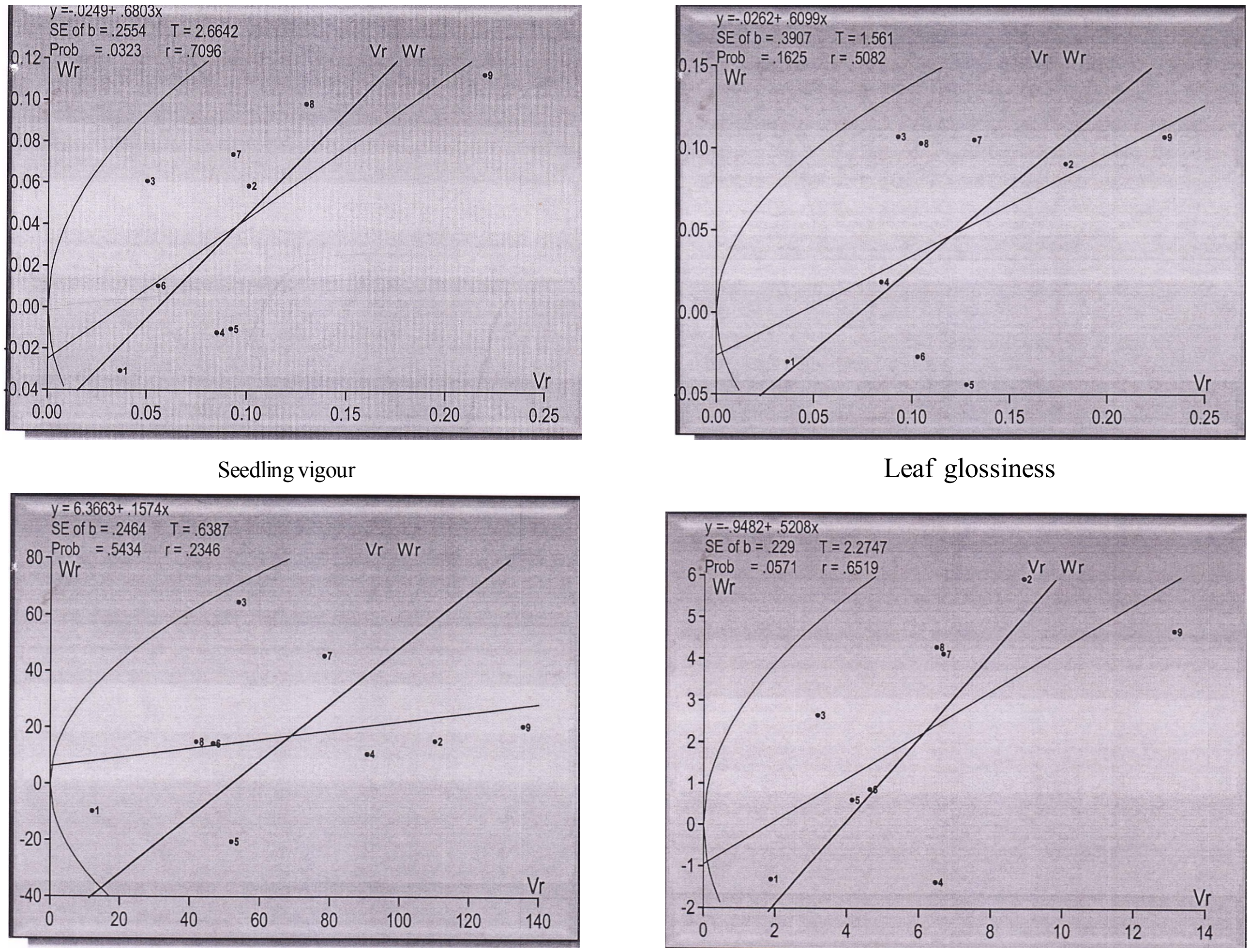


Dead heart percentage at 28 DAE



Trichome density

Fig. 1 : Vr-Wr graph.



Seedling vigour

Leaf glossiness

Recovery percentage

Chlorophyll content

Fig. 2 : Vr-Wr graph.

chlorophyll content index in F_1 diallel progenies. Third parent identified to contribute favourable genes was SPV 504 in F_1 diallel crosses for number of eggs per plant at 14 and 21 DAE, dead heart percentage at 28 DAE, and recovery percentage in F_1 diallel progenies. The parent Ringni was found to be capable of transmitting favourable genes for genes for number of eggs per plant at 14 and 21 DAE, recovery percentage and grain yield per plant, in F_1 diallel progenies. The parent AKSV 13R also possessed favourable genes for dead heart percentage at 28 DAE, trichome density, number of eggs at 14 and 28 DAE and grain yield per plant.

First cross that exhibited significant desirable sca effects in F_1 diallel set for characters related to shoot fly resistance was CSV 18R × IS 18551. This cross exhibited significant desirable *sca* effects for number of eggs per plant in 14 DAE, dead heart percentage at 14 DAE, trichome density per mm^2, seedling vigour 14 DAE, leaf glossiness, recovery percentage, chlorophyll content index, and grain yield per plant in F_1 diallel. The next cross, Ringni × AKRMS 45B, recorded significant desirable *sca* effects for most of the shoot fly resistance traits in F_1 diallel. The characters included number of eggs per plant at 14 DAE, trichome density, seedling vigour, leaf glossiness, recovery percentage, chlorophyll content index and grain yield per plant.

The third cross which exhibited non significant but negative *sca* effect for dead heart percentage at 14 DAE, but exhibited negative significant *sca* effect for dead heart percentage at 28 DAE was IS 2312 × 1S 18551. The same cross also showed significant desirable *sca* effect for some of the shoot fly resistance traits. Some other promising crosses included AKSV 13R × MS 104B, AKRMS 45B × CSV 18R, M-35-1 × IS18551, MS 104B × AKRMS 45B, SPV 504 × AKSV 13R and MS 104B × CSV 18R. Some of the crosses with desirable *sca* effects for grain yield are CSV 18R × IS 18551, M-35-1 × AKRMS 45B and Ringni × IS 2312. Positively significant *sca* effects for grain yield were recorded by 22 crosses in F_1 diallel progenies.

Table 4 : Estimates of specific combining ability effects for F_1 crosses in 9 x 9 diallel set.

S. no.	Characters	Seedling vigour	Leaf glossiness	Trichome density	Chlorophyll content index
	Crosses				
1	Ringni × M-35-1	-0.11	0.009	-0.167 **	0.744
2	Ringni xSPV 504	0.014	0.071	-0.188 **	0.582
3	Ringni × AKSV 13R	-0.061	-0.117	-0.402 **	0.661
4	Ringni × MS 104B	-0.151	-0.208 **	0.211**	-0.935
5	Ringni × AKRMS 45B	-0.291 **	-0.319 **	1.022**	-2.179 **
6	Ringni × CSV 18R	-0.205*	-0.211 *	0.121**	-0.341
7	Ringni × IS 2312	-0.068	-0.068	-0.055	0.568
8	Ringni × IS 18551	0.584**	0.582**	-2.261 **	4.086**
9	M-35-1 × SPV 504	0.136	0.309**	-0.989**	2.201*
10	M-35-1 ×AKSV 13R	0.338**	0.308**	-1.32**	2.840**
11	M-35-1 × MS 104B	-0.423**	-0.590**	1.846**	-0.16
12	M-35-1 × AKRMS 45B	-0.046	0.042	0.321**	3.700**
13	M-35-1 × CSV 18R	0.274**	0.374**	-1.32 **	0.191
14	M-35-1 × IS 2312	-0.263**	-0.373**	2.068**	-2.373**
15	M-35-1 × IS 18551	-0.144	-0.393 **	0.978**	-2.475**
16	SPV 504 × AKSV 13R	-0.208*	-0.437 **	1.056**	-1.712
17	SPV 504 × MS 104B	0.174*	0.109	-0.188 **	0.981
18	SPV 504 × AKRMS 45B	0.151	0.355**	-0.817**	-0.252
19	SPV 504 × CSV 18R	-0.049	0.016	-0.044	0.555
20	SPV 504 × IS 2312	0.391**	-0.037	-0.740 **	2.434**
21	SPV 504 × IS 18551	-0.127	0.049	-0.356**	-0.338
22	AKSV 13R × MS 104B	-0.373 **	0.277**	0.488**	-2.009*
23	AKSV 13R × AKRMS 45B	-0.300 **	-0.370**	0.859**	-2.546**
24	AKSV 13R × CSV 18R	0.243**	0.024	-1.244 **	2.684**
25	AKSV 13R × IS2312	-0.077	0.201*	-0.757 **	1.144
26	AKSV 13R × IS18551	0.575**	0.451**	-2.517 **	4.992**
27	MS 104-B × AKRMS 45B	-0.284 **	-0.705 **	0.669**	-1.999
28	MS 104-B × CSV 18R	-0.018	0.183*	-0.125 **	2.428**
29	MS 104-B × IS 2312	-0.061	0.200**	0.416**	-1.502
30	MS 104-B × IS18551	0.564**	0.360**	-2.194 **	3.935**
31	AKRMS 45-B × CSV 18R	-0.051	-0.071	-0.190 **	0.764
32	AKRMS 45-B × IS 2312	0.389**	0.196**	-0.973 **	2.434**
33	AKRMS 45-B × IS 18551	-0.006	0.356**	-1.096 **	1.172
34	CSV 18R × IS 2312	0.279**	0.287**	-0.694 **	2.338**
35	CSV 18R × IS 18551	-0.512 **	-0.643 **	2.617**	-4.121**
36	IS 2312 × IS 18551	-0.209 **	-0.149*	0.321**	-0.451
	SE (m) Sij	**0.080**	**0.075**	**0.024**	**0.863**
	CD Sij at 5%	**0.158**	**0.148**	**0.048**	**1.715**
	CD Sij at 1%	**0.209**	**0.196**	**0.064**	**2.272**
	SE (m) Sij-Sik	**0.117**	**0.109**	**0.036**	**1.272**
	CD (Sij-Sik) at 5%	**0.232**	**0.217**	**0.071**	**2.527**
	CD (Sij-Sik) at 1%	**0.308**	**0.287**	**0.100**	**3.349**

* Significant at 5% level and ** Significant at 1% level and others are non-significant.

Table 4 contd…

Table 4 contd…

S. no.	Characters	Number of eggs per plant at 14 DAE	Number of eggs per plant at 21 DAE	Dead heart percentage at 14 DAE	Dead heart percentage at 28 DAE	Recovery percentage
	Crosses					
1	Ringni × M-35-1	0.281**	0.174**	-0.041	-0.165	1.587
2	Ringni × SPV 504	0.187*	0.143*	-0.157	0.201	0.747
3	Ringni × AKSV 13R	0.282**	0.124*	-2.105	1.182	1.152
4	Ringni × MS 104B	-0.146	-0.296**	8.220**	0.185	1.053
5	Ringni × AKRMS 45B	-0.488 **	-0.849**	-0.298	-4.255*	5.887**
6	Ringni × CSV 18R	-0.818 **	-0.103	-3.849*	3.305*	1.307
7	Ringni × IS 2312	0.282**	0.135*	-0.368	0.199	-3.830**
8	Ringni × IS 18551	0.684**	0.661**	8.166**	10.300**	-11.642**
9	M-35-1 × SPV 504	0.359**	0.332**	4.706**	6.162**	-7.706**
10	M-35-1 × AKSV 13R	0.391**	0.443**	1.519	-3.244*	-10.360 **
11	M-35-1 × MS 104B	-0.584 **	-0.606**	-2.463	6.426**	12.083**
12	M-35-1 × AKRMS 45B	-0.269 **	-0.550**	-3.255	2.876	4.723**
13	M-35-1 × CSV 18R	0.321**	0.376**	11.801**	5.882**	-10.253 **
14	M-35-1 × IS 2312	-0.375**	-0.386**	-5.251 **	-4.046	10.030**
15	M-35-1 × IS 18551	-0.244 **	-0.210**	-5.148**	-5.182**	10.784**
16	SPV 504 × AKSV 13R	-0.200*	-0.179**	-7.141 **	-4.621**	7.196**
17	SPV 504 × MS 104B	0.096	-0.088	-2.526	0.915	-1.177
18	SPV 504 XAKRMS 45B	0.081	-0.292**	2.666	0.759	-9.386**
19	SPV 504 × CSV 18R	0.091	0.054	4.054*	-1.661	0.931
20	SPV 504 × IS 2312	0.494**	0.413**	5.036**	8.710**	-4.823 **
21	SPV 504 × IS 18551	0.196*	0.139*	-0.951	0.691	2.258
22	AKSV 13R × MS 104B	-0.243 **	-0.377**	2.300	-3.654*	3.389**
23	AKSV 13RXAKRMS 45B	-0.518 **	-0.801**	1.018	0.463	7.576**
24	AKSV 13R × CSV 18R	0.312**	0.385**	5.320**	6.552**	-11.511 **
25	AKSV 13R × IS2312	0.276**	0.274**	1.025	5.514**	-4.235 **
26	AKSV 13R × IS18551	0.697**	0.670**	10.542**	13.578**	-16.343 **
27	MS 104-B × AKRMS 45B	-0.612**	-1.030**	-6.477 **	-4.521 **	8.250**
28	MS 104-B × CSV 18R	-0.082	-0.244**	-5.735 **	-3.854*	-2.233
29	MS 104-B × IS 2312	-0.079	-0.256**	-4.327*	-2.243	2.853*
30	MS 104-B × IS18551	0.543**	0.410**	5.783**	10.028**	-15.876 **
31	AKRMS 45-B × CSV 18R	-0.227*	-0.548**	-4.233*	-0.117	-3.236 **
32	AKRMS 45-B × IS 2312	0.196*	-0.119*	3.522	-0.309	-4.417**
33	AKRMS 45-B × IS 18551	0.078	-0.283**	1.502	6.072**	-1.882
34	CSV 18R × IS 2312	0.316**	0.237**	0.224	3.907*	-3.010 **
35	CSV 18R × IS 18551	-0.792**	-0.794**	-12.446 **	-11.245**	13.698**
36	IS 2312 × IS 18551	-0.589	-0.029	0.589	-1.641	3.961**
	SE (m) Sij	**0.087**	**0.058**	**1.781**	**1.581**	**1.231**
	CD Sij at 5%	**0.173**	**0.116**	**3.539**	**3.141**	**2.416**
	CD Sij at 1%	**0.229**	**0.154**	**4.689**	**4.163**	**3.241**
	SE (m) Sij-Sik	**0.129**	**0.086**	**2.620**	**2.331**	**1.818**
	CD (Sij-Sik) at 5%	**0.256**	**0.171**	**5.219**	**4.632**	**3.612**
	CD (Sij-Sik) at 1%	**0.339**	**0.226**	**6.912**	**6.138**	**4.787**

* Significant at 5% level and ** Significant at 1% level and others are non-significant.

Table 5 : Gene action governing inheritance of different characters in F_1 diallel set.

S. no.	Characters	Gene action
1.	Seed yield per plant (g)	Non-additive
2.	Number of eggs per plant 14 DAE	Non-additive
3.	Number of eggs per plant 21 DAE	Non-additive
4.	Dead heart percentage 14 DAE	Non-additive
5.	Dead heart percentage 28 DAE	Non-additive
6.	Trichomes density per mm^2	Non-additive
7.	Seedling vigour 14 DA E	Non-additive
8.	Leaf glossiness 14 DAE	Non-additive
9.	Recovery percentage	Non-additive
10.	Chlorophyll content index	Non-additive

Thus, it could be concluded that, three specific combinations *viz*., CSV 18R × IS 18551, Ringni × AKRMS 45B and IS 2312 × IS 18551 recorded in table 4 were observed to be most desirable, since it had significant desirable *sca* effects in desirable direction in F_1 diallel set.

When the performance of all the desirable combinations or crosses are reviewed, it has been observed that these crosses involved parents having all three possible combinations of gca effects *i.e.* high × high, high × low and low × low. It was also observed that two parents with high *gca* effects may not necessarily give superior combinations. But, highly superior combinations have involved at least one parent of high gca effects.

In the present investigation, it could be concluded that *sca* variances were predominant for most of the studied characters like grain yield per plant, number of eggs per plant at 14 DAE and 28 DAE, dead heart percentage at 14 and 28 DAE, trichome density, seedling vigour, leaf glossiness, recovery percentage and chlorophyll content index. Rao *et al.* (1974) concluded that inheritance of ovipositional non preference appears to be additive and hybrids are generally superior to their parents. Thus, predominance of *sca* variances indicated that shoot fly resistance appears to be largely non-additive, though there are some evidences for additive type. These were in line with the results of Nimbalkar and Bapat (1987) reported that egg laying and dead heart were under the control of non additive gene action. Aruna and Padmaja (2009) also reported that non additive gene action played important role in governing glossiness, seedling vigour and proportion of plants with dead hearts. But, Starks *et al.* (1970) reported that additive gene action contributed to most of the variation, which was against the present findings. Dhillion *et al.* (2006) indicated the predominance of additive gene effects for leaf glossiness, trichomes and plants with dead hearts. Bhadouriya and Saxena (1997), Aruna *et al.* (2011) indicated the presence of both types of gene action for all the characters studied.

In Hayman's approach of diallel analysis, a graph is drawn with the help of variances of arrays (V_r) and covariances between parents and their offsprings (Wr). The graph is between parents and their offsprings (Wr). The graph (figs. 1 & 2) is known as Vr-Wr (Hayman, 1954b). The position of the regression line on a Vr-Wr graph provides information about the average degree of dominance. The line with unit slope cuts the Wr axis below the point of origin, tending to move downward indicating the presence of over dominance for grain yield. The array of points of various parents were scattered widely indicating diversity among parents. Points near the origin indicates increasing dominance while the points ascending the unit line of slope indicates recessiveness. The additive component (D) was non significant, but the dominance components (H_1 and H_2) were significant and greater in magnitude than additive component(D) indicating over dominance for grain yield. Existence of over dominance suggests the superiority of hetrozygotes over homozygotes and thus warrants the development of hybrid varieties (Farshadfar *et al.*, 2011). Operation of over dominance for grain yield per plant was also observed by Nazeer *et al.* (2011) in wheat. The Fr is a positive value indicating the proportion of dominance allele is in excess than the recessive alleles. The value of $H_2/4H_1$ which should be theoretically equal to 0.25 was 0.23 indicating asymmetrical distribution of genes with positive and negative effects among the parents. The ratio K_D/K_r, more than 1 indicated more of dominant alleles in the parents. The narrow sense heritability for this trait was 13.7 per cent and 'E' estimate was non significant suggesting minimum role of environment in modifying this trait.

The traits contributing resistance to shoot fly included number of eggs at 14 DAE, dead heart at 14 DAE and 28 DAE, seedling vigour, leaf glossiness, trichome density and chlorophyll content at 14 DAE and recovery percentage. The position of regression line on a Vr-Wr graph provides information about average degree of dominance (Singh and Narayan, 1993). The regression line for number of eggs per plant at 14 DAE, dead heart percentage at 14 DAE and 28 DAE, trichome density, seedling vigour, leaf glossiness, recovery percentage and chlorophyll content passes below the origin cutting the Wr axis in the negative region or additive effect (D) $<H_1$ (dominance variance) indicating the presence of overdominance. The existence of overdominance suggests the superiority of heterozygote over homozygote and thus warrants the development of hybrid varieties. When the

Table 6 : Estimates of genetic parameters and genetic ratios for grain yield and shoot fly resistance traits for shoot fly resistance in sorghum.

Parameter/ratio	Grain yield per plant	Number of eggs/plant 14 DAE	Number of eggs/plant 28 DAE	Dead heart percentage	Dead heart percentage 28 DAE	Trichomes density per mm^2	Seedling vigour 14DAE	Leaf glossiness 14 DAE	Recovery percentage	Chlorophyll content index
Additive effect (D)	20.72±68.25	0.87*±0.07	2.18*± 0.09	82.43*±3.70	95.07*±16.18	3.26*±0.75	0.17*±0.03	0.19*±0.05	91.71*±30.35	6.56*±1.93
Dominance effect (H_1)	1407.96*± 150.64	1.11*± 0.17	2.16*± 0.21	118.18*± 30.23	135.40*± 35.71	7.27*± 1.65	0.38*±0.07	0.47*±0.10	295.75*± 66.99	20.52*±4.27
Symmetry/asymmetry of allele (H_2)	1312.50*± 12.50	0.72*± 0.14	1.06*± 0.18	103.63*± 25.99	120.28*± 30.70	5.72*± 1.42	0.32*± 0.06	0.411*± 0.06	243.24*± 57.59	19.71±2.46
Mean F_r over arrays (F)	11.35±159.23	1.12*±0.18	3.06*±0.22	56.34±31.95	68.44±37.74	4.03*±1.74	0.19*±0.07	0.19±0.11	115.30±70.81	4.47±4.51
Heritability (h^2)	1766.91*± 86.75	-0.003±0.09	0.57*±0.12	6.21±17.1	112.32*± 20.56	1.94±0.95	-0.002±0.04	-0.003±0.059	30.02±38.58	19.47±2.46
Environmental component (E)	1.47±21.58	0.009± 0.023	0.004± 0.03	3.72± 4.33	2.98± 5.12	0.0007± 0.24	0.008± 0.010	0.007± 0.015	1.85± 9.60	0.94± 0.61
Average degree of dominance	8.24	1.13	0.99	1.20	1.20	1.50	1.50	1.59	1.80	1.77
Proportion of positive and negative alleles in parents (H_2/ $4H_1$)	0.23	0.16	0.12	0.22	0.22	0.20	0.211	0.22	0.21	0.24
Proportion of dominant and recessive alleles in the parents (K_D/K_r)	1.07	3.64	5.82	1.80	1.87	2.41	2.12	1.91	2.08	1.48
Heritability in narrow sense (%)	13.7	27	28	41	39	22	21	21	18.8	20
Number of groups of genes which control the character and exhibit dominance (h^2/H_2)	1.35	-0.004	0.54	0.06	0.93	0.34	-0.009	-0.006	0.12	0.99

regression line pases through the origin, it indicates complete dominance (D=H_1). The character, number of eggs per plant at 21 DAE indicated complete dominance. The dispersion of parents aroud the regression line for this character showed that the parents M-35-1, Ringni, AKSV 13RR, CSV 18R and IS 18551 are close to the origin of co-ordinate and accordingly have more than 75% dominant genes, while all the other parents have mostly recessive genes. But, most of the dominant genes for all the shoot fly contributing traits were mostly distributed in parent Ringni. Most of the other parents possessed recessive allele for almost all the shoot fly resistance contributing traits. Positive value of Fr indicates that dominance alleles are more than recessive alleles. The parameters $H_2/4H_1$ was ≠ 0.25, for all the shoot fly resistance contributing traits. Accordingly, dominant genes having increasing and decreasing effects on these traits and are irregularly distributed in parents or they have asymmetric distribution (Mather and Jinks, 1982). Narrow sense heritability being lower for all te traits indicated that dominance variance was more than additive variance. Genetic advance is directly related to magnitude of narrow sense heritability. (Kearsey and Pooni, 2004). Thus, early generation selection for traits contributing to shoot fly resistance will not be effective. The ratio of K_D/K_r is more than 1 for all the characters indicating more dominant alleles in parents. The non significant environment component (E) for all the characters indicated that these traits were not influenced by environment. Pervasiveness of dominance phenomena as depicted by genetic components was verified by graphs which demonstrated over dominance for all the shoot fly contributing traits. This called for a prudent and more cautious selection exercise for exploitation of these attributes and suggested that manipulation of these parents might be useful through heterosis.

Thus, Hayman's diallel analysis showed predominance of over dominance for grain yield and traits contributing to shoot fly resistance. Hence, for improvement of these traits heterosis breeding would be rewarding.

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