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Research Article

Screening of sorghum [*Sorghum bicolor* (L.) Moench] genotypes against shootfly [*Atherigona soccata* (Rondani)] in correlation with physico-chemical traits

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Abstract
Field screening of 20 sorghum genotypes against shoot fly resistance was carried out at Agricultural Research Station (ARS), Kovilpatti during *Rabi* 2016 - 2017. Based on six parameters *viz*., Trichome density, glossiness, seedling vigour, number of eggs per seedling, seedling with eggs and dead hearts, four entries *viz.,* IS 2205, IS 2660, IS 2952 and IS 18551 were found to be highly resistant to shoot fly. Susceptibility to shoot fly was associated with high soluble sugars and fat composition while highest leaf glossiness, trichome density, seedling vigour and tannin content were associated with resistance to shoot fly.

Keywords
Field screening, sorghum genotypes, shoot fly, physico- chemical traits

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is an important grain and fodder crop in Asia, Africa, Australia and the America. In India, the total production of sorghum is 4.80 million metric tonnes and India ranks 3rd in world after Sudan and Nigeria USDA(2017). Insect pests are one of the major yield reducing factors in sorghum causing more than $1000 million loss in grain and forage yield of sorghum worldwide. Nearly 150 insect species damage sorghum. 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 heavy yield losses. Plant resistance to sorghum shoot fly appears to be complex character and depends on the interplay of number of componential characters, which finally sum up in the expression of resistance to shoot fly Dhillon (2005). In this context, it is important to identify genotypes with different mechanisms to increase the levels and diversity of bases of resistance to shoot fly. Therefore, the present studies were carried out on a diverse array of sorghum genotypes with a view to identify plant characteristics influencing the resistance / susceptibility to *A. soccata* to further genetic programs like molecular breeding and QTLs mapping.

Materials and Methods

Field screening of sorghum was carried out at Agricultural Research Station (ARS), Kovilpatti during *Rabi* 2016 - 2017 with 20 genotypes obtained from the Department of Millets, Tamil Nadu Agricultural University (TNAU), Coimbatore and ARS, Kovilpatti. Each genotype was sown in 2 rows of 1 m length with a row to row and plant to plant spacing of 45x15 cm. Genotypes IS 18551 and Swarna were used as resistant and susceptible checks, respectively Chamarthi *et al.*, (2010). Each treatment was replicated two times in a Randomized Block Design (RBD). The crop was grown by following recommended agronomic practices (Crop Production Guide, 2014) without spraying any insecticide.

Screening of genotypes was carried out by recording observations on the number of eggs per seedling and numbers of seedlings with eggs at 14 and 21 days after emergence (DAE) and plants with dead hearts at 21 and 28 DAE. Observation on seedlings with eggs and plants with dead hearts were expressed in terms of percentage.

Observations were recorded on physical traits v*iz.*, trichome density on abaxial (lower) and adaxial (upper) surfaces of the leaf, leaf glossiness and seedling vigour. For all the 20 genotypes, the leaf glossiness was visually estimated on a 1 to 5 rating scale (1= highly glossy, light green, shining, narrow and erect leaves , 2 = glossy, light green, less shining, narrow and erect leaves, 3 = moderate glossy, fair green, light shining, medium leaf width, and less drooping leaves, 4 = moderate non-glossy, green, pseudo-shine, broad, and drooping leaves, 5= non-

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glossy, dark green, dull, broad, and drooping leaves) Sharma and Nwanze (1997) at 10 DAE in the early morning hours when there was maximum reflection of light from the leaf surfaces. For trichome density, fifth leaf at central portion of the plant was taken from three seedlings selected at random. The leaves were cut into 2 sq. cm pieces and placed in acetic acid and alcohol solution (2:1) in a stoppered glass vial (10 ml capacity). The leaf pieces were kept in this solution for 24 h and thereafter transferred into lactic acid (90%) for overnight. Leaf segments cleared of the chlorophyll content were observed for the trichome density. The leaf sections were mounted on a slide in a drop of lactic acid and observed under stereomicroscope at a magnification of 10 X. The trichomes on both abaxial and adaxial surfaces of the leaf were counted in microscopic fields selected at random and expressed as number of trichomes per sq. cm. The seedling vigour was recorded at 10 DAE on 1 to 5 rating scale (1= highly vigorous, plants showing maximum height, more number of fully expanded leaves, good adaptation, and robust seedlings, 2 = vigorous, good plant height, good number of fully expanded leaves, and good adaptation and seedling growth, 3 = moderately vigorous, moderate plant height with moderate number of fully expanded leaves, and fairly good seedling growth, 4 = less vigorous less plant height with poor leaf expansion, and poor adaptation, 5 = poor seedling vigor, plants showing poor growth, and weak seedlings) Sharma and Nwanze (1997).

Bio chemical composition *viz.*, soluble sugars, protein, tannin, lignin, fats and polyphenols were analysed by following standard procedures. Soluble sugars by phenol sulphuric acid method Dubois *et al.* (1956), hydrolysable tannins by vanillin– hydrochloric acid method Price *et al.(*1978), lignins by acid detergent dispersible lignin (ADDL) method Van Soest and Robertson(1985), fat content by Soxhlet extraction procedure AOCS(1981) and polyphenols by Folin Denis method AOAC(1984) was analysed. For protein assay, N content of the sample was determined by digesting the sample with sulphuric acid – selenium and the digested sample were analysed using an auto-analyser. Then the protein content was estimated by multiplying N content with a constant 6.25 Sahrawat *et al.(* 2000).

The data obtained from field and laboratory experiments were subjected to Analysis of variance (ANOVA) using software SPSS. The significance of differences was tested by F-tests, while the significance of difference between the treatment means were compared by LSD at 5 and 1 per cent probability. Simple correlation was performed to understand the association between the physico- bio chemical characters and other resistant parameters of 20 genotypes.

Results and Discussion

Results revealed significant difference among the genotypes screened. In the field screening, number of eggs per seedling was observed to be in the range of 0.14 to 1.93 and 0.36 to 2.21 at14 and 21 days after emergence (DAE), respectively. On 14 DAE, resistant check IS 18551 recorded the least number of eggs (0.14 nos. / seedling) which was on par with IS 2205 (0.21 nos. / seedling) followed by IS 2952 (0.29 nos. / seedling), while Swarna (1.93 nos. / seedling), DJ 6514 (1.86 nos. / seedling) and K8 (1.86 nos. / seedling) recorded maximum numbers of eggs. Similarly, significantly minimum number of shoot fly eggs was recorded in resistant check IS 18551 (0.36 nos./ seedling) and IS 2205 (0.39 nos./ seedling) at 21 DAE and maximum number of eggs were recorded on Swarna (2.21 nos./ seedling), K8 (2.11 nos./ seedling) and K 11 (2.07 nos. / seedling) (Table 1).

Seedlings with eggs ranged from 6.67 to 66.7 per cent, and 11.67 to 85.00 per cent at 14 and 21 DAE, respectively (Table 1). On 14 DAE, the genotypes IS 2660 and IS 18551 recorded minimum per cent of seedlings with eggs (6.67 %) followed by IS 2205 (8.33 %). While the genotypes, DJ 6514 (66.67 %) Swarna (60.00 %) and K 8 (56.67 %) recorded maximum per cent seedlings with eggs. Similar trend was also observed on 21 DAE.

The genotypes IS 2205 (5.00 %) was on par with the resistant check, IS 18551 which recorded 6.67 per cent of dead hearts (DH) on 21 DAE. The entries K8 (56.67 %), K 11 (55.00 %) and DJ 6514 (53.33 %) recorded the highest per cent dead hearts. On 28 DAE, the resistant check IS 18551 and IS 2205 recorded significantly minimum per cent dead hearts and genotype K8 (76.67 %) and Swarna (75.00 %) recorded maximum per cent dead hearts. This is in accordance with Patil *et al.* (2017) who reported significantly minimum numbers of eggs on resistant checks *viz.*, IS 2312 (0.12 nos. / seedling), IS 2205 (0.13 nos. / seedling) and IS 18551 (0.14 nos. / seedling) and minimum per cent dead hearts of 5.27, 6.21 and 6.03 per cent, respectively on IS 2312, IS 2205 and IS 18551 at College of Agriculture, Kolhapur, Maharastra. Khandare *et al.* (2013) also screened 22 advanced breeding lines on 7, 14, 21 and 28 DAE and reported minimum number of eggs per seedling in resistant check IS 18551 (0.10 and 0.30 nos./ seedling on 14 and 21 DAE, respectively) and IS 2205 (0.10 and 0.80 nos./ seedling on 14 and 21 DAE, respectively) with minimum percentage of dead hearts (20.10 and 31.56% on 14 and 21 DAE, respectively).

The results revealed that among the 20 genotypes screened, the genotype IS 18551 recorded significantly maximum numbers of trichomes (107.10 nos./ 2 sq. cm) on abaxial surface of leaves, while minimum

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numbers of trichomes were recorded in Swarna (11.40 nos./ 2 sq. cm) and K12 (11.75 nos./ 2 sq. cm). In adaxial surface of leaves, maximum numbers of trichomes (83.45 nos./ 2 sq. cm) was recorded in TNS 662 followed by IS 2952 (75.90 nos./ 2 sq. cm). Whereas, minimum numbers of trichomes were recorded in Co 29 (8.40 nos./ 2 sq. cm) and Co 28 (8.45 nos./ 2 sq. cm) (Table 2). Lowest leaf glossiness (4.70) was recorded in Co 28 followed by K 8 (4.60) while highest glossiness was observed in IS 2660 (2.10) and IS 2205 (2.30). These finding are in line with the reports of Patel and Sukhani (1990), Dhillon *et al*. (2005) and Chamarthi *et al.* (2010) who reported that the genotypes with highest leaf glossiness and trichome density were relatively less susceptible to shoot fly damage. Seedling vigour (2.25) was maximum in IS 18551, IS 2205 and IS 2979. While genotypes Co 26 (4.40), DJ 6514 (4.35) and Swarna (4.30) recorded the lowest seedling vigour. These finding was in close agreement with Bhagwat *et al.* (2011) who reported maximum seedling vigour in the genotypes IS 2312, IS 18551 and IS 2205 (2.3, 2.2 and 2.4, respectively).

The results revealed significant differences in the total sugar content among the 20 genotypes of sorghum (Table 3). Significant and maximum sugar content (3.01 %) was recorded in DJ 6514 followed by Swarna (2.95 %), K 11 (2.93 %) and K 12 (2.89 %). Whereas sugar content was low in IS 18551 (2.21 %), IS 2205 (2.24 %) and IS 2660 (2.25). The genotype TN 661 and K 12 had the highest lignin content (1.74 %) and was significantly superior to other genotypes, while lowest lignin content was recorded in Co 27 (1.24 %), IS 2205 (1.26 %) and Co 30 (1.27 %). Maximum tannin content (0.25 %) was recorded in IS 2660, TNS 662 and TNS 623 followed by IS 2205 (0.23 %) while minimum tannin content was recorded in Swarna (0.09 %) and DJ 6514 (0.10 %). High fat content (7.51 %) was observed in K 8 followed by K 12 (7.24 %) while lowest fat content was found in IS 2205 (4.26 %) and IS 2979 (4.82 %). No significant difference in protein and phenol content was observed among the genotypes. However, the protein content in sorghum genotypes ranged from 31.74 (DJ 6514 and K8) to 37.38 per cent (TNS 661). Phenol content was found to be high in Co 30 (37.04 mg/g) and IS 2660 (35.34 mg/g) and low in Co 28 (27.06 mg/g) and TNS 661 (27.36 mg/g). Simple correlation analysis carried out between shoot fly resistant parameters of 20 genotypes and its physico-bio chemical resistance traits revealed significantly difference for its relative susceptibility/ resistance (Table 4). The trichome density on abaxial and adaxial surface of leaves, leaf glossiness, seedling vigour were significantly and negatively associated with number of eggs/ seedling, seedlings with eggs and dead heart incidence. Total soluble sugar and fat contents were positively correlated with susceptibly to shoot fly, while tannins showed a negative correlation with shoot fly incidence. There was no association between protein, phenol and lignin content and resistance to shoot fly. Chamarthi *et al.* (2010) also reported similar results. According to them, susceptibility to shoot fly was associated with high amounts of soluble sugars, fats, leaf surface wetness and seedling vigour. While leaf glossiness, plumule and leaf sheath pigmentation, trichome density, high tannin, Mg and Zn showed positive correction with shoot fly resistance. The study indicated that the genotypes IS 2205, IS 2660 and IS 2952 are relatively resistant to sorghum shoot fly which may further be exploited in breeding programs like QTLs mapping and Marker Assisted Breeding (MAS) to develop shoot fly resistant sorghum lines.

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Table 1. Reaction of sorghum genotypes to shoot fly under field condition

S. No.	Genotypes*	No. of eggs / seedling**		Seedling with eggs (%)#		Plants with Dead hearts (%)#	
		14 DAE	21 DAE	14 DAE	21 DAE	21 DAE	28 DAE
1	IS 18551(R)	0.14 (0.38) a	0.36 (0.59) a	6.67 (14.97)a	11.67 (18.19)a	6.67 (16.70)ab	8.33 (16.70)a
2	IS 2205	0.21 (0.46) ab	0.39 (0.62) a	8.33 (12.74) a	13.33 (29.99) a	5.00 (18.19)a	8.33 (21.27) a
3	IS 2660	0.43 (0.65) b	0.54 (0.71) a	6.67 (23.66) a	21.67 (25.15) ab	11.67 (21.41) ab	13.33 (23.66) ab
4	IS 2952	0.29 (0.53) ab	0.57 (0.75) a	11.67 (24.10) a	20.00 (27.72) ab	10.00 (22.76) ab	13.33 (26.49) ab
5	IS 2979	0.36 (0.59) b	0.64 (0.80) ab	16.67 (34.18)ab	21.67 (41.02) a-c	11.67 (29.99) ab	18.33 (41.14) ab
6	TNS 661	0.93 (0.96) c	0.93 (0.96) bc	11.67 (41.14)a	15.00 (55.82) ab	13.33 (41.14) ab	15.00 (45.96) ab
7	TNS 662	1.21 (1.10) c-e	1.14 (1.07) cd	15.00 (45.96) ab	16.67 (52.81) ab	15.00 (45.00) bc	18.33 (45.96) ab
8	TNS 623	1.07 (1.03) cd	1.21 (1.10) c-e	18.33 (44.05) ab	26.67 (51.75) bc	13.33 (44.05) ab	21.67 (55.77) b
9	Paiyur 1	1.29 (1.13) c-e	1.50 (1.22) d-f	28.33 (47.91)bc	36.67 (55.82) cd	26.67 (47.91)cd	43.33 (49.82) cd
10	Paiyur 2	1.21 (1.10) c-e	1.36 (1.16) c- f	38.33 (57.85)cd	48.33 (67.25)de	33.33 (45.00)de	38.33 (58.96) c
11	Co 26	1.43 (1.19) d-f	1.43 (1.19) d-f	48.33 (16.70)d-f	66.67 (22.76) fg	48.33 (10.51) ef	56.67 (16.70)d-f
12	Co 27	1.36 (1.16) de	1.57 (1.25) d-g	48.33 (21.27) d-f	71.67 (24.10) f-h	48.33 (19.93) ef	56.67 (21.27) d-f
13	Co 28	1.50 (1.22) eg	1.57 (1.25) d-g	50.00 (19.93) d-f	61.67 (25.33)e-f	50.00 (19.93)f	55.00 (23.99) d-f
14	Co 29	1.29 (1.13) de	1.64 (1.28) e-g	51.67 (23.99) d-f	60.00 (27.31)ef	53.33 (21.41) f	60.00 (26.57)fg
15	Co 30	1.21 (1.10) de	1.50 (1.22)e-f	41.67 (36.22) de	63.33 (40.20)ef	41.67 (36.22) d-f	73.33 (38.25)gh
16	K 8	1.86 (1.36) fg	2.11 (1.45)gh	56.67 (46.93) d-f	66.67 (57. 10)fg	56.67 (46.93) f	76.67h (51.75)h
17	K 11	1.64 (1.28) eg	2.07 (1.44)gh	55.00 (45.00) d-f	68.33 (49.82) fg	55.00 (46.91) f	58.33 (52.73)ef
18	K 12	1.57 (1.25) eg	1.57 (1.25)d-g	56.67 (45.00) d-f	66.67 (55.77) fg	53.33 (45.00) f	70.00 (64.67)f-h
19	DJ 6514	1.86 (1.36) fg	1.79 (1.33)f-h	66.67 (48.87)f	78.33 (54.76) gh	51.67 (48.87) f	66.67 (56.93)e-h
20	Swarna (S)	1.93 (1.39) fg	2.21 (1.49)h	60.00 (47.91)ef	85.00 (62.41)h	56.67 (47.89) f	75.00 (55.82)h
	SEd	0.91	0.098	5.22	4.5	4.47	4.12
	CD (0.05)	0.11	0.20	10.94	9.5	9.37	8.6
	CD(0.01)	0.27	0.27	14.9	13.1	12.80	11.80

**Mean of two replications

**Values in parentheses are square root transformed values

#Values in parentheses are arcsine transformed values

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Table 2. Physical parameters of sorghum genotypes evaluated for resistance to shoot fly

S. No.	Genotypes*	Trichome density (Nos./ 2 sq.cm)		Leaf glossiness (1-5 rating scale)	Seedling vigour (1-5 rating scale)
		Abaxial suface	Adaxial surface		
1	**IS 18551(R)**	107.10 (10.35)^{a}	51.15 (7.14)^{cd}	2.45 ^{b}	2.25 ^{a}
2	**IS 2205**	100.70 (10.03) ^{a}	40.60 (6.36)^{de}	2.30 ^{ab}	2.25 ^{a}
3	**IS 2660**	99.55 (9.96) ^{ab}	40.10 (6.32)^{de}	2.10 ^{a}	2.75 ^{bc}
4	**IS 2952**	102.30 (10.10) ^{a}	75.90 (8.71)^{ab}	3.15 ^{cd}	3.10 ^{ef}
5	**IS 2979**	94.55 (9.72) ^{ab}	62.25 (7.88)^{bc}	3.05 ^{c}	2.25 ^{a}
6	**TNS 661**	67.40 (8.18)^{cd}	60.05 (7.74)^{bc}	2.35 ^{ab}	2.40 ^{ab}
7	**TNS 662**	64.25 (7.99) ^{cd}	83.45 (9.13)^{a}	3.25 ^{cd}	2.65 $^{a-c}$
8	**TNS 623**	74.35 (8.61) ^{c}	55.35 (7.44)^{c}	4.15 ^{f}	3.40 ^{ef}
9	**Paiyur 1**	43.55 (6.54) ^{ef}	24.30 (4.93)^{fg}	2.95 ^{c}	3.20 $^{d-f}$
10	**Paiyur 2**	18.50 (4.24)$^{g-i}$	23.25 (4.82)$^{f-h}$	3.10 ^{c}	3.35 ^{ef}
11	**Co 26**	28.80 (5.34)^{fg}	36.75 (6.06)^{e}	3.45 ^{de}	4.40 ^{h}
12	**Co 27**	59.00 (7.68)$^{c-e}$	15.00 (3.86)^{hi}	3.25 ^{cd}	3.30 ^{ef}
13	**Co 28**	49.00 (7.00)^{de}	8.45 (2.89)^{ij}	4.70 ^{i}	4.10 ^{gh}
14	**Co 29**	18.40 (4.25)$^{g-i}$	8.40 (2.81)^{j}	4.55 ^{hi}	3.65 ^{fg}
15	**Co 30**	18.50 (4.28) $^{g-i}$	29.55 (5.42)$^{e-g}$	4.10 ^{f}	4.20 ^{h}
16	**K 8**	22.40 (4.61) $^{g-i}$	37.70 (6.12)^{de}	4.60 ^{i}	4.25 ^{h}
17	**K 11**	25.05 (5.00) ^{gh}	32.60 (5.71)$_{ef}$	4.20 ^{fg}	3.60 ^{f}
18	**K 12**	11.75 (3.42) ^{i}	19.50 (4.40)^{gh}	3.60 ^{e}	3.35 ^{ef}
19	**DJ 6514**	13.45 (3.66) ^{hi}	9.50 (3.05)^{ij}	4.25 $^{f-h}$	4.35 ^{h}
20	**Swarna (S)**	11.40 (3.36) ^{i}	9.20 (3.02) ^{ij}	4.50 $^{g-i}$	4.30 ^{h}
	SEd	0.65	0.51	0.15	0.23
	CD (0.05)	1.38	1.04	0.31	0.49
	CD(0.01)	1.88	1.42	0.43	0.67

*Mean of two replications

Values in parentheses are square root transformed values

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Table 3. Biochemical composition of sorghum genotypes evaluated for resistance to shoot fly

S. No.	Genotypes*	Soluble sugars (%)#	Protein (%)#	Lignin (%)#	Tannin (%)#	Fats (%)#	Poly phenols (mg/ g)**
1	IS 18551(R)	2.21 [a]	33.90	1.30 [a-c]	0.20 [f-g]	4.91 [ab]	32.87
2	IS 2205	2.24 [ab]	34.41	1.26 [de]	0.23 [hi]	4.26 [a]	29.28
3	IS 2660	2.25 [a-c]	37.25	1.50 [b-e]	0.25 [i]	5.69 [b-d]	35.34
4	IS 2952	2.29 [a-d]	34.75	1.37 [ab]	0.21 [g-i]	5.14 [a-c]	27.87
5	IS 2979	2.26 [c-g]	35.78	1.44 [a]	0.20 [f-h]	4.82 [ab]	34.75
6	TNS 661	2.64 [b-f]	31.74	1.74 [e]	0.20 [f-h]	6.14 [d-f]	27.36
7	TNS 662	2.56 [a-f]	31.90	1.40 [a-e]	0.25 [i]	5.99 [c-f]	29.24
8	TNS 623	2.50 [a-e]	34.20	1.32 [ab]	0.25 [i]	6.00 [c-g]	34.47
9	Paiyur 1	2.66 [d-g]	33.25	1.41 [a-e]	0.21 [g-i]	5.83 [c-e]	34.75
10	Paiyur 2	2.82 [e-g]	34.88	1.53 [b-e]	0.18 [e-g]	5.44 [b-d]	31.81
11	Co 26	2.70 [e-g]	35.97	1.39 [a-e]	0.15 [c-e]	6.23 [d-g]	30.46
12	Co 27	2.67 [d-g]	35.77	1.24 [a-c]	0.15 [c-e]	6.19 [d-g]	33.74
13	Co 28	2.61 [b- f]	33.68	1.44 [a-e]	0.18 [ef]	5.50 [b-d]	27.06
14	Co 29	2.67 [d-g]	36.20	1.29 [a-c]	0.13 [cd]	5.82 [c-e]	32.39
15	Co 30	2.83 [e-g]	34.75	1.27 [a]	0.15 [c-e]	6.60 [e-g]	37.04
16	K 8	2.82 [e-g]	37.38	1.36 [c-e]	0.16 [d-f]	7.51 [i]	28.75
17	K 11	2.93 [fg]	35.55	1.33 [a-d]	0.14 [b-e]	6.88 [g-i]	31.50
18	K 12	2.89 [e-g]	34.90	1.74 [e]	0.12 [bc]	7.24 [hi]	30.78
19	DJ 6514	3.01[g]	37.74	1.39 [a-e]	0.09 [a]	6.83 [f-i]	33.04
20	Swarna(S)	2.95[fg]	34.21	1.44 [e]	0.10 [ab]	6.69 [e-i]	32.23
	SEd	0.19	NS	0.07	0.02	0.42	NS
	CD (0.05)	0.39		0.15	0.04	0.88	
	CD(0.01)	0.53		0.21	0.06	1.21	

* Mean of two replications.
* Values in parentheses are square root transformed values
\# Values in parentheses are arcsine transformed values

Table 4. Simple correlation analysis between shoot fly resistant parameters and physic-biochemical traits of sorghum genotypes

Physico- bio chemical parameters		R value					
		Nos. of eggs / seedling		Seedling with eggs (%)		Plants with Dead hearts (%)	
		14 DAE	21 DAE	14 DAE	21 DAE	21 DAE	28 DAE
Trichome Density (Nos./ 2 Sq. cm)	Abaxial surface	-0.91**	-0.90**	-0.90**	-0.86**	-0.89**	-0.91**
	Adaxial surface	-0.61**	-0.63**	-0.77**	-0.79**	-0.76**	-0.74**
Leaf glossiness (1-5 rating scale)		0.77**	0.82**	0.80**	0.76**	0.77**	0.78**
Seedling vigour (1-5 rating scale)		0.82**	0.82**	0.85**	0.87**	0.83**	0.87**
Soluble sugars (%)		0.88**	0.86**	0.80**	0.80**	0.75**	0.76**
Protein (%)		0.19	0.24	0.44	0.46	0.42	0.40
Lignin (%)		0.10	-0.03	-0.02	-0.09	-0.01	-0.05
Tannin (%)		-0.67**	-0.70**	-0.88**	-0.88**	-0.85**	-0.83**
Fats (%)		0.84**	0.82**	0.73**	0.72**	0.75**	0.79**
Poly phenols (mg/ g)		-0.06	0.01	0.00	0.10	-0.03	0.11

Correlation coefficient significant at P = 0.01**