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Research Article

Correlation study of traits associated with shoot fly resistance in recombinant inbred lines (RILs) population of sorghum [*Sorghum bicolor* (L.) Moench]

Ehab, A.A. Salama[1,5]*, N. Kumaravadivel[2], S. Mohankumar[3] and N. Muthukrishnan[4]

[1]Research Scholar, Department of Plant Biotechnology, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore - 641 003. Tamil Nadu, India.
[2]Professor and Head, Department of Plant Molecular Biology and Bioinformatics, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore - 641 003. Tamil Nadu, India.
[3]Director, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore - 641 003. Tamil Nadu, India.
[4]Professor, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore - 641 003. Tamil Nadu, India.
[5]Department of Agricultural Botany, Faculty of Agriculture (Saba Basha), Alexandria University, Alexandria- 21531, Egypt.
***E-Mail:** kumaravadiveln@yahoo.com

Abstract

The shoot fly resistance in sorghum appears to be a complex trait and depends upon the interaction of a number of component characters, which finally sum up in the expression of shoot fly resistance. The present study was conducted during *Summer*-2019 to assess the correlation and study the relationship of different plant characters with shoot fly resistance in sorghum. Observations were recorded on the shoot fly components traits *viz.,* dead heart percentage and oviposition as well as the morphological characters *viz.,* trichome density, leaf glossiness, seedling vigour, 100 seed weight and grain yield per plant. The experimental data were collected and analyzed for correlation. Shoot fly resistance was found to be significant and positively correlated with components traits *viz.,* seedling vigour, glossiness and trichome density at the abaxial and the adaxial surface of leaves lamina. Whereas a hundred grains weight and grain yield per plant were showed strongly significant, but negatively correlated with dead heart percentage at 21, 28 DAE and oviposition% in 14, 21 DAE respectively. The strong correlation of grain yield and these traits could indicate that improvement of all the characters is possible simultaneously and might be used to select shoot fly-resistant lines from the segregating breeding materials for use in sorghum improvement.

Keywords

Sorghum, shoot fly, correlation study, resistance and yield.

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.)] Moench] belongs to family Poaceae and commonly known as "Great millet". It is the fifth major cereal crop after wheat, rice, maize and barley it is an important grain and fodder crop in Asia, Africa, Australia and America. Sorghum is cultivated as a staple crop in the semi-arid tropics (SAT) because of its better adaptation to a wide range of ecological conditions, low input cultivation and diverse uses (Aruna *et al.,* 2011) and grown between 40°N and 40°S of the equator (Doggett, 1988). It is mainly a rain-fed crop of lowland, semi-arid areas of the tropics and sub-tropics and a post-rainy season crop grown on residual soil moisture, particularly in India. In India, it is cultivated in an area of 6.18 m ha with 5.33 million tonnes production and productivity of 863 kg/ha (Agricultural Census, 2013) and India ranks 3rd in the world after Sudan and Nigeria USDA (2017). The yield penalties to sorghum are very high starting from seedling stage to harvest and are allotted maximally to biotic stresses (Craufurd *et al.,* 1999).Insect pest situations are dynamic in nature and changes with climate, farming practices, the introduction of improved varieties have been known to result in pest outbreaks or changes in pest status

(Duale and Nwanze, 1999). Sorghum is attacked by more than 150 insect species causing a 32% crop loss (Borad and Mittal, 1983). Losses in sorghum due to insect pests differ in magnitude on a regional basis and have been estimated at the US $ 1089 million in the SAT, US $ 250 million in the USA and the US $ 80 million in Australia (Anonymous, 1992). Among them, the sorghum shoot fly, *Atherigona soccata* (Rondani) (Diptera: Muscidae), is the most destructive pest causing severe damage up to 4 weeks of sowing leading to 75.6% yield losses (Pawar *et al.*, 1984).

Shoot fly (*Atherigona soccata*) of the genus *Atherigona* is known to cause 'dead hearts' in a number of tropical grass species and wheat (Pont and Deeming, 2001). The shoot fly females lay eggs singly on the undersurface of the leaves, parallel to the midrib. After egg hatching, the larvae crawl to the plant whorl and move down the central leaf and cut the growing tip resulting in 'dead heart' symptoms (Sharma *et al.,* 2006). The late sown crop in most cases is affected by the hoot fly infestation due to erratic rainfall distribution which is common on the SAT. Agronomic practices, natural enemies, synthetic insecticides and host plant resistance have been employed for shoot fly management to minimize the losses (Kumar *et al.,* 2008). The severity of shoot fly infestation can be reduced by good management practices, of which the use of resistant cultivars is the most effective, economical and eco-friendly approach to control the pest. Although many notable successes have been achieved through conventional breeding in the improvement of plant resistance to insects, the breeding process is often slow and laborious, and sufficient levels of resistance have not been achieved due to the quantitative nature of resistance (Tao *et al.,* 2003).

However, concerted efforts toward breeding for shoot fly resistance have resulted in some progress, and a number of genotypes with resistance to shoot fly have been identified (Sharma *et al.,* 2003). The economic impact of shoot fly, the improvement of genetic resistance to this pest is one of the major goals of sorghum breeding programs in India (Nagaraj *et al.,* 2005). The shoot fly resistance in sorghum appears to be a complex trait and depends upon the interaction of a number of component traits, which finally sum up in the expression of shoot fly resistance (Dhillon, 2005). The traits like trichome density, leaf glossiness, seedling vigor and some biochemical factors are reported as marker traits for shoot fly resistance. In this framework, it would be necessary to study and find out the correlations of the shoot fly resistant components traits and importance of the contribution to the pest resistance.

MATERIALS AND METHODS

The field experiment was carried out at Eastern Block Farm, Tamil Nadu Agricultural University during *summer*, 2019 and the plant materials used for this study consisted of a set of 110 F_3 RILS derived from a cross between (K8 × IS 2205) were planted along with parents K8 (Susceptible variety) and IS 2205 (Resistant variety). The initial cross conducted between, (K8 × IS 2205) after that a single F_1 plant was selfed and resulting F_2 seeds from each single F_2 plant head-to-row (single seed descent method) randomly chosen to provide seeds for next generations up to F_4 RILS. The experiment materials were raised in a randomized block design. Each parental verities and F_3 lines were planted in a single row (1.5 m) length with the recommended inter and intra row spacing of 45 x 15 cm, respectively. All the recommended cultural operations based on Crop Production Guide (2014) without spraying any insecticide and the interlard fish meal technique (Soto, 1974) were carried out to raise a good crop and attain uniform shoot fly pressure under field condition for screening respectively. Thinning was carried out for 7 days after seedling emergence (DAE) and before the onset of shoot fly incidence, and 20 plants were retained in each row. Inter culture was carried out at 15 and 30 DAE; earthing up and application of urea at 100 kg/ha were carried out at 30 DAE and the field was irrigated after every 20 days of interval and hand weeding was carried out whenever necessary.

Phenotyping and Genetic Analysis for Traits

In one month after emergence, the observations were recorded for the characters related to shoot fly resistance on following component traits of resistance as below,

Shoot Fly damage parameters

Seedling with eggs was recorded by counting the total number of eggs laid on five random seedlings from each row. The mean number of eggs per seedling were calculated at 14 and 21 DAE, the mean value was calculated by the formula (ratio of the number of seedling with eggs/total number of plants * 100). Overall resistance was recorded as the percentage of the dead heart (DH%) caused by shoot fly infestation. The mean values of a DH per cent (number of the plant's dead heart / total number of plants × 100) were recorded on 21^{th} and 28^{st} DAE.

Morphological Characteristics

Leaf surface glossiness (denoted as GS), seedling vigour (abbreviated as SV), trichome density at abaxial (lower; TDL) and adaxial (upper; TDU), 100 seed weight (gm) and grain yield per plant (gm). Leaf glossiness was visually scored on a scale of 1–5 scores at 12 DAE [1 = non-glossy (dark green, dull, broad, and drooping leaves and 5 = high glossy (light green, shiny, narrow and erect leaves)] (Apotikar, 2011). The seedling vigour was recorded at 10 DAE on 1 to 5 rating scale [1= poor seedling vigour, plants showing poor growth, and weak seedlings and 5 = highly vigorous, plants showing maximum height, more number of fully expanded leaves, good adaptation, and robust seedlings] (Sharma and Nwanze1997). Trichome density was recorded at 14 DAE on the abaxial and the adaxial leaf surface on the central portion of the fifth leaf from the base, in five randomly selected seedlings in each row as per the procedure outlined by Sharma and Nwanze (1997). Briefly, the leaf segments (~ 2 cm^2) were cleared in acetic acid: alcohol (2:1) and transferred to 90 per cent lactic acid in small vials. The leaf segments were then mounted on a slide with a drop of water and observed under the microscope field at a magnification of 10X. The number of trichomes on the abaxial leaf surface was counted in three microscopic fields at random and expressed as trichome density (no./cm^2). The phenotypic correlations among different characters worked out and significance was tested using SPSS ver. 13.0. To understand the association between the shoot fly component traits and other resistant parameters.

RESULTS AND DISCUSSION

In the present investigation, the correlation between shoot fly resistance and its component traits was worked out among ten relevant parameters in *summer*2019. Shoot fly resistance was found to be significantly correlated with components traits *viz.,* dead heart percentage, seedling vigour, glossiness and trichome density on the abaxial and the adaxial surface of leaves. These traits could be considered as important for improving shoot fly resistance and yield per plant (**Table 1**). The hundred grains weight and Grain yield per plant were showed strongly significant but negatively correlated with a dead heart per cent at 21, 28 DAE and 14, 21 DAE Oviposition in RILs lines respectively, whereas they recorded significantly positive correlation among RILs in remaining component traits. The strong correlation of grain yield and these traits could indicate that improvement of all the characters is possible simultaneously. This is in line with the reports of (Ezeaku and Mohammed, 2006), (Aruna and Audilakshmi, 2008), (Sharma *et al*., 2006), (Elangovan *et al.,* 2007). Warkad *et al.,* (2010) reported that a hundred seed weight is positively and significantly associated with grain yield per plant.The highly significant negative correlation was observed between per cent oviposition at 14, 21 DAE and other eight traits associated with resistance whereas per cent oviposition and dead heart percentage were showed a strong positive association with each other. This may be due to fact that high egg load is due to heavy shoot fly population, which ensures availability of a large number of shoot flies for oviposition, thereby ultimately leads to high dead heart percentage in the genotypes. Thus, these traits are interrelated one and influence the other (Kamatar *et al.,* 2010). These results are in agreement with the findings of Omori *et al*., (1983), Taneja and Leuschner (1985), Mate (1979), Maiti and Bidinger (1979), Bapat and Mote (1982), Jayanti (1997), and Kamatar and Salimath (2002).

Table 1. Phenotypic correlations among component traits of shoot fly resistance in sorghum

Characters	Trichome density Abaxial	Trichome density Adaxial	Leaf glossiness	Seedling Vigor	Oviposition (%) 14 DAE	Oviposition (%) 28 DAE	Dead Heart (%) 21 DAE	Dead Heart (%) 28 DAE	Hundred grains weight (g)	Grain yield (g/pl)
Trichome density (Abaxial)	1									
Trichome density (Adaxial)	0.981**	1								
Leaf glossiness	0.902**	0.897**	1							
Seedling Vigor	0.936**	0.914**	0.865**	1						
Oviposition (%) 14 DAE	-0.855**	-0.846**	-0.796**	-0.822**	1					
Oviposition (%) 28 DAE	-0.732**	-0.715**	-0.686**	-0.688**	0.887**	1				
Dead Heart (%)21 DAE	-0.920**	-0.910**	-0.851**	-0.882**	0.891**	0.778**	1			
Dead Heart (%) 28 DAE	-0.909**	-0.897**	-0.845**	-0.875**	0.886**	0.767**	0.980**	1		
Hundred grains weight (g)	0.929**	0.927**	0.935**	0.895**	-0.826**	-0.704**	-0.880**	-0.876**	1	
Grain yield (g/pl)	0.933**	0.931**	0.945**	0.892**	-0.834**	-0.708**	-0.885**	-0.872**	0.971**	1

Note: Correlation coefficient significant at P = 0.01**

Leaf glossiness mainly acts as a non-preference mechanism. Glossiness plays a significant role in shoot fly resistance in sorghum, since and it is an inherited character Omori *et al., (*1972). The leaf glossiness intensity at seedling stage is positively associated with the resistance level to shoot fly possibly because of their effect on the reflection of light from the leaf surface, which influences the oviposition behaviour of shoot fly females (Sharma and Nwanze 1997). Seedling vigour revealed a negative association with shoot fly damage parameters (Ovipositional and dead heart incidence). These findings are in close agreement with Bhagwat *et al.,* (2011) and Syed *et al,.* (2017) and accordance with the reports of Patel and Sukhani (1990), Dhillon *et al*., (2005), Gomashe (2010), Chamarthi *et al.,* (2010) and they reported that the genotypes with highest leaf glossiness and trichome density were relatively less susceptible to shoot fly damage.

A highly significant negative association was found for trichome density at the adaxial and abaxial surface of leaf lamina and shoot fly damage parameters (ovipositional preference at 14 and 21 DAE and per cent dead hearts on 21 and 28 DAE). Trichomes or plant hairs are common anatomical features on leaves, stem, and/or reproductive structures in higher plants. Levin (1973) described the role of trichomes in plant defence and pointed out in numerous species, there is a negative association between trichome density and insect feeding, oviposition responses. The importance of trichome on the undersurface of leaves for shoot fly resistance has been reported by several workers (Gibson and Maiti, 1983 and Taneja Lauchner, 1985). Despite efforts to manipulate the resistance utilizing the existing sources, the level of resistance achieved is low. This is because several components are involved for resistance to shoot fly, and each is controlled by one or more genes and further influenced by the environment, thus affecting the efficiency of selection and improvement of resistance in an elite background. The level of resistance to shoot fly was higher when both glossy and trichome traits occurred together (Agrawal and House 1982; Dhillon *et al.,* 2005). Principal component analysis in the present study showed that trichome density is the most important trait contributing for shoot fly resistance in sorghum, supporting the earlier report by (Omori *et al.,* 1983; Sekar *et al.,* 2018; Abinaya, *et al.,* 2019). The inheritance of trichome density was reported to be complex and it differed with the type of parents involved and with the seasons (Jayanthi *et al.,* 1999). Oviposition non-preference (antixenosis), antibiosis and tolerance are the major components of resistance in sorghum to shoot fly (Doggett *et al.,* 1970; Raina *et al.,* 1981; Sharma and Nwanze 1997; *Dhillon et al.,* 2005, 2006a and Sivakumar *et al.,* 2008). The plants with more number of eggs have higher rates of dead heart formation indicating that oviposition has a direct correlation with dead heart incidence (Dhillon *et al*., 2006b). All the above component traits were found to be connected to a resistance mechanism known as non-preference for oviposition (Gorthy *et al*., 2017).

In the present study, those promising lines for both (grain yield and shoot fly tolerance) will be utilized for developing high yielding varieties and hybrids of sorghum with better resistance to shoot fly. Based on the results obtained from the present experiment, a high yielding line with a high level of resistance to shoot fly are recorded high seedling vigour, glossy leaves, and more number of trichomes on upper and lower leaves.

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