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# Heterosis for biochemical traits governing resistance to shoot fly in sorghum [*Sorghum bicolor* (L.) Moench.]

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## Abstract

**The present investigation is an attempt to study the heterosis manifested by the hybrids over mid parent and better parent for biochemical traits of shoot fly resistance in sorghum [*Sorghum bicolor* (L.) Moench]. Results revealed that chlorophyll, epicuticular wax, and protein content were under the control of both additive and non-additive gene action. Preponderance of non-additive gene action was noticed for free phenols and tannin content. Total sugar was under the influence of additive gene action. Maximum desirable heterosis over mid parent was observed for epicuticular wax (81.8%), followed by chlorophyll (–49.6%) and total sugars (–35.8%). Similar trend for heterobeltiosis was observed for epicuticular wax (66.7%), chlorophyll (–43.4%) followed by total free phenols (24.9%) and total sugars (–22.2%). Hybrid SPSFR 94022A × IS 5636 had considerably higher desirable heterosis over mid and better parent for total chlorophyll, total sugars, epicuticular wax and total free phenols whereas 27A × IS 22144 was the only hybrid to exhibit desirable positive and significant heterosis over mid parent for tannin content, and also over better parent though not at significant level. Heterosis exploitation is the best method for exploiting total free phenols and tannin content for shoot fly resistance. Both parents should have low protein to develop shoot fly resistant hybrids.**

**Key words:** Heterosis, biochemical traits, sorghum shoot fly, resistance

## Introduction

Sorghum shoot fly [*Atherigona soccata* (R)] is an important pest in Africa, Asia and Mediterranean Europe. It attacks sorghum from 5-25 days after seedling emergence, causing dead heart formation of central growing tip thus causing total loss to the infested plant. However some genotypes may produce tillers and make up the loss to some extent; this type of genotypes possess recovery resistance. Upto 20 per cent dead heart formation may not cause significant reduction in grain yield. Infestation leading to as high as 90 per cent dead heart formation [1] and 75 and 68 per cent loss in grain and fodder yield, respectively are noticed in severe cases [2]. All the three mechanisms of resistance *viz.*, antixenosis, antibiosis, and recovery resistance operate in sorghum for resistance to shoot fly. Antibiosis resistance operate mainly through secondary metabolites produced in the plant. Hence, measurement of concentration of allelochemicals present in the plant tissues permits the rapid determination of potentially resistant plant material. This also removes the variation associated with insect density and the effect of environmental influences on the expression of resistance to insects [3]. The percentage of nitrogen, reducing sugars, total sugars, moisture, and chlorophyll content of leaves have been reported to be higher in susceptible cultivars than in resistant ones [4, 5]. Lowest chlorophyll "a" and chlorophyll "b" contents were observed in a cultivar that had lowest infestation [6]. Higher quantities of total amino acid content were observed in shoot fly resistant lines than in the susceptible ones [7]. Susceptibility to shoot fly is positively correlated with phosphorus and negatively with total phenol content [8]. Lower levels of chlorophyll, protein, total sugars and higher tannin, were found in resistant genotypes [9]. However, not many studies are available on exploitation of heterosis for the above biochemical parameters. Since, hybrids are important and have occupied a prominent place in sorghum cultivation, it is desirable to study the behaviour and genetic control of these biochemical parameters to incorporate them in the shoot fly resistant hybrid development programmes.

## Materials and methods

The experimental material consisted of four female parents and three male parents. Among the female parents, three were resistant *viz.*, SPSFR 94012A, SPSFR 94022A and SPSFR 94031A, and one was susceptible, 27A. Among the male parents, one was susceptible *viz.*, RS 29 and other two *viz.*, IS 5636 and IS 22144 were resistant to shoot fly. These were crossed during 1998, the resulted twelve cross combinations were grown during 1999 in randomized block design with three replications for biochemical analysis and heterosis studies. Central leaf samples from 15 days old seedlings were collected from each replication. These samples were first dried in the sun

light and further oven dried at 80°C for 24 hours. Following six biochemical constituents were estimated in the biochemistry laboratory by using appropriate standard method as mentioned below: (i) chlorophyll by calorimetric method [10], (ii) epicuticular wax by spectrophotometric method [11], (iii) total sugars by anthrone method [12], (iv) Protein by Folin-ciocalteau method [13], (v) total free phenols by Folin-ciocalteau reagent method [14], (vi) tannin by Burns method [15]. The data obtained were used for statistical analysis. The amount of heterosis shown by hybrids for six biochemical traits over mid parents and better parents were estimated as per cent increase or decrease in the mean values of $F_1$ over mid parent and better parent values, respectively.

**Results and discussion**

Per cent heterosis over mid parent and better parent were estimated to know the possible gene action as well as to exploit heterosis for biochemical constituents. The magnitude of heterosis manifested over mid parent and better parent estimated for biochemical characters of the present study are presented in Table 1. Literature reveals that lower levels of chlorophyll, protein, epicuticular wax, total sugars and higher tannin and phenols are desirable in a sorghum plant to resist the shoot fly infestation. Hence, negative heterosis for the first four traits and positive heterosis for latter two is desired to exploit the heterosis for resistance to sorghum shoot fly.

*Total chlorophyll*: The magnitude of heterosis over mid parent varied form –49.6 (SPSFR 94022A × IS 5636) to 10.1 per cent (SPSFR 94031A × IS 22144) for total chlorophyll. Six of the 12 hybrids exhibited negative significant heterosis. Further, four out of these six hybrids were promising as they had overdominance gene action as measured by the negative significant heterobeitiosis. None of the hybrids possessed significant positive heterosis over mid parent, whereas four hybrids had positive significant heterosis over better parent.

*Total sugars*: Only one hybrid, 27A × IS 5636 recorded desirable significant negative heterosis over mid parent for this trait. However, additional five hybrids exhibited nonsignificant negative heterosis over mid parent. Similarly, five hybrids exhibited positive heterosis and remaining hybrid SPSFR 94022A × IS 22144 remained neutral for heterosis. No hybrid was significantly superior over their respective better parent in negative direction. Nine hybrids showed positive heterobeltiosis, but only three hybrids had significant levels.

*Protein*: Mid parent heterosis varied from –20.7 to 59.8 per cent. Six hybrids each exhibited significant and nonsignificant heterosis. Among the significant hybrids, four were in positive direction and only two hybrids, 27A × RS 29 (–19.9) and SPSFR 94022A × RS 29 (–20.7) were in desired negative direction. Among these two, former hybrid also expressed significant heterobeltiosis (–19.1). On the other hand six hybrids had significant positive heterobeltiosis.

*Epicuticular wax*: Heterosis over mid parent ranged between -41.2 (SPSFR 94012A × IS 5636) and 81.8 per cent (27A ×IS 5636). Five hybrids recorded significant positive heterosis and only one hybrid (SPSFR 94012A × IS 5636) possessed significant negative heterosis. Only two hybrids *viz.*, SPSFR 94022A × IS 5636 (62.5%) and SPSFR 94031A × IS 22144 (66.7%) expressed significant positive heterobeltiosis and none was significant in reverse direction. Heterobeltiosis varied from –44.4 to 66.7 per cent.

*Total free phenols*: Nine hybrids had desired significant positive heterosis over mid parent. SPSFR 94022A × IS 5636 recorded highest positive heterosis (31.8%) over mid parent followed by SPSFR 94012A × RS 29 (24.4). Mid parent heterosis ranged between -1.3 and 31.8 per cent, where as range of heterobeltiosis was also of similar magnitude with minimum limit of -9.9 and maximum limit of 24.9 per cent. Above two hybrids also recorded highest positive and significant heterobeltiosis, followed by SPSFR 94031A × IS 5636 and 27A × IS 5636.

*Tannin*: Only one hybrid, 27A × IS 22144 (16.2) had desired significant positive heterosis for tannin content. This hybrid was unable to prove its significance over better parent with 7.1 per cent heterobeltiosis. On the other hand, 10 hybrids exhibited negative and significant superiority over mid and better parent. The mid parent deviation ranged between –37.1 and 16.2 per cent, whereas heterobeltiosis varied from –45.6 to 7.1 per cent.

Maximum desirable heterosis over mid parent was observed for epicuticular wax (81.8%), followed by chlorophyll (–49.6%) and total sugars (–35.8%). Similar trend of heterosis over better parent was observed for epicuticular wax (66.7%) and chlorophyll (–43.4%) followed by total free phenois (24.9%) and total sugars (–22.2%).

Fifty per cent of the hybrids exhibited significant heterosis over mid parent for total chlorophyll, epicuticular wax, and protein content indicating the importance of both additive and non-additive gene action for these traits. Further, four hybrids each categorized themselves into positive significant, negative significant and non-significant better parent heterosis for chlorophyll content, indicating different roles of chlorophyll in

**Table 1.** Magnitude of heterosis manifested over mid parent and better parent for biochemical characters associated with resistance to sorghum shoot fly

| Genotypes | Total chlorophyll | | Total sugars | | Protein | | Epicuticular wax | | Total free phenols | | Tannin | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MP | BP | MP | BP | MP | BP | MP | BP | MP | BP | MP | BP |
| 27A × IS 5636 | −6.4 | 24.5** | −35.8** | −22.2 | 9.7* | 32.4** | 81.8* | 25.0 | 16.7** | 12.8** | −19.8** | −22.8** |
| × IS 22144 | 6.4 | 83.3** | 14.6 | 71.9** | 6.2 | 34.7** | 63.6* | 12.5 | 10.8** | 4.2 | 16.2** | 7.1 |
| × RS 29 | −34.2** | −23.9* | −12.1 | −9.4 | 19.9** | −19.1* | 7.7 | −30.0 | −1.3 | −2.3 | −4.1 | −8.9 |
| SPSFR 94012A | | | | | | | | | | | | |
| × IS 5636 | −16.3* | −13.2 | 3.8 | 20.6 | 16.2** | 18.9** | −41.2* | −44.4 | 8.4** | 4.2 | −12.2** | −26.4 |
| × IS 22144 | −3.2 | 25.0* | 18.2 | 21.8 | 59.8** | 70.7** | −17.7 | −22.2 | 6.2* | 0.47 | −37.1** | −45.6** |
| × RS 29 | −43.5** | −38.6** | 21.6 | 82.4** | 9.7* | 30.5** | 26.3 | 20.0 | 24.4** | 23.8** | −27.6** | −43.7** |
| SPSFR 94022A | | | | | | | | | | | | |
| × IS 5636 | −49.6** | −43.4** | −22.8 | −15.8 | 0.4 | 1.7 | 73.3* | 62.5* | 31.8** | 24.9** | −30.5** | −42.2** |
| × IS 22144 | −29-4** | 0.0 | 0.0 | 9.4 | 0.4 | 6.1 | 20.0 | 12.5 | 11.7* | −3.1 | −15.3** | −26.9** |
| × RS 29 | −3.8 | −3.0 | −15.1 | 18.4 | −20.7** | −4.5 | 29.4 | 10.0 | −0.86 | −9.9* | −22.5** | −39.9** |
| SPSFR 94031A | | | | | | | | | | | | |
| × IS 5636 | −30.2** | −30.2** | −7.7 | 9.1 | 2.8 | 7.2 | 41.2* | 33.3 | 21.3** | 20.6* | −18.6** | −33.6** |
| × IS 22144 | 10.1 | 36.1** | −10.3 | −9.4 | −9.6 | −9.6 | 76.5* | 66.7** | 8.1* | −0.9 | −25.0** | −36.5** |
| × RS 29 | −1.7 | −11.9 | 16.8 | 78.8** | 2.2 | 31.2** | −15.8 | −20.0 | 5.0 | 1.0 | −23.3** | −41.4** |
| CD at 5% | 0.24 | 0.28 | 0.41 | 0.47 | 1.38 | 1.60 | 0.12 | 0.14 | 0.81 | 0.94 | 0.94 | 1.09 |
| CD at 1% | 0.34 | 0.39 | 0.57 | 0.66 | 1.94 | 2.24 | 0.17 | 0.20 | 1.13 | 1.31 | 1.31 | 1.53 |

*,** denote significance at 5 and 1 per cent level respectively; MP = Mid parent; BP = Better parent; #negative heterosis for total chlorophyll, total sugars protein and epicuticular wax, and positive heterosis for tannin and total free phenols.

antibiosis of parents and their inheritance in the hybrids. Lower level of chlorophyll is desired for a genotype to be resistant to shoot fly as revealed by the earlier workers [6]. Thus parents producing non-heterotic hybrids for chlorophyll content may be preferred while aiming to produce shoot fly resistant hybrids. Better parent heterosis for protein content was associated with over dominance for higher protein content in six crosses. In general, higher protein content appears to be dominant. Lower protein content is desirable in a genotype in resisting the infestation by shoot fly [7, 9]. Therefore, it is essential to select both the parents with lower protein content to develop hybrids with low protein as to build up resistance in them. Nine of the twelve hybrids exhibited significant heterosis over mid parent for total free phenols and tannin content indicating preponderance of nonadditive gene action for these two traits. This indicates that heterosis breeding can be effectively used for these characters while developing commercial hybrids with shoot fly resistance. Except one, all the hybrids were non-significant for mid parent heterosis indicating presence of additive gene action for total sugars.

Most of the hybrids exhibiting mid parent heterosis for epicuticular wax have shown heterobeltiosis in undesirable direction. Heterosis for quantity of epicuticular wax alone has very little importance; in fact earlier workers have envisaged that the quality of epicuticular wax plays more important role in shoot fly resistance than quantity itself. Genotypes that are resistant and moderately resistant to shoot fly possessed a smooth amorphous wax layer and sparse wax crystals on their leaves while susceptible lines are characterised by a dense meshwork of crystalline epicuticular wax [16].

Better parent heterosis indicated over dominance for higher levels of protein, phenols, sugars, and lower tannin content. May be for this reason, most of the hybrids under cultivation are susceptible to shoot fly as such the hybrids may exhibit higher protein and sugars by virtue of hybrid vigour and make themselves susceptible to shoot fly infestation. This is in agreement with views of earlier workers that susceptible sorghum genotypes produce more of sugar in their leaves [4, 9]. Hybrid SPSFR 94022A × IS 5636 had considerably higher desirable heterosis over mid parent and better parent for total chlorophyll, total sugars, epicuticular wax and total free phenols whereas 27A × IS 22144 was the only hybrid to exhibit desirable positive and significant heterosis over mid parent, and also over better parent but not at significant level. Greater dominance effects and duplicate type of epistasis for tannin content were observed by earlier workers [17]. Thus the results indicate that heterosis is the best method for exploiting tannin content in sorghum for shoot fly resistance.

From the results of the present investigation and forgoing discussion, it is inferred that heterosis breeding can form best method for exploiting total free phenols and tannin content for shoot fly resistance. Both parents should have low protein content to develop shoot fly resistant hybrids.

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