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Morphological plant factors affecting resistance to *Atherigona* spp. in maize

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Abstract

Seven maize genotypes were evaluated against shoot fly species (*Atherigona soccata* Rondani and *A. naqvii* Steyskal) under heavy natural infestation during spring, 1995 and 1996 seasons. The shoot fly species did not discriminate amongst the plants of different varieties while laying eggs in the field. All the varieties differed significantly from each other in relation to dead-heart formation due to shoot flies, the lowest being in Antigua Gr. I and highest in CM - 300. Significantly more number of dead-hearts were formed in 1996 than 1995. Morphological plant characters were either positively or negatively correlated with the number of eggs laid by shoot fly species showing insignificant differences indicating that these did not influence the egg laying by shoot flies in the field. The leaf width and stem thickness, number of leaves/plant and leaf length were positively and negatively, respectively significantly correlated with dead-heart percentages. It showed that resistant varieties had less stem thickness and leaf width, more leaf length and number of leaves/plant as compared to susceptible ones. However, other plant characteristics were either negatively or positively correlated showing non-significant difference.

Key words : *Atherigona soccata, Atherigona naqvii*, resistance, morphological factors, *Zea mays* L.

Introduction

The shoot fly species, *Atherigona soccata* Rondani and *A. naqvii* Steyskal, cause dead-heart formation in seedling stage of maize leading to total loss of the crop and posing a serious threat to maize cultivation during spring season in India [1]. It accounts to 69-97 per cent infestation [2] and up to 20 per cent loss in maize grain yield [3]. Several types of morphological defenses in maize varieties deter insect feeding and oviposition, rendering them less suitable or unsuitable. Individuals surviving the direct effect of these plant defenses may exhibit the debilitating effects of reduced body size and weight, prolonged periods of development in the immature stages and reduced fecundity as surviving adults. Keeping this in view, the role of morphological characters in different maize varieties at various crop growth stages was observed to see their effect on shoot fly resistance, if any.

Materials and methods

Seven maize cultivars *viz.*, Antigua Gr I, Deccan-103, Kiran, Ganga-11, Deccan-105, Pusa composite-1 and CM-300 were evaluated against shoot fly species under heavy natural infestation during spring 1995 and 1996 in a randomized block design. Each cultivar was replicated four times and each replication consisted of two rows. Five seedlings were randomly selected in each row and were carefully examined for the presence of eggs of *A. soccata* and *A. naqvii* on leaves, stalks and in/on soil around the plants when the plants were 9-11 days old. The number of dead-hearts produced by shoot fly species were counted in 30-day old crop. The percentages of dead hearts were calculated based on total plant count. The observations on leaf length, leaf width, number of leaves/plant, total leaf area, leaf thickness, leaf vein thickness and trichomes on leaves, were recorded on each of seven maize cultivars at 5, 10 and 15 days after emergence (DAE) in spring, 1995 and 1996.

The data on number of eggs and per cent dead hearts were transformed to square root [4] and sin inverse values [5], respectively before subjecting to ANOVA. Correlation of morphological plant factors with number of eggs laid and dead-heart percentages due the shoot flies were also worked out.

Results and discussion

The analysed-pooled data of 1995 and 1996 showed that the various varieties did not differ significantly among themselves in respect of eggs/plant laid by shoot flies. Significantly more number of eggs were laid in 1996 than 1995 (Table 1). It showed that shoot fly species did not discriminate amongst the plants of different varieties while laying eggs in the field.

As regards the dead-heart formation due to shoot flies all the varieties differed significantly from each other. Lowest and highest numbers of dead-hearts were formed in Antigua Gr. I and CM-300, respectively. The interaction effect was also pronounced between variety and year resulting Antigua Gr. I with less number of dead-heart in both the years vis-a-vis other varieties (Table 1).

Table 1. Average number of eggs per plant and per cent dead-heart due to *A. socata* and *A. naqvii* in maize germplasms during 1995 and 1996 spring seasons.

Maize Germplasm	Mean number of eggs/plant			Mean per cent dead-hearts		
	1995	1996	Mean	1995	1996	Mean
Antigua Gr. I	2.0 (1.406)	4.5 (2.121)	3.3 (1.764)	29.0 (32.53)	26.5 (30.94)	27.8 (31.78)
Deccan-103	3.5 (1.858)	7.4 (2.625)	5.5 (2.242)	32.9 (34.97)	32.1 (34.51)	32.5 (34.76)
Kiran	3.1 (1.735)	5.6 (2.354)	4.4 (2.045)	39.9 (39.17)	40.6 (39.57)	40.2 (39.38)
Ganga-11	2.1 (1.430)	4.8 (2.182)	3.5 (1.806)	41.9 (40.33)	36.4 (37.12)	39.2 (38.73)
Deccan-105	2.9 (1.708)	5.2 (2.272)	4.1 (1.990)	42.3 (40.57)	47.7 (43.65)	45.0 (42.13)
Pusa composite-I	2.7 (1.568)	4.9 (2.200)	3.8 (1.884)	47.0 (43.26)	53.6 (47.05)	50.3 (45.17)
CM-300	2.8 (1.650)	5.1 (2.247)	4.0 (1.949)	54.6 (47.63)	68.5 (55.90)	61.6 (51.75)
Mean	2.7 (1.622)	5.4 (2.286)	4.1 (1.954)	41.1 (39.80)	43.63 (41.25)	42.37 (40.53)
C.D. at 5%	NS	0.172	NS	1.66	0.89	2.35

Figures in parentheses denote transformed values

Morphological plant characters

Morphological plant characters recorded at 5, 10 and 15 DAE during spring 1995 and 1996 were pooled together and statistically analysed. The results are presented below :

Table 2. Leaf length in maize germplasms at different stages of crop growth during spring, 1995 and 1996

Maize germplasm	Mean leaf length (cm)								
	5 DAE			10 DAE			15 DAE		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Antigua Gr. 1	9.23	9.41	9.32	18.49	17.95	18.22	33.46	34.10	33.78
Deccan-103	8.99	9.01	9.00	17.51	17.14	17.33	31.32	32.24	31.78
Kiran	8.71	8.67	8.69	17.07	16.64	16.86	33.47	30.16	31.82
Ganga-11	9.43	8.83	9.13	18.54	18.37	18.46	29.54	30.91	30.23
Deccan-105	8.76	9.65	9.21	17.48	16.92	17.20	30.19	35.78	32.99
Pusa composite-I	8.12	8.23	8.18	16.44	16.26	16.35	27.46	27.59	27.53
CM-300	8.28	8.43	8.36	16.49	16.47	16.48	26.98	28.68	27.83
Mean	8.79	8.89	8.84	17.43	17.11	17.27	30.35	31.35	30.85
C.D. at 5%	NS	NS	NS	0.95	NS	NS	1.24	0.66	1.75

DAE = Days after germination

Leaf length - Significantly more leaf length was observed in Ganga-11 (10 DAE) and Antigua Gr. I (15 DAE) as compared to rest of the varieties. Significantly more leaf length was observed in 1996 than 1995 at 15 DAE (Table 2).

Leaf width - The leaf width was significantly less in Deccan - 105 as compared to other varieties at 5 and 10 DAE. Among the other varieties, Antigua Gr. I and Deccan - 103 had significantly less leaf width than rest of the varieties except Ganga-11. Significantly more leaf width was observed in 1996 than 1995 at 5 DAE whereas it was just reversed at 15 DAE (Table 3).

Table 3. Leaf width in maize germplasm at different stages of crop growth during spring, 1995 and 1996

Maize germplasm	Mean leaf width (cm)								
	5 DAE			10 DAE			15 DAE		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Antigua Gr.1	1.14	1.41	1.28	1.37	1.72	1.55	2.58	3.17	2.88
Deccan-103	1.39	1.14	1.27	1.78	1.22	1.50	3.38	2.55	2.97
Kiran	1.32	1.43	1.38	1.89	1.68	1.79	3.19	2.36	2.78
Ganga-11	1.29	1.39	1.34	1.67	1.83	1.73	2.95	2.89	2.92
Deccan-105	1.09	1.10	1.10	1.28	1.14	1.21	2.50	3.37	2.94
Pusa composite-I	1.68	1.82	1.75	2.34	2.42	2.38	4.27	3.66	3.97
CM-300	1.66	1.71	1.69	2.33	2.27	2.30	4.34	3.84	4.09
Mean	1.37	1.43	1.40	1.81	1.75	1.78	3.32	3.12	3.22
C.D. at 5%	0.09	0.05	0.12	0.23	NS	0.32	0.24	0.13	0.34

DAE = Days after germination

Number of leaves - Antigua Gr.I, Ganga-11 and Deccan - 105 had significantly more number of leaves per plant than CM - 300 and Pusa composite - I except Deccan - 103 and Kiran (Table 4)

Table 4. Number of leaves per plant in maize germplasms at different stages of crop growth during spring, 1995 and 1996

Maize germplasm	Mean number of leaves/plant								
	5 DAE			10 DAE			15 DAE		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Antigua Gr. 1	3.20	3.20	3.20	4.70	4.70	4.70	6.70	6.80	6.75
Deccan-103	3.10	3.00	3.05	4.50	4.60	4.55	6.50	6.60	6.55
Kiran	3.05	3.10	3.08	4.30	4.50	4.40	6.40	6.40	6.40
Ganga-11	3.25	3.00	3.13	4.80	4.60	4.70	6.80	6.50	6.65
Deccan-105	3.10	3.30	3.20	4.40	4.90	4.65	6.40	6.90	6.65
Pusa composite-1	3.00	2.70	2.85	4.20	4.20	4.20	6.20	6.30	6.25
CM-300	3.00	2.80	2.90	4.20	4.40	4.30	6.20	6.30	6.25
Mean	3.10	3.01	3.06	4.44	4.56	4.50	6.40	6.54	6.50
C.D. at 5%	NS	NS	NS	0.34	NS	NS	0.36	NS	NS

DAE = Days after germination

Total leaf area - The leaf area at 5 and 10 DAE was significantly less in Deccan - 105 as compared to other varieties but was at par with Deccan - 103 at 5 DAE. At 15 DAE, the leaf area in Kiran and Ganga - 11 was significantly less as compared to other varieties but was at par with Deccan - 103 (Table 5).

Table 5. Total leaf area in maize germplasms at different stages of crop growth during spring, 1995 and 1996.

Maize germplasm	Mean total leaf area (cm^2)								
	5 DAE			10 DAE			15 DAE		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Antigua Gr.1	25.21	31.34	28.28	87.46	110.11	98.79	429.47	544.34	486.91
Deccan - 103	28.97	22.89	25.93	104.25	71.80	88.03	514.52	401.66	458.09
Kiran	26.19	28.14	27.17	100.07	92.24	96.16	506.69	341.33	424.01
Ganga-11	29.75	27.67	28.71	108.17	113.51	110.84	442.88	430.10	436.49
Deccan-105	22.12	26.68	24.40	73.20	70.19	71.70	360.42	616.39	488.41
Pusa comp.-I	30.46	30.42	30.44	120.58	123.05	121.82	537.42	471.39	504.41
CM-300	30.83	29.95	30.39	119.95	121.09	120.52	538.90	513.73	526.32
Mean	27.65	28.16	27.91	101.95	100.28	101.12	475.76	474.13	474.95
C.D. at 5%	3.68	NS	5.21	14.83	NS	20.97	46.75	NS	66.11

DAE = Days after germination

Leaf thickness - Deccan - 105 and Kiran had significantly more leaf thickness vis-a-vis other varieties. Among the other varieties the leaf thickness was significantly more in Ganga - 11 and Deccan - 103 than CM-300 and Pusa composite - I but was at par with Antigua Gr. I (Table 6).

Table 6. Leaf thickness in maize germplasms at different stages of crop growth during spring, 1995 and 1996

Maize germplasm	Mean leaf thickness (μm)								
	5 DAE			10 DAE			15 DAE		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Antigua Gr.1	174	169	172	216	224	220	288	335	312
Deccan-103	214	181	198	247	258	253	345	361	353
Kiran	183	197	190	345	352	349	392	382	387
Ganga-11	190	182	186	263	283	273	361	379	370
Deccan-105	233	200	217	362	374	368	400	284	342
Pusa comp.-I	123	117	120	152	154	153	357	343	350
CM-300	140	128	134	169	135	152	263	308	286
Mean	180	168	174	251	254	253	344	342	343
C.D. at 5%	NS	NS	NS	71.3	NS	NS	NS	NS	NS

DAE = Days after germination

Leaf vein thickness - Deccan - 105 had significantly more leaf vein thickness as compared to other varieties at 5% and 15 DAE. At 10 DAE, Deccan - 105, Kiran, Ganga-11 and Deccan - 103 had significantly more leaf vein thickness than CM-300 and Pusa composite-I but was at par with Antigua Gr. I (Table 7)

Trichome - The Trichome length at 10 and 15 DAE was significantly less in Antigua Gr. I and Deccan - 105 than rest of the varieties except Ganga-11 at 10 and 15 DAE Kiran and Pusa composite-I at 10 DAE (Table 8). Trichome density was significantly more in Antigua Gr, I and Deccan - 105 as compared to other varieties at 15 DAE (Table 9).

It can be deduced from the above results that more leaf length, less leaf width, more number of leaves per plant, less leaf area, more leaf and vein thickness, less trichome length and more trichome density were recorded in resistant varieties as compared to susceptible ones.

Table 7. Leaf vein thickness in maize germplasms at different stages of crop growth during spring, 1995 and 1996

Maize germplasm	Mean leaf vein thickness (mm)								
	5 DAE			10 DAE			15DAE		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
Antigua Gr1	0.78	0.78	0.78	1.09	1.25	1.17	1.42	1.55	1.49
Deccan-103	0.97	0.79	0.88	1.38	1.17	1.28	1.78	1.46	1.62
Kiran	0.83	0.93	0.88	1.18	1.40	1.29	1.49	1.88	1.69
Ganga-11	0.86	0.82	0.84	1.21	1.36	1.29	1.54	1.56	1.55
Deccan-105	1.00	0.95	0.98	1.42	1.42	1.42	1.86	1.92	1.89
Pusa comp.I	0.72	0.67	0.69	0.91	0.90	0.90	1.24	1.28	1.26
CM-300	0.73	0.69	0.71	0.95	0.96	0.96	1.37	1.31	1.34
Mean	0.84	0.80	0.82	1.16	1.21	1.19	1.53	1.57	1.55
C.D. at 5%	0.09	NS	NS	0.27	NS	NS	0.09	NS	0.12

DAE = Days after germination

Table 8. Leaf trichome length in maize germplasms at different stages of crop growth during spring 1995 and 1996.

Maize germplasm	Mean trichome length (μm^2)					
	10 DAE			15 DAE		
	1995	1996	Mean	1995	1996	Mean
Antigua Gr.1	33	34	34	45	46	45
Deccan-103	43	45	44	62	63	63
Kiran	39	39	39	58	58	58
Ganga-11	38	39	39	54	55	55
Deccan-105	32	35	34	43	45	44
Pusa comp.-I	39	40	40	59	59	59
CM-300	45	48	47	64	66	65
Mean	38	40	39	55	56	56
C.D. at 5%	8.39	NS	NS	11.20	NS	NS

DAE = Days after germination

Correlation coefficients

The leaf thickness, leaf vein thickness and trichome length were positively correlated and leaf width, number of laves/plant, leaf area and trichome density

Table 9. Leaf trichome density in maize germplasms at different stages of crop growth during spring 1995 and 1996

Maize germplasm	Mean trichome density/mm^2					
	10 DAE			15 DAE		
	1995	1996	Mean	1995	1996	Mean
Antigua Gr.1	3.18	3.24	3.21	4.30	4.28	4.29
Deccan-103	2.68	2.87	2.78	3.94	3.85	3.90
Kiran	2.13	2.31	2.22	3.19	3.13	3.16
Ganga-11	2.74	2.92	2.83	4.02	3.92	3.97
Deccan-105	2.94	3.15	3.05	4.27	4.17	4.22
Pusa comp-I	2.67	2.84	2.76	3.88	3.74	3.81
CM-300	2.05	2.23	2.14	3.08	3.06	3.04
Mean	2.63	2.79	2.71	3.80	3.74	3.77
C.D. at 5%	NS	NS	NS	0.14	NS	NS

DAE = Days after germination

were negatively correlated with number of eggs/plant but did not reach significant level except for leaf length, leaf width and number of leaves per plant with percent check heat. The correlation of leaf length with oviposition could not be established. It appears that perhaps morphological characters of the plant do not play any significant role in eggs laying by *A. soccata* and *A. naqvii* (Table 10).

Table 10. The correlation of morphological plant characters with number of eggs/plant and dead-heart percentages due to *A. soccata* and *A. naqvii* in maize at different stages of crop growth during spring, 1995 and 1996

Morphological plant character	Number of eggs/plant^0			Per cent dead heart^{00}		
	Days after emergence			Days after emergence		
	5	10	15	5	10	15
Leaf length	–0.093	–0.396	0.092	–0.759*	–0.728	–0.794*
Leaf width	–0.195	–0.235	–0.130	0.676	0.671	0.823*
No. of leaves per plant	–0.131	–0.179	–0.260	–0.703	–0.705	–0.790*
Total leaf area	–0.519	–0.447	–0.222	0.452	0.487	0.580
Leaf thickness	0.370	0.286	0.209	–0.568	–0.372	–0.444
Leaf vein thickness	0.432	0.292	0.379	–0.407	–0.553	–0.377
Trichome length	-	0.487	0.459	-	0.506	0.445
Trichome density	-	–0.326	–0.278	-	–0.634	–0.621

^{0}The number of eggs/plant were observed in 9-11 days old crop
^{00}The dead-heart formation was recorded in 30 day old crop
*Significant at 5%

The total leaf area, trichome length were positively and leaf and vein thickness and trichome density were negatively correlated with dead-heart percentages but the differences were not significant in both the cases.

The leaf length at 5 and 15 DAE and number of leaves/plant at 15 DAE were significantly correlated with percentages of dead-hearts by shoot flies. However, the leaf width was significantly correlated positively at 15 DAE (Table 10). It indicated that the resistant varieties possessed distinctly more leaf length and number of leaves/plant with less leaf width as compared to susceptible ones at 15 DAE. In case of sorghum, various workers [6, 7, 8, 9] observed negatively correlation of leaf length and number of leaves/plant with dead- hearts caused by *A. soccata*. A positive correlation between leaf length and *A. soccata* susceptibility in sorghum was also reported [10].

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