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Character association and path coefficient analysis of shoot fly resistance and yield components in sorghum (*Sorghum bicolor* (L.) Moench)

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Abstract

The present study was carried out to analyze and determine the component traits having strong association with shoot fly resistance and true contribution or mutual relationship toward the grain yield in sorghum. Sorghum RILs population, 110 lines were evaluated and the field experiment was conducted during *Kharif* season. Grain yield per plant recorded a strong negative correlation with days to 50% flowering, Per cent of oviposition at 14 DAE and dead heart per cent at 21, 28 DAE. Whereas, it showed significant positive correlation with hundred grain weight, seedling vigour, leaf glossinees and trichome density on both surface of leaves. Path coefficient analysis data showed that the characters, hundred grain weight (0.378), trichome density on abaxial leaf surface (0.257), per cent of oviposition at 21 DAE (0.208), dead heart per cent at 21 DAE (0.110), leaf glossiness (0.108) and trichome density on adaxial leaf surface (0.104) had positive direct effect on grain yield. Whereas, negatively direct effects were observed with number of eggs per seedling at 21 DAE (-0.192), dead heart per cent at 28 DAE (-0.190) and days to 50% flowering (-0.183) respectively. The characters, plant height, number of leaves per plant, leaf width and hundred grain weight were showed positive indirect effect on grain yield but stem girth, leaf length and days to 50% flowering had negative indirect effects. The obtained results from this investigation could help the selection for these traits and improve the shoot fly resistance and high yield varieties in sorghum.

Keywords: Shoot fly resistance, character association, path analysis and sorghum, grain yield

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is an annual diploid self-pollinated crop (2n = 2x = 20) known as jowar crop belonging to family Poaceae, subfamily Panicoidae, tribe Andropoganae and subtribe Sorghastrae (Price *et al.*, 2005) [25]. It has the ability to grow and produce grains under a wide range of agro-climatic conditions *viz.*, arid and semi-arid regions which almost have much less water and high temperatures, It is one important source of food, feed, fiber, and fuel in Asia, Africa, Australia and America. Sorghum grain is the second most important feedstock for bio-ethanol production in USA, after maize grain. In 2015, more than 63.5 million metric tonnes of sorghum were globally produced with productivity of 1.08 metric tonnes per hectare. The higher producer countries (in amount kg/h) were reported in USA, India, México, Nigeria, Sudan and Ethiopia (FAOSTAT, 2015) [13]. The higher producer country with an 11.5 million metric tonnes of yield was reported in USA followed by India, (USDA, 2016) [37]. The crop plays an important role in the food security of millions people and globally it is the fifth largest cereal crop after wheat, rice, maize, and barley. In India, it is cultivated in an area of 6.18 million hectare with 5.33 million tonnes production with 920 kg/ hectare and It is ranked 3rd in the world after Sudan and Nigeria (USDA, 2019) [38]. In Tamil Nadu state it is cultivated in 0.35 million hectare and the state ranked fourth after Maharashtra, Karnataka and Rajasthan states.

In different stages of plant growth and development, more than 150 insect pests attacking sorghum are reported in a loss of 32% (Borad and Mittal, 1983) [7]. Sorghum shoot fly, *Atherigona soccata* (Rondani) (Diptera: Muscidae), is the more destructive pest causing severe damage in 7-28 days after seedling emergence leading to 75.6% yield losses (Pawar *et al.*, 1984) [24]. Sorghum shoot fly lays eggs singly white, elongated and cigar-shaped on abaxial (lower) surface of the leaves parallel to mid-rib resulted in dead heart formation and the young seedlings may be killed outright or they may produce productive side tillers which serve as a mechanism of recovery resistance, but continues of shoot fly infestation the dead heart appearance will increase and lead to unproductive side tillers (Dhillon *et al.*, 2005) [10].

Generally, one of the most important and sustainable approach for management of insect pests and diseases is through the mechanisms of host plant resistance (HPR). The resistance level to sorghum shoot fly in earlier studies was categorized into three main components *viz*., antixenosis, antibiosis and tolerance (Soto, 1974) [33] and reported that the resistance component traits are quantitative complex traits (Agrawal and Abraham 1985) [2], with mostly additive gene effects (Nimbalkar and Bapat, 1992) [22]. Dhillon, (2005) [10] stated that the interaction between these components traits could finally sum up in the expression of shoot fly resistance. Leaf glossiness, trichomes density on both leaf surfaces, seedling vigour are important bio-physical component traits which quantitative in nature (Nwanze *et al.*, 1992) [23] and other biochemical factors *viz.*, tannin, proteins, fats and suger content are reported as marker traits associated with shoot fly resistance in sorghum (Singh *et al.*, 2004) [32]. Good agronomic practices (the use of resistant cultivars), natural enemies, host plant resistance and eco-friendly approaches have been employed for shoot fly management to minimize the production losses (Kumar *et al.*, 2008) [19]. Dewey and Lu (1959) [9] demonstrated the path coefficient analysis by partionating the simple correlation coefficient into direct and indirect effects of different traits which helps in estimating the cause-effect relationship in addition effective selection. Hence, it is very important to study path coefficient analysis, which concerns the causal and degree of relationship (Santosh *et al.*, 2017) [27].

With this background, due to the integration effect of component traits associated with shoot fly resistance and grain yield in sorghum, simple correlation alone is not effective way to understand the mutual relationship and true contribution of these traits toward grain yield in sorghum. So, this study aimed to analyze and determine the component traits having strong association with shoot fly resistance in sorghum through the correlation and path coefficient analysis.

Materials and Methods

Design of the field experiment

The present field experiment on F_4 RILS population derived from a cross between K8 (susceptible and high yielding variety) and IS2205 (resistant and low yielding variety) was conducted in Eastern Block farm with latitude and longitude of 11.0087 ^{0}N and 76.9404 ^{0}E respectively, Tamil Nadu Agricultural University during *Kharif*, 2019. The RILs along with their parents were raised and evaluated in randomized block design (RBD) with tow replications and 1.5 m row length with inter row spacing of 45 cm and intra row spacing 15 cm. Overall recommended practices were followed without spraying of any insecticide and other crop cultural management operations *viz.*, thinning, earthing up, fertilization, irrigation, weeding were followed to raise a successful crop.

Phenotyping of RILs population

All the observations from seedling stage to harvest were recorded on different characters associated with shoot fly resistance and grain yield in sorghum as following,

Per cent of oviposition, 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 was calculated at 14 and 21 DAE by formula

$$\text{Seedlings with eggs (\%)} = \frac{\text{number of seedlings with eggs}}{\text{total number of seedlings}} X\ 100$$

Dead heart per cent, the mean values of dead heart per cent (number of the plants dead heart / total number of plants × 100) were recorded on 21th and 28st DAE.

Leaf glossiness, it was is taken visually in the early morning and scored on a scale of 1–5 scores at 12 DAE [1 = non-glossy (dark green, dull, broad, and drooping leaves, 2 = Plants with moderate non glossy green pseudo-shining leaves which are broad and drooping leaves, 3 = Plants with moderate glossiness with fair green coloured light shining, leaf width moderate and shows less drooping of leaves, 4 = Plant with glossy light green, less shining with narrow and erect leaves 5 = high glossy (Plants with highly glossy light green leaves which are shining, narrow and erect)] (Apotikar, 2011) [3].

Seedling vigour, it is observed as seedling height, leaf growth and robustness after 14 DAE and visually scored on a scale of 1-5 [1 = Plants with poor seedling vigour, growth and seedlings, 2 = Plants with less vigour and plant height with poor adaptation and leaf expansion, 3 = Plants with moderate vigour, moderate plant height and moderate number of fully expanded leaves showing fairly good seedling growth, 4 = Vigorous plants having good seedling growth and fully expanded leaves and good height with good adaptation, 5 = Highly vigorous, robust plants having a maximum height with more number of fully expanded leaves with good adaptation] (Sharma and Nwanze, 1997) [31].

Trichome density: it was recorded at 14 DAE on the abaxial (lower; TDL) and adaxial (upper; TDU) 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) [31]. 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 in a drop of water and observed under microscope field at a magnification of 10X. The number of trichomes on abaxial leaf surface was counted in three microscopic fields at random and expressed as trichome density (no./cm^2).

Days to 50% flower in, the total number of days from sowing day to first flowering in 50 per cent of plants in each entry was counted and recorded as days to 50 percent flowering.

Plant height, height of the plants was measured from the ground level to the tip of the plant, including the panicle after flowering and recorded in cm.

Leaf length, the length of the fifth leaf from the top was measured for all the plants with the help of scale and recorded in cm at its maturity stage.

Leaf width width of the top fifth leaf was measured at its central position by scale at the maturity stage and expressed in cm.

Stem girth, the stem diameter from the middle of plant was measured and recorded in cm

Numbers of leaves per plant, the same number of leaves was measured on five random selected plants in each line

Hundred grain weight: Weight of 100 seeds was recorded in gm.

Grain yield, the total grain yield of individual plant yield was weighed and expressed in gm after harvesting the dried seeds of its panicles**.**

Statistical analysis

Simple correlation and Path coefficient analysis (direct & indirect effects) were estimated for all eighteen traits. Correlation was estimated by (Searle 1961) [28] and path-coefficient as elaborated by Dewey and Lu (1959) [9].

Results and Discussion

Selection based on the deep knowledge of magnitude and direction of association between grain yield and shoot fly resistance components traits is very important approach to identifying the key characters, which useful while planning a breeding programme for improving shoot fly resistance and grain yield varieties in sorghum.

Correlation

Correlation coefficient is a statistical parameter, which measure the degree and magnitude of association between any two casually related traits. In the present study, the correlation coefficient study was undertaken in order to find out the interrelationship of different yield components and the shoot fly resistance traits. The resistance level was recorded to be strongly correlated with components traits *viz.,* seedling vigour, leaf glossiness and trichome density on abaxial and adaxial surface of leaves which are considered an important traits for improving shoot fly resistance and grain yield per plant in sorghum as presented in (Table 1). Taking together**,** grain yield per plant was showed strongly significant but negatively correlated with days to 50% flowering, per cent of oviposition at 14 DAE and dead heart per cent at 21, 28 DAE in RILs. On the other hand, it showed significantly positive correlation with other components traits *viz*., hundred grain weight, seedling vigour, glossines and trichome density on abaxial and adaxial surface of leaves. These results are in agreement with the reports of (Sharma *et al*., 2006) [30], (Elangovan *et al.,* 2007) [11], (Aruna and Audilakshmi, 2008) [4], (Warkad *et al.,* (2010) [40]. (Sekar *et al.,* 2018) [29] reported that hundred seed weight is positively and significantly associated with grain yield per plant. Days to 50% flowering had showed negative significant correlation with hundred grain weight, trichome density on both surfaces of leaves, leaf glossines, seedling vigour and grain yield per plant but recorded a positive correlation with per cent of oviposition (0.199) and daed heart percent (0.222) at 21 DAE respectively. These results are in line with the findings of Ezeaku *et al.* (2005) [12]; Khaled *et al.* (2014) [18]. Kengra *et al.* (2006) [17] reported negative significant correlation for days to 50% flowering and 100 grain weight. The less number of days to flowering reduces the crop period, this helpful in terms of economic cultivation of sorghum crop. So, the negative correlation was desirable for days to 50% flowering. However, in contrast Rizwan (2001) observed significant positive correlation between days to 50% flowering and grain yield. Number of leaves per plant and the leaf length were showed positive correlation with the plant height whereas, number of leaves per plant showed negative correlation with dead heart per cent at 28 DAE. In addition stem girh recorded positive significant correlation with leaf width. These results are in confirmation with the findings of Ezeaku *et al.* (2005) [12]; Khaled *et al.* (2014) [18]. Warkad *et al.* (2010) [40] reported negative significant correlation for the same traits. Per cent of oviposition and dead heart percentage recorded strong positive association with each other. These results are in agreement with the findings of Kamatar and Salimath (2002) [16] and Abinaya *et al.,* 2019 [1]. The leaf glossiness intensity at seedling stage is positively associated with the resistance level to shoot fly because of their effect on reflection of light from the leaf surface, which influence the oviposition behavior of shoot fly females (Sharma and Nwanze 1997) [31]. Seedling vigour recorded negative association with shoot fly damage parameters (per cent of oviposition and dead heart incidence). These finding are in close agreement with Bhagwat *et al.,* (2011) [6] and Syed *et al.,* (2017) [34] and accordance with the reports of Dhillon *et al*., (2005) [10], Gomashe (2010) [15] and Chamarthi *et al.,* (2010) [8] which reported that the genotypes with highest leaf glossiness and trichome density were relatively less susceptible to shoot fly damage. Highly significant negative association was found for trichome density at 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) [20] described the role of trichomes in plant defense and pointed out in numerous species, there is negative association between trichome density and insect feeding, oviposition responses. The importance of trichome on the under surface of leaves for shoot fly resistance has been reported by several workers (Gibson and Maiti, 1983 and Taneja Lauchner, 1985) [14, 36].

Path analysis

Path coefficient analysis measures both direct and indirect effects of simple correlation and estimate the relative importance of the causal factor individually. Analysis the direct effect and their indirect effects of shoot fly components traits on grain yield provided the mutual relationship among various characters. Hence, the path coefficient analysis was estimated for grain yield and shoot fly component traits and the obtained results are furnished in Table 2.

Direct effect

From all analyzed phenotypic traits, it has been evident that the characters, hundred grain weight (0.378), trichome density on abaxial leaf surface (0.257), per cent of oviposition at 21 DAE (0.208), dead heart per cent at 21 DAE (0.110), leaf glossiness (0.108) and trichome density on adaxial leaf surface (0.104) were recorded a positive direct effect on grain yield per plant. Direct negative effects for grain yield were observed with number of eggs per seedling at 21 DAE (-0.192), dead heart per cent at 28 DAE (-0.190) and days to 50% flowering (-0.183). These results are in line with Vijaya kumar *et al.* (2012) [39] reported negative direct effect for days to 50% flowering and Arunkumar (2013) [5] reported the same for days to 50% flowering and stem girth. Either too early or too late to flowering may decrease the yield levels of sorghum. Hence breeder has to decide the optimum time of flowering which commensurate with sorghum grain yield. Hence, hundred grain weight may directly contribute for increasing yield also it indicates that selection can be performed for this trait in order to increase with grain yield.

Indirect effect

The characters *viz*., plant height, number of leaves per plant, leaf width, hundred grain weight, trichome density on abaxial and adaxial surface of leaves, leaf glossiness and seedling vigour showed a positive indirect effects on grain yield.

Whereas, negative indirect effects on grain yield were recorded with stem girth, leaf length, days to 50% flowering, number of eggs per seedling at 14, 21 DAE, per cent of oviposition at 14,21 DAE and dead heart per cent at 21, 28 DAE. These finding are in line with Tag El-Din et al. (2012) [35], Mahajan *et al.* (2011) [21] and Khaled *et al.* (2014) [18].

The critical analysis of the current investigation results through character association and path coefficient analysis revealed that grain yield per plant and shoot fly components traits had both positive association and highly positive direct effects. Hence, selection for these traits might helping the breeder for enhancement the resistance level of shoot fly and grain yield in sorghum.

Table 1: Phenotypic correlations among shoot fly resistance traits and yield components in sorghum

		PH (cm)	SG (cm)	NL	LL (cm)	LW (cm)	DTF	HGW (g)	TDL	TDU	LG	SV	NEg		Ovi (%)		DH %		GY (g/pl)
													14 DAE	21 DAE	14 DAE	21 DAE	21 DAE	28 DAE	
PH (cm)		1	-0.060	0.751**	0.227*	-0.012	-0.051	0.126	0.135	0.134	0.078	0.093	-0.100	-0.041	-0.107	-0.157	-0.097	-0.183	0.094
SG (cm)			1	0.093	0.092	0.2768**	-0.033	-0.022	-0.025	0.028	-0.063	-0.052	0.113	-0.095	0.111	0.098	0.132	0.114	-0.009
NL				1	0.130	0.048	-0.010	0.065	0.032	0.059	0.027	0.085	-0.121	0.047	-0.127	-0.118	-0.166	-0.190*	0.003
LL (cm)					1	0.147	0.074	0.011	0.012	-0.059	-0.036	-0.030	0.050	0.117	0.051	0.072	0.042	0.053	-0.053
LW (cm)						1	-0.148	0.086	0.066	0.071	0.098	-0.056	0.030	0.064	0.038	0.057	0.069	0.049	0.050
DTF							1	-0.734**	-0.801**	-0.761**	-0.802**	-0.256**	0.173	0.060	0.176	0.199*	0.222*	0.127	-0.805**
HGW (g)								1	0.890**	0.793**	0.865**	0.362**	-0.400**	-0.133	-0.396**	-0.346**	-0.399**	-0.263**	0.890**
TDL									1	0.888**	0.933**	0.351**	-0.397**	-0.154	-0.396**	-0.381**	-0.414**	-0.312**	0.910**
TDU										1	0.874**	0.380**	-0.389**	-0.175	-0.389**	-0.399**	-0.358**	-0.321**	0.847**
LG											1	0.297**	-0.370**	-0.074	-0.371**	-0.342**	-0.381**	-0.263**	0.885**
SV												1	-0.434**	-0.396**	-0.442**	-0.495**	-0.363**	-0.437**	0.328**
NEg	14 DAE												1	0.537**	0.994**	0.859**	0.900**	0.847**	-0.358**
	21 DAE													1	0.545**	0.617**	0.398**	0.525**	-0.132
Ovi (%)	14 DAE														1	0.866**	0.898**	0.849**	-0.355**
	21 DAE															1	0.766**	0.916**	-0.322**
DH %	21 DAE																1	0.811**	-0.356**
	28 DAE																	1	-0.265**
GY (g/pl)																			1

Note: * - Significant at 5% probability; ** - Significant at 1% probability

Note: PH- plant height, SG-stem girth, NL-number of leaves per plant, LL-leaf length, LW-leaf width, DTF-days to 50 per cent flowering, HGY-hundred grain yield, TDL-trichome density on lower surface, TDU-trichome density on upper surface, LG-leaf glossiness, SV-seedling vigor, NEg- number of eggs per plant, DAE-days after emergence, Ovi %- per cent of oviposition, DH%,- dead hear percent and GY(g/pl)-garin yield per plant

Table 2: Path coefficients of shoot fly resistance traits and yield components in sorghum

		PH (cm)	SG (cm)	NL	LL (cm)	LW (cm)	DTF	HGW (g)	TDB	TDD	LG	SV	NEg		Ovi (%)		DH %		GY (g/pl)
													14 DAE	21 DAE	14 DAE	21 DAE	21 DAE	28 DAE	
PH (cm)		0.044	-0.002	-0.056	-0.008	0.001	0.009	0.048	0.035	0.014	0.008	-0.001	0.019	0.000	-0.008	-0.033	-0.011	0.035	0.094
SG (cm)		-0.003	0.029	-0.007	-0.003	-0.014	0.006	-0.008	-0.006	0.003	-0.007	0.001	-0.022	0.000	0.009	0.020	0.015	-0.022	-0.009
NL		0.033	0.003	-0.074	-0.005	-0.002	0.002	0.024	0.008	0.006	0.003	-0.001	0.023	0.000	-0.010	-0.025	-0.018	0.036	0.003
LL (cm)		0.010	0.003	-0.010	-0.035	-0.007	-0.014	0.004	0.003	-0.006	-0.004	0.000	-0.010	-0.001	0.004	0.015	0.005	-0.010	-0.053
LW (cm)		-0.001	0.008	-0.004	-0.005	-0.051	0.027	0.033	0.017	0.007	0.011	0.001	-0.006	0.000	0.003	0.012	0.008	-0.009	0.050
DTF		-0.002	-0.001	0.001	-0.003	0.008	-0.183	-0.277	-0.206	-0.079	-0.086	0.002	-0.033	0.000	0.014	0.041	0.025	-0.024	-0.805
HGW (g)		0.006	-0.001	-0.005	0.000	-0.004	0.134	0.378	0.228	0.083	0.093	-0.003	0.077	0.001	-0.030	-0.072	-0.044	0.050	0.890
TDL		0.006	-0.001	-0.002	0.000	-0.003	0.146	0.337	0.257	0.093	0.100	-0.003	0.076	0.001	-0.030	-0.079	-0.046	0.059	0.910
TDU		0.006	0.001	-0.004	0.002	-0.004	0.139	0.300	0.228	0.104	0.094	-0.003	0.075	0.001	-0.030	-0.083	-0.039	0.061	0.847
LG		0.003	-0.002	-0.002	0.001	-0.005	0.147	0.327	0.239	0.091	0.108	-0.003	0.071	0.000	-0.028	-0.071	-0.042	0.050	0.885
SV		0.004	-0.002	-0.006	0.001	0.003	0.047	0.137	0.090	0.040	0.032	-0.009	0.083	0.002	-0.034	-0.103	-0.040	0.083	0.328
NEg	14 DAE	-0.004	0.003	0.009	-0.002	-0.002	-0.032	-0.151	-0.102	-0.041	-0.040	0.004	-0.192	-0.002	0.076	0.179	0.099	-0.161	-0.358
	21 DAE	-0.002	-0.003	-0.004	-0.004	-0.003	-0.011	-0.050	-0.039	-0.018	-0.008	0.004	-0.103	-0.004	0.042	0.128	0.044	-0.100	-0.132
Ovi (%)	14 DAE	-0.005	0.003	0.009	-0.002	-0.002	-0.032	-0.150	-0.102	-0.041	-0.040	0.004	-0.191	-0.002	0.077	0.180	0.099	-0.161	-0.355
	21 DAE	-0.007	0.003	0.009	-0.003	-0.003	-0.036	-0.131	-0.098	-0.042	-0.037	0.005	-0.165	-0.003	0.066	0.208	0.084	-0.174	-0.322
DH %	21 DAE	-0.004	0.004	0.012	-0.002	-0.004	-0.041	-0.151	-0.106	-0.037	-0.041	0.003	-0.173	-0.002	0.069	0.159	0.110	-0.154	-0.356
	28 DAE	-0.008	0.003	0.014	-0.002	-0.003	-0.023	-0.099	-0.080	-0.034	-0.028	0.004	-0.163	-0.002	0.065	0.190	0.089	-0.190	-0.265

Note: RESIDUAL EFFECT = 0.337

Note: PH- plant height, SG-stem girth, NL-number of leaves per plant, LL-leaf length, LW-leaf width, DTF-days to 50 per cent flowering, HGY-hundred grain yield, TDL-trichome density on lower surface, TDU-trichome density on upper surface, LG-leaf glossiness, SV-seedling vigor, NEg- number of eggs per plant, DAE-days after emergence, Ovi %- Per cent of oviposition, DH%,- dead hear percent and GY(g/pl)-garin yield per plant

Conclusion

It is summarized that traits *viz.*, 100 grain weight, seedling vigour, leaf glossiness and trichome density on leaf surface had higher correlation and positively associated among themselves and could be improved simultaneously. In addition, plant height, number of leaves, leaf width and hundred grain weight showed positive indirect effect on grain yield. Whereas, negative indirect effect on grain yield was recorded with stem girth, leaf length and days to 50% flowering. So, these traits should be taking into accounts while planning a breeding programme for improving the shoot fly resistance and grain yield components in sorghum.

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