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Heterosis for Resistance against Sorghum Downy Mildew [*Peronosclerospora sorghi* (Weston and Uppal) C.G. Shaw] Infection in Maize (*Zea mays* L.)

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ABSTRACT

Background: Sorghum downy mildew (SDM) of maize caused by the fungus *Peronosclerospora sorghi* (Weston and Uppal) C.G. Shaw is one of the most important diseases of maize and it remains vital constraint in maize production. Since maize is the highly cross pollinated crop, exploitation of heterosis is one of the breeding methods to increase the production. Negative values in the expression of heterosis indicate a contribution towards resistance which is highly needed in order to have reduced incid ence of sorghum downy mildew in maize hybrids.

Methods: The materials selected as parents for the present study consisted of nine maize inbred lines which comprised of three resistant (UMI102, UMI936(w) and UMI285), three moderately resistant (UMI176, UMI13 and UMI57) and three susceptible (UMI79, UMI432 and UMI467) inbreds to SDM incidence. Nine inbred lines were crossed in all possible combinations including reciprocals in diallel fashion and the resultant seventy two hybrids along with their parents and the check (COH(M)5) were raised and evaluated for resistance against SDM under glass house condition. The extent of heterosis was estimated over mid parent, better parent and popular check hybrid.

Result: Analysis of variance for sorghum downy mildew incidence revealed highly significant differences among parents and hybrids indicating greater diversity among the genotypes for sorghum downy mildew incidence under study. Out of seventy two hybrids, only three hybrids namely UMI 13 × UMI 936 (W), UMI 467 × UMI 936 (W) and UMI 432 × UMI 936 (W) exhibited three types heterosis significantly in negative direction.

Key words: Diallel crosses, Heterosis, Maize, Resistance, Sorghum downy mildew.

INTRODUCTION

Maize or Indian corn (*Zea mays* L.) is an important cereal crop of the world after wheat and rice. In India, the demand for maize is increasing every year due to poultry and other animals feed industry, industrial utilization and human consumption. The commercial exploitation of single cross hybrids in maize, initially suggested by Shull (1909), is emerging again because of their uniformity in plant characters than other types of hybrids and high yield potential. Hence, high yielding single cross hybrids are the need to meet the growing demand. One of the major factors limiting productivity in maize is the increasing incidence of pest and diseases. Among the various maize diseases, downy mildews are considered to be the major diseases. In origin, the downy mildews are “old world” diseases that now are very damaging and prevalent on the “new world crop” - maize (Shaw, 1975). None of the downy mildew diseases originated on maize (Shaw, 1975) but they possessed the ability to attack maize when maize was introduced from the new world to old world. Heavy losses (as high as 100 per cent) in maize due to downy mildew pathogens have been recorded in Philippines, Taiwan, Indonesia, Thailand, India, West Africa, Venezuela, Japan, Australia, Europe, North America and other parts of the world (Bonde, 1982 and Rifin, 1983). Downy mildews caused by species belonging to the genera Peronosclerospora and Sclerophthora are some of the most destructive diseases of maize (Frederiksen and Renfro, 1977). Of these, sorghum downy mildew (SDM) caused by *Peronosclerospora sorghi* (Weston and Uppal) C.G. Shaw is the most prevalent downy mildew in the tropical and subtropical areas of the world (Frederiksen *et al*., 1969, Pupipat, 1975 Frederiksen and Renfro, 1977 and Williams, 1984). In the case of disease resistance, heterosis in negative direction is expected to be present in the hybrids in order to have decreased incidence of disease.

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MATERIALS AND METHODS

The research work was carried out to study the extent of heterosis in single cross maize hybrids at the Department

of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore during 2007. The materials selected as parents for the present study consisted of nine maize inbred lines maintained by sib mating. The source and details of the parent materials are given in Table 2. Nine inbred lines were crossed in all possible combination including reciprocals in diallel fashion to synthesize seventy two F_1 hybrids by following tassel bag method (Jugenheimer, 1976).

In this present study, the parents, seventy two hybrids and a check (CM 500) were screened against Sorghum Downy Mildew infection by conidial spray inoculation method under green house condition as described by Craig (1976). Conidial suspension was prepared daily as described by Cardwell *et al*. 1994. The disease reaction was assessed at 21 days after plant emergence of test entries in seedling spray inoculation method under green house condition. Disease incidence in per cent was scored in all test entries after susceptible check, CM 500 showed 100 % infection by counting number of infected plants to total number of plants in each entry. Downy mildew incidence % was calculated as per standard procedure (Lal and Singh, 1984).

$$\text{Downy Mildew incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

The rating scale was followed as below:

Downy Mildew incidence (%)	Reaction
0 – 10	Resistance (R)
>10 – 30	Moderately resistance (MR)
>30 – 50	Moderately susceptible (MS)
>50	Susceptible (S)

The percentages covered a wide range of values between zero and one hundred and such data generally have a binomial distribution rather than a normal distribution. The arcsine transformation is the appropriate transformation recommended by Little and Hills (1978) for this type of data. The statistical analyses were conducted on transformed data.

The magnitude of heterosis in hybrids was expressed as percentage of increase or decrease of a character over the mid parent, better parent and standard hybrid which were estimated by following the formula of Fonesca and Patterson (1968).

RESULTS AND DISCUSSION

After sorghum downy mildew was recognized as an important corn disease, several maize breeding programmes emphasized special breeding objectives with respective to genetic resistance to the causal agent, *Peronosclerospora sorghi*. Maize growing countries are cognizant that a disease with the destructive potential of sorghum downy mildew must be carefully studied, anticipated and controlled.

Mean performance of parents and hybrids for SDM incidence

Analysis of variance revealed significant differences among the genotypes namely parents and hybrids with respect to SDM disease incidence (Table 1). The percentage of SDM incidence recorded under glass house for parents and hybrids and their reaction to SDM are presented in Table 2. Highly significant differences among parents and hybrids for sorghum downy mildew incidence indicate greater diversity among the genotypes for sorghum downy mildew incidence under study. So selection can be possible to improve this trait in this population. The parents differed significantly from the hybrids indicating the presence of significant heterosis for sorghum downy mildew incidence in maize.

The susceptible check, CM 500 showed 100 per cent incidence. The mean for SDM incidence of parents was 39.80 per cent and the average of hybrids was 52.27 per cent. The SDM disease severity in parents ranged from 2.62 per cent in UMI 936 (W) to 100 per cent in UMI 79. Among the parents UMI 102, UMI 936 (W) and UMI 285 were resistant and the parents UMI 176, UMI 13 and UMI 57 showed moderate response to SDM. The parents UMI 79, UMI 432 and UMI 467 were susceptible to SDM disease infection.

SDM per cent incidence for hybrids ranged from 8.70 per cent in cross UMI 936 (W) × UMI 102 to 96.82 per cent in UMI 79 × UMI 176. Out of seventy two hybrids, thirty one, twenty nine and eight hybrids showed susceptible, moderately susceptible and moderately resistant reaction and only four hybrids showed resistant response to SDM infection (Table 2).

The susceptible x susceptible hybrids, UMI 79 × UMI 432 (94.21 per cent), UMI 79 × UMI 467 (71.62 per cent), UMI 432 × UMI 79 (89.77 per cent), UMI 467 × UMI 79 (90.00 per cent) and UMI 467 × UMI 432 (65.00 per cent) showed susceptible reaction, while the hybrid UMI 432 × UMI 467 showed moderately susceptible response which was slightly below the reaction of susceptibility (48.61 per cent) (Table 2). These data indicated a dominance type of gene action in the mode of inheritance, with susceptibility being dominant. The range of dominance is from partial to complete dominance. This was in accordance with the results of Singburaudom and Renfro (1982) and Craig (1982b) in maize. Mochizuki (1975) suggested that when open pollinated varieties are used as parents, resistance was controlled by a polygenic system with no dominance.

In the crosses between susceptible and moderately resistant lines, UMI 79 × UMI 176 (96.82 per cent), UMI 79 × UMI 13 (71.73 per cent), UMI 432 × UMI 13 (54.49 per cent), UMI 432 × UMI 176 (63.86 per cent) and UMI 467 × UMI 176 (83.90 per cent) showed only susceptible reaction, while the other susceptible × moderately resistant hybrids UMI 79 × UMI 57 (40.08 per cent), UMI 432 × UMI 57 (37.84 per cent), UMI 467 × UMI 13 (33.81 per cent) and UMI 467 × UMI 57 (48.90 per cent) showed moderately susceptible reaction. Moderately resistant reaction was also shown by two hybrids, UMI 432 x UMI 936 (W) (25.44 per cent) and UMI 467 × UMI 936 (W) (19.52 per cent) (Table 2).

Table 1: Analysis of variance for downy mildew incidence.

Sources	df	Downy mildew incidence
Replicates	2	14.91
Genotypes	80	998.50**
Parents	8	2134.15
Hybrids	71	865.25
Par. Vs hybrids	1	1373.60
F1's	35	719.06
Reciprocals	35	1025.34
F1 Vs reciprocals	1	378.95
Error	160	18.98
Total	242	342.75
SE		3.56
CD @ 5%		6.98
CD @ 1%		9.19

** Significance at 1 per cent level.

The crosses between moderately resistant × susceptible parents UMI 176 × UMI 432 (87.56 per cent), UMI 176 × UMI 467 (69.09 per cent), UMI 176 × UMI 79 (92.34 per cent), UMI 13 × UMI 79 (91.53 per cent) and UMI 13 x UMI 467 (72.41 per cent) showed susceptible reaction to SDM infection while other moderately resistant × susceptible hybrids UMI 13 × UMI 432 (40.29 per cent), UMI 57 × UMI 79 (49.43 per cent), UMI 57 × UMI 432 (41.44 per cent) and UMI 57 × UMI 467 (40.12 per cent) showed moderately susceptible reaction (Table 2).

All the six hybrids between moderately resistant × moderately resistant parents namely UMI 176 x UMI 13 (49.01 per cent), UMI 176 × UMI 57 (46.27 per cent), UMI 13 × UMI 57 (43.36 per cent), UMI 13 × UMI 176 (44.41 per cent), UMI 57 x UMI 176 (45.24 per cent) and UMI 57 × UMI 13 (36.67 per cent) showed moderately susceptible reaction to SDM infection (Table 2).

All the crosses between moderately resistant × moderately resistant exhibited incidence greater than the intermediate values. All the crosses between resistant × moderately resistant and moderately resistant × resistant parents were susceptible than their respective parents except UMI 13 × UMI 936 (W) and UMI 57 × UMI 102. This indicated epistatic effects involved in the inheritance of sorghum downy mildew incidence.

Out of nine hybrids between moderately resistant × resistant parents, only one hybrid namely UMI 13 × UMI 936 (W) (9.69 per cent) recorded resistant response to SDM infection. Three (UMI 57 × UMI 102, UMI 57 × UMI 936 (W) and UMI 57 × UMI 285) of them showed moderately resistant reaction (15.24 per cent, 26.43 per cent and 19.17 per cent respectively), while other two hybrids UMI 176 × UMI 285 (32.34 per cent) and UMI 13 × UMI 102 (40.71 per cent) recorded moderately susceptible reaction. The hybrids UMI 176 × UMI 102 (81.74 per cent), UMI 176 × UMI 936 (W) (55.41 per cent) and UMI 13 × UMI 285 (68.20 per cent) showed susceptible reaction.

The crosses between resistant x susceptible parents UMI 102 × UMI 79 (89.77 per cent), UMI 102 × UMI 432 (79.89 per cent), UMI 102 × UMI 467 (62.20 per cent), UMI 936 (W) × UMI 79 (95.26 per cent), UMI 936 (W) × UMI 432 (94.59 per cent) UMI 285 × UMI 79 (88.00 per cent) and UMI 285 × UMI 432 (78.82 per cent) showed only susceptible reaction, while other two hybrids UMI 936 (W) × UMI 467 (39.03 per cent) and UMI 285 × UMI 467 (35.00 per cent) showed moderately susceptible reaction to SDM infection. The resistant × moderately resistant hybrids UMI 102 × UMI 13 (40.54 per cent), UMI 936 (W) × UMI 176 (40.22 per cent), UMI 936 (W) x UMI 13 (30.81 per cent), UMI 936 (W) × UMI 57 (37.36 per cent), UMI 285 × UMI 176 (32.94 per cent) and UMI 285 × UMI 13 (33.83 per cent) showed moderately susceptible reaction to SDM infection, while other two hybrids namely UMI 102 × UMI 57 (23.84 per cent) and UMI 285 × UMI 57 (18.36 per cent) recorded moderately resistant reaction. The hybrid UMI 102 × UMI 176 (53.66 per cent) showed susceptible reaction to SDM infection (Table 2).

All the crosses between moderately resistant × moderately resistance exhibited incidence greater than the intermediate values. All the crosses between resistant × moderately resistant and moderately resistant × resistant parents were susceptible than their respective parents except UMI 13 × UMI 936 (W) and UMI 57 × UMI 102. This indicated epistatic effects involved in the inheritance of sorghum downy mildew incidence.

Both susceptible × moderately resistant and moderately resistant × susceptible crosses showed moderately susceptibility reaction. Analysis of various categories of crosses indicated the complex and polygenic nature of inheritance of sorghum downy mildew incidence in maize. This result was in conformity with the earlier findings of Yen *et al*. (2001).

Heterosis for SDM infection in maize

The estimates of relative heterosis, heterobeltiosis and standard heterosis for SDM incidence are presented in Table 2. Negative values in the expression of heterosis indicate a contribution towards resistance, while positive values represent for susceptibility. Negative values require in the expression of heterosis in order to have reduced incidence of sorghum downy mildew. The parents differed significantly from the hybrids indicating the presence of significant heterosis for sorghum downy mildew incidence in maize.

Relative heterosis for SDM incidence ranged from -35.08 per cent (UMI 79 × UMI 57) to 214.53 per cent (UMI 102 × UMI 936 (W). Out of seventy two hybrids, thirty eight hybrids exhibited significant positive relative heterosis and only twelve hybrids exhibited significant negative relative heterosis. Highly significant positive relative heterosis was recorded in the cross UMI 102 × UMI 936 (W) (214.53 per cent) followed by UMI 176 x UMI 102 (172.55 per cent), UMI 102 × UMI 285 (138.84 per cent), UMI 13 × UMI 285 (128.75 per cent) and UMI 176 × UMI 936 (W) (123.36 per

Table 2: Per cent downy mildew incidence and heterosis over mid (di), better (dii) and standard hybrid (diii) for downy mildew incidence.

Entries	SDM incidence (%)	Reaction to *P. sorghi*	Heterosis (%)		
			di	dii	diii
Parents					
UMI 79	100.00 (89.40)	S	-	-	-
UMI 176	27.23 (31.47)	MR	-	-	-
UMI 432	88.02 (70.00)	S	-	-	-
UMI 467	69.54 (56.53)	S	-	-	-
UMI 13	25.55 (30.33)	MR	-	-	-
UMI 57	27.46 (31.57)	MR	-	-	-
UMI 102	7.77 (16.13)	R	-	-	-
UMI 936 (W)	2.62 (11.63)	R	-	-	-
UMI 285	10.04 (18.37)	R	-	-	-
Hybrids					
UMI 79 × UMI 176	96.82 (81.43)	S	34.75**	-8.91*	112.39 **
UMI 79 × UMI 432	94.21 (78.50)	S	-1.51	-12.19**	104.82 **
UMI 79 × UMI 467	71.62 (64.50)	S	-11.60**	-27.85**	68.27 **
UMI 79 × UMI 13	71.73 (57.93)	S	-3.23	-35.20**	51.13 **
UMI 79 × UMI 57	40.08 (39.27)	MS	-35.08**	-56.08**	2.48
UMI 79 × UMI 102	65.51 (54.07)	S	2.46	-39.52**	41.08 **
UMI 79 × UMI 936 (W)	66.35 (54.60)	S	8.08	-38.93**	42.38 **
UMI 79 × UMI 285	70.12 (56.90)	S	5.60	-36.35**	48.46 **
UMI 176 × UMI 432	87.56 (69.83)	S	37.65**	-0.24	82.19 **
UMI 176 × UMI 467	69.09 (56.27)	S	27.88**	-0.47	46.73 **
UMI 176 × UMI 13	49.01 (44.43)	MS	43.80**	41.21**	15.92
UMI 176 × UMI 57	46.27 (42.83)	MS	35.91**	35.69**	11.81
UMI 176 × UMI 102	81.74 (64.87)	S	172.55**	106.14**	69.26 **
UMI 176 × UMI 936 (W)	55.41 (48.13)	S	123.36**	52.97**	25.52 **
UMI 176 × UMI 285	32.34 (34.67)	MS	39.13**	10.17	-9.60
UMI 432 × UMI 467	48.61 (44.20)	MS	-30.14**	-36.86**	15.37
UMI 432 × UMI 13	54.49 (47.57)	S	-5.18	-32.05**	24.11 **
UMI 432 × UMI 57	37.84 (37.93)	MS	-25.30**	-45.81**	-0.99
UMI 432 × UMI 102	40.66 (39.60)	MS	-8.05	-43.43**	3.37
UMI 432 × UMI 936 (W)	25.44 (30.27)	MR	-25.85**	-56.76**	-21.01 *
UMI 432 × UMI 285	79.87 (63.43)	S	43.57**	-9.38	65.54 **
UMI 467 × UMI 13	33.81 (35.50)	MS	-18.27*	-37.21**	-7.29
UMI 467 × UMI 57	48.90 (44.37)	MS	0.72	-21.52**	15.76
UMI 467 × UMI 102	34.20 (35.80)	MS	-1.47	-36.67**	-6.60
UMI 467 × UMI 936 (W)	19.52 (26.17)	MR	-23.23*	-53.71**	-31.64 **
UMI 467 × UMI 285	63.65 (52.97)	S	41.43**	-6.31	38.14 **
UMI 13 × UMI 57	43.36 (41.17)	MS	33.01**	30.41**	7.51
UMI 13 × UMI 102	40.71 (39.67)	MS	70.73**	30.77**	3.44
UMI 13 × UMI 936 (W)	9.69 (14.50)	R	-30.90*	-52.20**	-62.18 **
UMI 13 × UMI 285	68.20 (55.70)	S	128.75**	83.63**	45.35 **
UMI 57 × UMI 102	15.24 (22.83)	MR	-4.26	-27.67*	-40.32 **
UMI 57 × UMI 936 (W)	26.43 (30.90)	MR	43.06**	-2.11	-19.37 *
UMI 57 × UMI 285	19.17 (25.90)	MR	3.74	-17.95	-32.41 **
UMI 102 × UMI 936 (W)	47.72 (43.67)	MS	214.53**	170.66**	14.00
UMI 102 × UMI 285	43.41 (41.20)	MS	138.84**	124.32**	7.55
UMI 936 (W) × UMI 285	17.60 (24.83)	MR	65.56**	35.21	-35.29 **
UMI 176 × UMI 79	92.34 (76.67)	S	26.86**	-14.24**	100.03 **
UMI 432 × UMI 79	89.77 (74.47)	S	-6.57	-16.70**	94.30 **

Table 2: Continue...

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UMI 432 × UMI 176	63.86 (53.10)	S	4.66	-24.14**	38.54**
UMI 467 × UMI 79	90.00 (74.63)	S	2.28	-16.52**	94.70**
UMI 467 × UMI 176	83.90 (66.43)	S	50.98**	17.51**	73.35**
UMI 467 × UMI 432	65.00 (53.77)	S	-15.02**	-23.19**	40.28**
UMI 13 × UMI 79	91.53 (73.20)	S	22.27**	-18.12**	90.96**
UMI 13 × UMI 176	44.41 (41.80)	MS	35.28**	32.84**	9.01
UMI 13 × UMI 432	40.29 (39.40)	MS	-21.46**	-43.71**	2.78
UMI 13 × UMI 467	72.41 (58.33)	S	34.31**	3.18	52.19**
UMI 57 × UMI 79	49.43 (44.67)	MS	-26.15**	-50.04**	16.56
UMI 57 × UMI 176	45.24 (42.27)	MS	34.11**	33.90**	10.31
UMI 57 × UMI 432	41.44 (40.07)	MS	-21.10**	-42.76**	4.54
UMI 57 × UMI 467	40.12 (39.30)	MS	-10.78	-30.48**	2.55
UMI 57 × UMI 13	36.67 (37.27)	MS	20.41*	18.06	-2.78
UMI 102 × UMI 79	89.77 (71.60)	S	35.69**	-19.91**	86.84**
UMI 102 × UMI 176	53.66 (47.10)	S	97.90**	49.68**	22.87*
UMI 102 × UMI 432	79.89 (63.40)	S	47.21**	-9.43	65.44**
UMI 102 × UMI 467	62.20 (52.10)	S	43.39**	-7.84	35.88**
UMI 102 × UMI 13	40.54 (39.53)	MS	70.16**	30.33*	3.14
UMI 102 × UMI 57	23.84 (29.17)	MR	22.29	-7.60	-23.83**
UMI 936 (W) × UMI 79	95.26 (79.53)	S	57.44**	-11.04**	107.49**
UMI 936 (W) × UMI 176	40.22 (39.30)	MS	82.37**	24.89*	2.63
UMI 936 (W) × UMI 432	94.59 (78.77)	S	92.98**	12.52*	105.57**
UMI 936 (W) × UMI 467	39.03 (38.67)	MS	13.45	-31.60**	0.87
UMI 936 (W) × UMI 13	30.81 (33.67)	MS	60.44**	10.99	-12.12
UMI 936 (W) × UMI 57	37.36 (37.67)	MS	74.38**	19.32	-1.70
UMI 936 (W) × UMI 102	8.70 (16.83)	R	21.25	4.34	-56.09**
UMI 285 × UMI 79	88.00 (69.83)	S	29.60**	-21.89**	82.27 **
UMI 285 × UMI 176	32.94 (34.97)	MS	40.33**	11.12	-8.72
UMI 285 × UMI 432	78.82 (62.67)	S	41.83**	-10.48*	63.48**
UMI 285 × UMI 467	35.00 (36.23)	MS	-3.25	-35.91**	-5.45
UMI 285 × UMI 13	33.83 (35.53)	MS	45.93**	17.14	-7.26
UMI 285 × UMI 57	18.36 (25.27)	MR	1.20	-19.96	-34.16**
UMI 285 × UMI 102	8.88 (17.10)	R	-0.87	-6.90	-55.32**
UMI 285 × UMI 936 (W)	8.97 (17.47)	R	16.44	-4.90	-54.55**
SE			**8.04**	**9.28**	**9.28**
CM 500	100.00 (89.40)				
COH(M)5	38.59 (38.32)				
Parental mean	39.80 (39.49)				
Hybrid mean	52.27 (47.05)				

Values in parentheses indicate arcsine transformed values.

R- Resistant; MR- Moderately resistant; MS- Moderately susceptible; S- Susceptible; **- Significance at 1 per cent level; *- Significance at 5 per cent level.

cent). Highly significant negative relative heterosis was recorded in the cross UMI 79 × UMI 57 (-35.08 per cent), UMI 13 × UMI 936 (W) (-30.90 per cent), UMI 432 × UMI 467 (-30.14 per cent), UMI 57 × UMI 79 (-26.15 per cent), UMI 432 × UMI 936 (W) (-25.85 per cent) and UMI 432 × UMI 57 (-25.30 per cent) (Table 2).

The heterobeltiosis ranged from -56.76 per cent (UMI 432 × UMI 936 (W)) to 170.66 per cent (UMI 102 × UMI 936 (W)). A total count of significant positive and negative heterobeltiosis was recorded in sixteen and thirty five hybrids respectively. A highly significant positive heterobeltiosis was exhibited in the cross, UMI 102 × UMI 936 (W) (170.66 per cent) followed by UMI 102 × UMI 285 (124.32 per cent), UMI 176 × UMI 102 (106.14 per cent), UMI 13 × UMI 285 (83.63 per cent), UMI 176 × UMI 936 (W) (52.97 per cent), UMI 102 × UMI 176 (49.68 per cent) and UMI 176 × UMI 13 (41.21 per cent). A highly significant negative heterobeltiosis was recorded by the cross UMI 432 × UMI 936 (W) (-56.76 per cent) followed by UMI 79 × UMI 57 (-56/08), UMI 467 × UMI 57 (-45.81 per cent).

The standard heterosis ranged from -62.18 per cent (UMI 13 × UMI 936 (W)) to 112.39 per cent (UMI 79 × UMI 176). Thirty one hybrids exhibited significant positive standard heterosis and twelve hybrids exhibited significant negative standard heterosis for SDM incidence. A highly significant positive standard heterosis was recorded in the crosses UMI 79 × UMI 176 (112.39 per cent), UMI 936 (W) × UMI 79 (107.49 per cent), UMI 936 (W) × UMI 432 (105.57 per cent), UMI 79 × UMI 432 (104.82 per cent), UMI 176 × UMI 79 (100.03 per cent), UMI 467 × UMI 79 (94.70 per cent), UMI 432 × UMI 79 (94.30 per cent) *etc*. A highly significant negative standard heterosis was recorded by the cross UMI 13 × UMI 936 (W) (-62.18 per cent) followed by UMI 936 (W) × UMI 102 (-56.09 per cent), UMI 285 × UMI 102 (-55.32 per cent), UMI 285 × UMI 936 (W) (-54.55 per cent), UMI 57 × UMI 102 (-40.32 per cent), UMI 936 (W) × UMI 285 (-35.29 per cent) and UMI 285 × UMI 57 (-34.16 per cent).

Among seventy two hybrids, only three hybrids namely UMI 13 × UMI 936 (W), UMI 467 × UMI 936 (W) and UMI 432 × UMI 936 (W) recorded three types of heterosis in negative direction. These results are in conformity with the earlier reports of Krishnappa *et al*. (1995) and Ruswandi *et al*. (2015).

CONCLUSION

Heterosis has been recognized for at least two hundred and fifty years. Shull discussed the beginning of the heterosis concept. A rational exploitation of heterosis has been one of the major reasons for the success of the commercial seed industry in maize. Negative values in the expression of heterosis indicate a contribution towards SDM disease resistance. The crosses UMI 79 × UMI 57, UMI 13 × UMI 936 (W), UMI 432 × UMI 467, UMI 57 × UMI 79, UMI 432 × UMI 936 (W) and UMI 432 x UMI 57 recorded highly significant negative relative heterosis and crosses UMI 432 × UMI 936 (W), UMI 79 × UMI 57, UMI 467 × UMI 936 (W), UMI 13 × UMI 936 (W), UMI 57 × UMI 79 and UMI 432 × UMI 57 showed highly significant negative heterosis over better parent. A highly significant negative standard heterosis was recorded by a cross UMI 13 × UMI 936 (W) followed by UMI 936 (W) × UMI 102, UMI 285 × UMI 102, UMI 285 × UMI 936 (W), UMI 57 × UMI 102, UMI 936 (W) × UMI 285 and UMI 285 × UMI 57. Out of seventy two hybrids, only three hybrids, UMI 13 × UMI 936 (W), UMI 467 × UMI 936 (W) and UMI 432 × UMI 936 (W) exhibited three types heterosis significantly in negative direction and they can be utilized as SDM resistant maize hybrids.

Conflict of interest

The authors declare no conflict of interest.

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