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PHYSICO-CHEMICAL RESISTANCE MECHANISM OF SORGHUM GENOTYPES AGAINST SHOOT FLY, *ATHERIGONA SOCCATA* (RONDANI)

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KEYWORDS

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ABSTRACT

Sorghum shoot fly (*Atherigona soccata*) is an important pest of sorghum, and host plant resistance is one of the important features for minimizing the losses. Resistance against shoot fly in sorghum with governed by the physical and chemical contribute. Resistance genotypes viz., RSV 1098 exhibited LSW 1.68, leaf glossiness 2.05, seedling vigour 1.54, recovery resistance 2.25, *i.e.* comparatively higher to other and susceptible ones, therefore amount of Polyphenol (33.67 mg/100g), total sugar 0.58 % was exhibited in the same varieties. Resistance check IS 2312 and 18551 possess higher trichome density and 50% flowering was more. Trichome density was negatively correlated with incidence; however glossiness was positively correlated at 21 and 28 DAE. Polyphenoloxidase and Peroxidase was negatively correlated at both DAE *i.e.* egg laying and dead heart. In general susceptible genotypes reflected higher moisture *i.e.* 90.20%, total sugar 0.97%, LSW 4.43, glossiness 4.48, seedling vigour 4.92 was estimated as compared to test genotypes.

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INTRODUCTION

Sorghum (*Sorghum bicolar* (L.) Monech) is the fifth most important cereal crop worldwide after wheat, rice, maize and barley (Anon, 2011). Sorghum being grown in about 86 countries covering an area of about 42 million ha with an annual production of 65.5 million tonnes (Anon, 2008). India's contribution is 24% in area and 16% in production of the world with the national average of 948 kg/ha (Anon, 2010). Insect pests are one of the major yield reducing-factors in sorghum, and results in losses of over $1000 million in grain and forage yield of sorghum worldwide. Nearly 150 insect species damage sorghum, and the sorghum shoot fly, *Atherigona soccata* (Rondani) (Diptera: Muscidae), is one of the most important pests in Asia and Africa. The neonate larva crawls to the plant whorl and continues to move downward between the folds of the young leaves. Pavan kumar *et al.*, 2015 shows the impact of weather parameters on shoot fly incidence in sorghum.

Many approaches have been employed to minimize the loss caused by shoot fly. Resistance to shoot fly, *A. soccata* in sorghum is expressed in terms of antixenosis for oviposition, antibiosis, and tolerance (Sharma and Nwanze, 1997; Dhillon *et al.*, 2005a, b, 2006). Host plant resistance (HPR) is the most important component of integrated pest management (IPM) in sorghum and not involve any extra cost. HPR can also enhance the effectiveness of natural enemies and reduce the need of pesticides (Sharma, 1993).

Host plant resistance to shoot fly is a complex phenomenon and depends on the interplay of number of componential characteristics of the plants, the insects and the environment. The factors associated with resistance to shoot fly can be quantified or monitored easily in the plant populations and such plant characteristics can be used as "Markers traits" to screen and select for resistance. Hence, some of the morphological characters responsible for shoot fly resistance are studied. Varieties with erect and narrow leaves are resistant to shoot fly (Maiti and Bidinger, 1979) and foliage with bright shiny green colour are resistant to shoot fly (Vedamoorthy, 1967).

A number of physico-chemical traits have earlier been reported to be associated with resistance/susceptibility in sorghum to shoot fly (Sharma and Nwanze, 1997). However, meagre studies are reported on different physic-chemical characteristics on the same set of genotypes. Therefore, the present study was aimed at characterizing a group of genotypes for different physico-chemical characteristics to identify the factors responsible for resistance/susceptibility to shoot fly in sorghum.

MATERIALS AND METHODS

The experimental material consisted of a diverse array of 15 sorghum genotypes comprising of seven germplasm lines RSV 1098, RSV 1145, RSV 1151, RSV 1188, RSV 1197, RSV 1226, RSV 1251, RSV 1338 and RSV 1357, three varieties *viz.*, M-35-1, Phule Vasudha and RSE 3, two resistant checks viz., IS 2312 and IS 18551 and a susceptible check *i.e.* DJ 6514. The experiments were conducted under field conditions at different shoot fly pressures *i.e.* high population pressure (August), medium population pressure (September and October) and low population pressure (November). Biochemical diversity was studied under laboratory conditions at Department of Biochemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.).

Characterization of sorghum genotypes for morphological traits

Data were recorded on leaf glossiness, trichome density, seedling vigour, leaf surface wetness, days to 50% flowering and plant height at maturity. Leaf glossiness was evaluated visually on a 1–5 scale at 10 DAE (fifth leaf stage, when the expression of this trait is most apparent) in the early morning hours when there was maximum reflection of light from the leaf surface (1 = highly glossy and 5 = non-glossy) (Sharma and Nwanze, 1997). The presence and density of trichomes was measured at 10 DAE on the central portion of the fifth leaf blade taken from three randomly selected seedlings. Leaf pieces (2 cm^2) were taken from the central portion of the leaf and placed in acetic acid and alcohol (2 : 1) in stoppared glass vials (10 ml capacity) for 24 h to clear the chlorophyll, and subsequently transferred into lactic acid (90%) as a preservative (Maiti and Bidinger, 1979). The leaf sections were mounted on a glass slide in a drop of lactic acid, and magnified at 10x under a stereomicroscope. The trichomes on lower surface of the leaf blade were expressed as number of trichomes in a microscopic field. Seedling vigour was recorded at 10 DAE on a 1–5 rating scale (1 = highly vigorous and 5 = poor seedling vigour) (Sharma and Nwanze, 1997). The leaf surface wetness on the central whorl leaf was recorded by using microscope. Seedlings (10-day-old) were brought to the laboratory in the early morning hours (04.30 to 06.30 h), the central leaf whorl was pulled out and mounted on a slide, and observed under the microscope (10x), and the data were recorded on a 1–5 scale (1 = leaf blade without water droplets; and 5 = entire leaf blade densely covered with water droplets) (Sharma and Nwanze, 1997).

Biochemical composition of sorghum genotypes

Biochemical analysis for ether extract (crude fat), soluble protein and total sugars in seedlings, average phenols, moisture content, and peroxidase and polyphenol oxidase activity of the seedlings was estimated at 14 days after emergence.

The total sugars, soluble protein and total phenols from the seedlings were estimated Dubois *et al.* (1956), Folin-Lowry method and Swain and Hills (1959) respectively. The enzyme extraction was done by following the procedure given by Kumar and Khan (1982) and enzyme activity was expressed as change in absorbance per minute per gram fresh weight (Δ O.D./min/g). The moisture content of the 10-day-old seedlings was determined by recording the fresh weight, and then the dry weight after 3 days of drying at 55ºC in oven.

RESULTS AND DISCUSSION

Morphological characteristics of different sorghum genotypes in relation to expression of resistance to shoot fly

Significant variation was existed in the leaf surface wetness, glossiness, trichome density, seeding vigour, recovery resistance, 50 % flowering and plant height at maturity (Table 1). Among the genotypes, the lowest score of LSW was recorded in genotype RSV 1098 (1.68) *i.e.* at par with the genotypes *viz.*, Phule Vasudha (1.77) and RSV 1188 (1.78). However, the highest score of LSW was recorded in RSV 1251 (3.80) and RSV 1357 (3.92). These results indicated that low leaf surface wetness of central shoot leaves of sorghum seedlings as an important factor in resistant to shoot fly. There results coincide with the studies recorded by Patil *et al.* (2006), Chikkarugi *et al.* (2008), Chikkarugi and Balikai (2011).

Genotypes, RSV 1098 (2.05), RSE 3 (2.05), RSV 1188 (2.06), RSV 1151 (2.10), RSV 1338 (2.11) and RSV 1145 (2.13) exhibited minimum leaf glossiness score *i.e.* below 2.5, indicated the better leaf glossiness of the genotypes, as an most important traits which provide non-preference for oviposition. The present findings corroborates with finding of

Table 1: Morphological characteristics of sorghum genotypes for resistance to sorghum shoot fly

Genotype	Leaf surface wetness	Leaf glossiness	Trichome density	Seedling vigour	Recovery resistance	Days to 50 % flowering	Plant height at maturity (cm)
RSV 1098	1.68	2.05	9.36 (3.13)	1.54	2.25	82.00	227.78
RSV 1145	2.57	2.13	5.47 (2.43)	2.21	3.75	82.25	231.67
RSV 1151	2.57	2.10	7.97 (2.90)	2.51	2.33	81.83	231.39
RSV 1188	1.78	2.06	9.08 (3.07)	1.61	2.33	82.00	236.53
RSV 1197	2.52	2.20	6.56 (2.65)	2.29	4.08	83.25	219.03
RSV 1226	2.55	2.35	7.89 (2.89)	2.34	3.00	81.75	221.25
RSV 1251	3.80	2.62	1.97 (1.56)	2.19	3.42	83.08	230.00
RSV 1338	2.63	2.11	1.92 (1.54)	2.06	4.33	81.92	225.28
RSV 1357	3.92	2.83	4.05 (2.12)	2.37	4.67	83.42	215.14
M-35-1	2.63	2.20	5.89 (2.51)	2.22	2.42	85.00	190.28
Phule Vasudha	1.77	2.17	7.42 (2.79)	2.03	2.42	83.50	221.39
IS-2312 (RC)	1.25	1.40	15.58 (4.00)	1.28	1.17	92.25	172.36
IS-18551(RC)	1.00	1.02	21.69 (4.70)	1.37	1.17	95.67	184.58
RSE-3	1.23	2.05	15.03 (3.93)	1.68	1.83	87.58	178.06
DJ-6514 (SC)	4.43	4.48	0.00 (0.71)	4.92	7.67	81.83	137.64
Mean	2.42	2.25	7.99 (2.73)	2.17	3.12	84.49	208.16
SE +	0.091	0.186	0.118	0.131	0.655	1.822	8.83
CD P=0.05	0.259	0.523	0.331	0.367	1.835	5.106	24.75

RC: Resistance check; SC: Susceptible check

Table 2: Biochemical constituents at seedling stage in different genotypes of sorghum

Genotype	Moisture (%)	Avg. Polyphenol (mg/100g)	Total Sugars(%)	Ether Extract (Crude Fat)(%)	Soluble Protein(%)	Avg. Polyphenol oxidase (Δ O.D./min/g)	Avg. Peroxidase (Δ O.D./min/g)
RSV 1098	81.51	33.67	0.58	5.44	0.12	0.61	4.75
RSV 1145	85.97	32.67	0.60	3.51	0.15	0.34	4.16
RSV 1151	81.32	25.33	0.65	4.43	0.13	0.58	3.80
RSV 1188	83.34	28.67	0.67	3.51	0.15	0.44	4.03
RSV 1197	85.26	33.33	0.84	3.53	0.16	0.43	4.33
RSV 1226	80.19	35.33	0.58	4.41	0.16	0.38	4.14
RSV 1251	85.22	36.33	0.75	4.30	0.25	0.34	3.80
RSV 1338	86.16	42.67	0.86	6.41	0.17	0.44	3.98
RSV 1357	88.64	45.67	0.95	4.52	0.18	0.44	4.08
M-35-1	80.62	33.67	0.55	4.29	0.11	0.48	5.94
Phule Vasudha	83.57	34.33	0.61	4.43	0.15	0.56	4.61
RSE-3	83.63	35.67	0.59	4.53	0.14	0.57	6.63
IS-2312 (RC)	83.92	33.67	0.48	4.12	0.14	0.61	6.00
IS-18551 (RC)	81.75	34.67	0.43	5.70	0.13	0.64	6.80
DJ-6514 (SC)	90.20	37.00	0.97	6.39	0.16	0.31	3.79
SE ±	1.373	1.235	0.0207	0.122	0.006	0.024	0.186
CD P=0.05	3.967	3.567	0.0599	0.352	0.018	0.072	0.538

RC: Resistance check; SC: Susceptible check

Ashok Kumar *et al.* (2008), Chikkarugi *et al.* (2008) and Chikkarugi and Balikai (2011).

The maximum number of trichomes were observed in resistant check, IS 18551 (21.69) which was significantly maximum than rest of the genotypes. However, other resistant checks *viz.* IS 2312 (15.58) and RSE 3 (15.03) were also exhibited more number of trichomes. While, other genotypes *i.e.* moderately resistant *viz.*, RSV 1098 (9.36), RSV 1188(9.08), RSV 1151 (7.97), RSV 1226 (7.89) and Phule Vasudha (7.42) recorded moderate number of trichomes. The susceptible genotypes *viz.*, DJ 6514 (0.00), RSV 1338 (1.92), RSV 1251 (1.97) and RSV 1357 (4.05) recorded lowest number of trichomes. Sree *et al.* (1992) and Taneja and Maiti (1992) also published similar findings correlates the present observations.

Seedling vigour differences were statistically significant (Table 1). The resistant check, IS 2312 recorded minimum score of seedling vigour (1.28 score) and as equal level of significance with resistant check, IS 18551; however, susceptible check, DJ 6514 recorded maximum score of seedling vigour (4.92) indicating poor seedling vigour. Among the genotypes, the lowest score of seedling vigour (1.54) recorded in RSV 1098 followed with RSV 1188 (1.61) and RSE 3 (1.68). Shoot fly resistant lines have a rapid growth rate as reported by Taneja and Leuschner (1985), Mote *et al.* (1986). The data recorded on average score of recovery resistance, the resistant check IS 2312 and IS 18551 recorded minimum score of recovery resistance (1.17) which were at par with the genotypes *viz.*, RSV 1098, RSV 1188, RSV 1151, RSV 1226, Phule Vasudha and RSE 3, thus indicates highest recovery resistance. However, susceptible check DJ 6514 recorded maximum score of recovery resistance (7.67). Dhillon *et al.* (2005b), Dhillon (2004) mentioned that recovery of damaged plants as an important factor in resistant breeding programme for getting normal yield.

It is revealed that from the Table 1 that, days to 50 % flowering of all the genotypes required > 85 days. IS 2312 and 18551 (RC) were noticed to be late and required 90 to more than 95 days to 50 per cent flowering. However, the genotypes, M-35-1, IS 2312, IS 18551, RSE 3 and DJ 6514 recorded lowest plant height (< 190 cm). However, the rest of the genotypes recorded more than 215 cm plant height. Dhutmal *et al.* (2014) and Arun kumar (2013) stated that the genetic variability related to plant heights and 50% flowering could decide the yield potential of the sorghum varieties.

Biochemical composition in relation to expression of resistance to shoot fly

Resistant genotypes possessed significantly lower amount of ether extract (crude fats), soluble protein, total sugars, phenols and high enzyme activities while higher moisture content was observed in susceptible genotypes. Highest moisture content (Table 2) was recorded in the susceptible check, DJ 6514 (90.20 %) and lowest (80.19%) was recorded in RSV 1226 *i.e.* at par with resistant check IS 2312 (83.92). Similar results were reported by Chamarthi *et al.*, 2010. Singh and Jotwani (1980) reported that the moisture content was significantly lower in the resistant as compared to susceptible entries. The maximum amount of phenols was noticed in the genotype, RSV 1357 (45.67 mg/100g) while lower phenol content was observed in RSV 1151 (25.33 mg/100g). These observations indicated that there was no specific trend in total phenols as far as shoot fly susceptible and resistance is concerned supports the result published by Jadhav, 2004.

The minimum total sugar was recorded in the genotype, IS 18551 (0.43%). Nevertheless, it was at par with the genotype, IS 2312. The maximum per cent sugar was noticed in the susceptible check, DJ 6514 (0.97%), which was significantly less than the rest of the genotype. Bhise *et al.* (1996) reported that the susceptible check, CSH 1 had the highest total sugars content, whereas the resistant variety, IS 5490 had the lowest total sugars content during the crop growth corroborates the present results.

The lowest crude fat was recorded in, RSV 1145 and RSV 1188 (3.51 %), significantly lower than the rest of the genotypes except RSV 1197. The highest fat per cent was observed in RSV 1338 (6.41 %), significantly more than rest of the genotypes. Genotypes with high amounts of fats were

Table 3: Correlation of different biochemical constituents and plant characters with egg laying and per cent dead hearts

Character	'r' with Egg/plant at 21 DAE	'r' with % DH at 28 DAE
Glossiness	0.82	0.84
Seedling vigour	0.83	0.90
Trichome density (mm2)	-0.92	-0.79
Leaf Surface Wetness	0.88	0.90
Moisture content	0.56	0.71
Crude Fat	0.11	0.33
Soluble Protein	0.29	0.35
Total Sugar	0.76	0.78
Polyphenols	0.20	0.40
Polyphenoloxidase	-0.80	-0.84
Peroxidase	-0.80	-0.61

DAE : Days after emergence; DH : Dead hearts; 'r' : Correlation Coefficient; P=0.05 = 0.514; P=0.01 = 0.641

susceptible to shoot fly (Chamarthi *et al.*, 2010). The resistant entries *viz.,* RSV 1098, RSV 1188, Phule Vasudha, RSE 3 and resistant checks, IS 2312 and IS 18551 exhibited significantly lower protein content (< 0.15 %) as compared with susceptible check, DJ 6514 (0.16 %).

The maximum enzyme (polyphenol oxidase and peroxidase) activities were recorded in resistant check, IS 18551 (0.64 " O.D./min/g and 6.80 "O.D./min/g) and minimum enzyme (polyphenol oxidase and peroxidase) in susceptible check, DJ 6514 (0.31 " O.D./min/g and3.79 "O.D./min/g). The higher enzyme activity might induced/activate an antibiosis mechanism that affects the magnitude of damage at lower level caused by shoot fly. Similar results were also reported by Bhise *et al.* (1996) and Patil *et al.* (2006).

Correlation of biophysical and biochemical characters with per cent dead hearts and egg laying

The generated data was subjected to simple correlation coefficient (r) of different biophysical and biochemical characters with per cent dead hearts at 28 DAE and egg laying at 21 DAE are presented in Table 3.

There was highly significant positive correlation of glossiness with shoot fly incidence (0.84 P= 0.01) and with egg laying on 21 DAE (0.82 P= 0.01). Similarly, the highly significant positive correlation of seedling vigour with egg laying on 21 DAE (0.90 P= 0.01) and shoot fly incidence (0.83 P= 0.01). However, existence of negative correlation of trichome density with egg laying on 21 DAE and shoot fly incidence was recorded (-0.90 P= 0.01 and -0.79 P= 0.01, respectively). The leaf surface wetness (LSW) on 12 DAE had highly significant positive correlation with shoot fly incidence (0.90 P= 0.01) and egg laying at 21 DAE (0.88 P= 0.01). Jadhav *et al.* (1986) related that per cent dead hearts was negatively associated with plant height, glossiness and trichome density. Omari *et al.* (1983) reported that the effects of trichome and glossiness were marginal on dead hearts as the number of eggs had accounted for most of the variability in dead hearts. Maiti *et* al. (1994), Jadhav *et al.* (1986) and Borse (2000) observed positive and significant association between oviposition and non-glossiness. Mote *et al.* (1986) reported that narrower and yellowish green colour of leaves were associated with shoot fly resistance.

The moisture content in the seedling was significantly and positively correlated with shoot fly incidence (0.71 P= 0.01) but non-significant positive correlation with egg laying (0.56). There was significant positive correlation of total sugar with egg laying at 21 DAE and shoot fly incidence (0.76 P= 0.01 and 0.78 P= 0.01, respectively). However, the crude fat, soluble protein and Polyphenols in seedling had non-significant but positive correlation with shoot fly egg laying (0.11, 0.29 and 0.20, respectively) and shoot fly incidence (0.33, 0.35 and 0.40, respectively).

The polyphenoloxidase and peroxidase activities in seedlings were significant and negatively correlated with egg laying at 21 DAE (-0.80 P= 0.01) and shoot fly susceptibility (-0.84 P= 0.01 and -0.61 P= 0.05), respectively. Not a single factor could assist for positive or negative correlation but contributory effect of different parameters could reflect on the resistance or susceptiblity of sorghum genotypes.

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