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SORGHUM ENTOMOLOGY

A LITERATURE REVIEW ON THE SOURCES AND MECHANISM OF RESISTANCE TO THE SORGHUM MIDGE (*CONTARINIA SORGHICOLA*)

H.C. SHARMA AND J.C. DAVIES

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
ICRISAT Patancheru P.O.
Andhra Pradesh 502 324, India

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This report lists the sorghum germplasm lines reported to be resistant/less susceptible to the sorghum midge in journal articles, short communications and workshops, and the progress made in screening and breeding for midge resistance. We intend to identify the most stable lines from these genotypes for use in breeding programs. It is hoped that this document will also be useful to breeders and entomologists, who are working with sorghum midge all over the world.

A LITERATURE REVIEW ON THE SOURCES AND MECHANISM OF RESISTANCE TO THE SORGHUM MIDGE (*CONTARINIA SORGHICOLA* COQ.)

H.C. Sharma and J.C. Davies

The sorghum midge, *Contarinia sorghicola*, is the most destructive pest of grain sorghum. It is very serious problem in Asian, African, Australian, European and American continents. There are many other insect-pests, diseases and disorders that may cause appreciable crop losses in sorghum locally, but there seems to be no other single species with such widespread and important effects on sorghum yields (Harris, 1976).

Current recommendations for the control of sorghum midge by cultural means are only moderately effective. Chemical control is normally costly and a large number of applications are required as infestation is often prolonged. Thresholds for insecticide application have been set. In Australia, it is recommended that treatment is started when there are six females/head (Passlow, 1973), while in Texas, the economic threshold is considered to be one female/head (Bottrell, 1971). The prospects for successful application of cultural and chemical control measures against sorghum midge in the semi-arid tropics are very low. It is practically impossible to plant at times when the midge incidence can be completely avoided but timely and early planting is in many areas effective. Normally, the farmers plant with first good showers of rains. However, all the farmers in an area do not plant simultaneously. Insecticides used for control purposes are expensive and often unobtainable by farmers with limited means. Resistant/less susceptible genotypes offer one possible effective way of keeping the midge populations below economic threshold levels.

Reference to midge resistance in sorghum was first made by Ball and Hastings in 1912, though, Gable et al (1928) failed to find resistance to sorghum midge. Subsequently, Evelyn (1951) obtained indications of varietal resistance to midge in the Gezira (Sudan), while Bowden and Neve (1953) in the Gold Coast reported "Nunaba" as resistant to midge attack. However, Harris (1961) and Passlow (1965) found that "Nunaba" was not resistant in the absence of a more favourable host. Screening efforts in several countries in recent years have indicated the existence of a number of resistant/less susceptible lines in sorghum (Pradhan, 1971; Johnson et al, 1973; Wiseman et al, 1973; Parodi et al, 1974; Berguist et al, 1974; Rossetto et al, 1975 and Jotwani, 1978).

Wiseman and McMillan (1968) and Johnson et al (1973) reported that breeding lines converted from Ethiopian material (Zera-zera type) possess resistance to sorghum midge. The resistant lines used in the program had been collected from Sudan, Ethiopia, Uganda, India and Pakistan and belonged to six working groups, viz. Zera-zera, Caudatum, Caudatum/Nigricans, Caffrorum/Darso, Durra and Durra/Nigricans (Johnson et al, 1979). Other important lines used in breeding programs in several countries include: SGIRL-MR-1, DJ 6514 and TAM-2566; but their reaction to midge has been variable (Faris et al, 1979; Wiseman et al, 1974; Raodeo and Karanjkar, 1975; Faris et al, 1976; Syamsunder et al, 1975; Venugopal et al, 1975 and Wuensche et al, 1978).

Sorghum cultivars reported to be resistant/less susceptible to sorghum midge are given in Table 1 & 2.

RESISTANCE SCREENING TECHNIQUES

Testing cultivars with a standard level of infestation is a useful tool for locating resistant parents in a breeding program aimed at incorporation of resistance into agronomically superior cultivars. One of the major difficulties in locating stable resistance source material against sorghum midge has been the lack of an appropriate and repeatable screening technique. So far, it has not been possible to maintain sufficient and constant population pressure on all the test entries in the resistance screening programs. Because of day-to-day variation in midge populations and different flowering periods of germplasm lines, the accurate identification of midge resistant genotypes had been very difficult.

Early plantings of susceptible sorghums have been used to increase midge incidence (Wiseman and McMillan, 1971 and Page, 1980, personal communication). This approach is useful in the initial large scale empirical screening of germplasm and breeding material. However, caging of midge flies with sorghum earheads is more useful in identifying stable resistance sources and reducing chances of error in identification of such sources (Rossetto et al, 1975; Jotwani, 1978 and Page, 1979). With this technique, a fairly constant relationship between number of midge flies and number of florets on an earhead can be obtained. Wuensche et al (1978) suggested field cages to restrict midge populations either to resistant or susceptible sorghum lines for entire season to obtain useful information on the impact of large scale plantings of resistant sorghums on the development of midge populations over time.

There is a great need for the development of a practical technique for artificial rearing of midge for obtaining high levels of infestation. It is a common experience among researchers that sorghum midge resistance is highly variable over space and time. Over several planting dates, Faris et al (1979) found that AF-28 was the most stable line. Other lines showed a highly variable reaction to midge incidence.

MECHANISM OF RESISTANCE

Identification of factors imparting resistance against a particular pest and the mode of their inheritance is important to the understanding and incorporation of resistant traits into agronomically elite material. Widely differing theories have been put forward on the nature of midge resistance in sorghum. Ball and Hastings (1912) reported short glumes as a possible factor contributing to midge resistance in sorghum lines while Geering (1953) considered the degree of apposition of glumes as a factor for resistance. The observations of Bowden and Neve (1953) on 'Nunaba" cultivar showed that length and thickness of glumes (Cleistogamous) contributed to resistance; however, Harris (1961) and Passlow (1965) found that resistance due to nature of glumes was only apparent and "Nunaba" lost its resistance in the absence of a more favoured host plant. Studies in recent years have shown the presence of resistance in non-cliestogamous sorghum lines (Pradhan, 1971; Johnson et al, 1973 & Jotwani, 1978). Murty and Subramaniam (1978) reported that length of glumes, presence of awns and rachis length had no relationship with resistance. They reported genotypes with compact heads resistant and those with semi-compact heads, highly susceptible.

Rossetto et al (1975) reported that resistance mechanism of AF 28 was due to non-preference for oviposition, fewer eggs were laid in it as compared to susceptible sorghums. They concluded that closed spikelets apparently made oviposition difficult in AF 28. The closed character of IS 2260 and IS 2263 has also been suggested to be responsible for imparting midge resistance to these lines (Bergulst et al, 1974).

The level of incidence in a cultivar may also be the function of number of midge flies attracted to/on the head. Wiseman and McMillan (1968) found 0.2 midge flies/head on ODC-19 compared to 52.2 flies on CI 938 (a susceptible line).

An antibiosis mechanism of resistance has also been reported to be operative against sorghum midge by Gowda and Thontadarya (1976); Rossetto

(1977); Jotwani (1978) and Page (1979). They reported the emergence of significantly fewer midge flies from the heads of resistant genotypes compared to the susceptible ones. Tannin content of grains have been suggested as the antibiotic factor imparting resistance. Santos and Carmo (1973) and Santos et al (1974) found some correlation between the infestation scores of Contarinia sorghicola and the tannin content of ripened grains. Sykes (1971) stated that genetic improvement in sorghums have reduced the tannin content considerably. He suggested that studies should be carried out on the extent to which the tannin content of seeds could be raised through genetic improvement.

Widstorm et al (1972) studied gene effects determining resistance to midge. Their studies showed highly additive gene effects. Dominance effects were significant only for the cross S-GIRL-MR-IX 130. Dominance conditions susceptibility to insect injury. They suggested that a simple backcrossing technique may not be sufficient to transfer midge resistance to breeding lines.

Table 1. Sorghum lines promising/resistant against sorghum midge, *C.sorghicola*

S.No.	Line	Remarks	Reference
1	A-25	Received lowest rating of 5.32 in late planting	Wiseman et al, 1974
2	AF-28	Resistant due to nonpreference for oviposition	Rossetto et al, 1974 and Rossetto, 1977
		Most stable line	Faris et al, 1979
3	AF 117	Resistant due to antibiosis	Rossetto, 1977
4	ATX 398xTAM 2566	Damage rating 2.66	Faris et al, 1976
5	ATX 378xTAM 2566	Damage rating 3.03	"
6	CO 4	3.25 to 7.38% incidence	Murty & Subramaniam, 1978
7	CO 11	"	"
8	CO 18	"	
9	1809 CM	Showed least damage	Wiseman et al, 1975
10	2321 CM	"	"
11	2331 CM	"	"
12	DJ 6514 (ShalluxGM2-3-1)	Incidence 27.87%	Syamsundar et al, 1975 Venugopal et al, 1977 Kulkarni et al, 1978
13	E 248A	Less susceptible	Wiseman et al, 1976
14	EC 92 792	Damage rating < 3	Jotwani, 1978
15	EC 92 793	Incidence < 10%	Raodeo and Karanjkar, 1975
16	EC 92 794	"	"
17	Granador INTA mf	Damage rating < 3	Wiseman et al, 1974
18	Hurein-INTA	Tolerant to midge and has improved agronomic adaptation	Parodi et al, 1974
19	IS 413	Promising	Pradhan, 1971
20	IS 1002	"	"
21	IS 1004	"	"
22	IS 1021	"	"

S.NO.	Line	Remarks	Reference
23	IS 1064	Promising	Pradhan, 1971
24	IS 1079	"	"
25	IS 1087	"	"
26	IS 1151	Damage rating < 2	" & Jotwani, 1978
27	IS 1457	< 20% incidence	Pradhan, 1971
28	IS 1462	"	"
29	IS 1472	"	"
30	IS 1474	"	"
31	IS 1501	"	Jotwani, 1978 & Pradhan, 1971
32	IS 1510	"	Pradhan, 1971
33	IS 1542	"	"
34	IS 1568	"	"
35	IS 2160	"	"
36	IS 2205	"	Jotwani, 1978 & Pradhan, 1971
37	IS 2501C	Damage rating < 4	Faris et al, 1976
38	IS 2508C (SC 414)	Moderately stable over environments	"
39	IS 2579	Highly resistant	Johnson et al, 1979
40	IS 2579C (SC 423)	Damage rating < 4.5	Johnson et al, 1973
41	IS 2660	Closed glume character	Berguist et al, 1974
42	IS 2662C (SC 114)	Damage rating < 4.5	Wuensche et al, 1978
43	IS 2663	Grain yield did not differ significantly from infested heads	Berguist et al, 1974
44	IS 2757C (SC 319)	Moderately stable over environments	Wuensche et al, 1978
45	IS 2816C	Damage rating < 4.5	Johnson et al, 1973
46	IS 3071	Highly resistant	Johnson et al, 1979

S.NO.	Line	Remarks	Reference
47	IS 3071C (SC 237)	Highly resistant	Wuensche et al, 1978
48	IS 3272	Damage rating<2	Jotwani, 1978
49	IS 3472	"	Pradhan, 1971; Jotwani, 1978 & Gowda & Thontadarya, 1976
50	IS 3574C	Damage rating < 4.5	Johnson et al, 1973
51	IS 3950	< 20% incidence	Pradhan, 1971
52	IS 4076	Damage rating < 2	Jotwani, 1978
53	IS 4114	"	"
54	IS 4307	< 20% incidence	Pradhan, 1971
55	IS 4308	"	"
56	IS 4316	"	"
57	IS 4411	< 1 midge fly emerged/ earhead	" & Gowda & Thontadarya, 1976
58	IS 4416	Damage rating < 2	Jotwani, 1978
59	IS 4429	< 20% incidence	Pradhan, 1971
60	IS 4477	"	"
61	IS 4511	"	"
62	IS 4528	"	"
63	IS 4544	"	"
64	IS 4569	"	"
65	IS 4653	"	"
66	IS 4757	"	"
67	IS 4761	"	"
68	IS 4782	"	"
69	IS 4808	"	Jotwani, 1978 & Pradhan, 1971
70	IS 4832	"	"
71	IS 4859	"	Pradhan, 1971
72	IS 4868	"	"

S.No.	Line	Remarks	Reference
73	IS 4870	< 1 midge fly emerged/earhead	Pradhan, 1971 & Gowda & Thontadarya, 1976
74	IS 4876	< 20% incidence	Pradhan, 1971
75	IS 4955	"	" & Jotwani, 1978
76	IS 5230	"	" "
77	IS 5384	"	Pradhan, 1971
78	IS 5389	"	"
79	IS 5452	"	"
80	IS 5475	"	"
81	IS 5656	"	"
82	IS 5940	< 1 fly emerged/head	Pradhan, 1971 & Gowda and Thontadarya, 1976
83	IS 5977	"	Pradhan, 1971; Jotwani, 1978 & Gowda and Thontadarya, 1976
84	IS 6146	< 20% incidence	Pradhan, 1971
85	IS 6163	"	"
86	IS 6170	"	Jotwani, 1978; Pradhan, 1971 & Gowda and Thontadarya, 1976
87	IS 6174	"	Jotwani, 1978
88	IS 6179	"	" & Pradhan, 1971
89	IS 6195	"	Pradhan, 1971
90	IS 6206	"	"
91	IS 6367	"	"
92	IS 7142	Highly resistant	Johnson et al, 1979
93	IS 8100C	Damage rating 2.10	Faris et al, 1976
94	IS 8231	Highly resistant	Johnson et al, 1973
95	IS 8263	"	Johnson et al, 1979

S.No.	Line	Remarks	Reference
96	IS 8337	Highly resistant	Johnson et al, 1979
97	IS 12593	"	"
98	IS 12612C	Damage rating 3.0 to 4.5	Johnson et al, 1973
99	IS 12608C	Superior to KS 19 & Alpha	Page, 1979
100	IS 12664C	"	"
101	IS 12666C	< 20% incidence	Johnson et al, 1973
102	IS 12676	Highly resistant	Johnson et al, 1979
103	K-4K	< 7.38% incidence	Murty & Subramanian, 1978
104	Linea 64/21 mf RS 2583	Damage rating < 5 over three years	Wiseman et al, 1974
105	Linea 63/54 mf RS 2324	"	"
106	Line 3017 (SA-8774-2-2-1D9Wh)	Promising	"
107	Nunaba	3% incidence	Bowden & Neve, 1953
108	ODC-19	0.2 flies per head compared to 52.2 on CI 938	Wiseman & McMillan, 1968
109	ODC 92793 (Sel)	Damage rating 2	Jotwani, 1978
110	S-GIRL-MR-1 (Originated from ODC-19, selected from a South African Hegari line over 7 years)	10% heads damaged	Raodeo & Karanjkar, 1975
		Damage rating < 5 over three years	Wiseman et al, 1974
		Damage rating 3.36	Faris et al, 1976
		27% incidence compared to 43% on ODC 19	Venugopal et al, 1977 & Wiseman et al, 1973
		Damage rating < 2	Jotwani, 1978
111	SC 239-14	Resistant due to antibiosis	Rossetto, 1977
112	SC 175-9	"	"

S.No.	Line	Remarks	Reference
113	SC 175-14	Resistant due to antibiosis	Rossetto, 1977
114	SC 574-6	"	"
115	SPV-4	Escaped midge incidence	Avadhani et al, 1977
116	SPV-80	< 30% incidence	"
117	SPV-97	Escaped midge damage	"
118	SPV-102	"	"
119	11157 (Arkansas)	Damage rating < 5 over three years	Wiseman et al, 1974
120	573-3/F3	Promising	Venugopal et al, 1977
121	575-2/F3	"	"
122	1209 cm	Less susceptible	Wiseman et al, 1976
123	1217 cm	"	"
124	1731 cm	"	"
125	1749 cm	"	"

Table.2. Lines reported to be promising/resistant in All India Coordinated Sorghum Improvement Project (1964-80)

S.No.	Line	Remarks	Reference
1	AF 28	< 20% incidence at Parbhani and rated as promising at Dharwar	AICSIP, 1979, 1977
2	CSH 6	< 20% incidence	AICSIP, 1979
3	DJ 6514	Significantly less damaged during 1975-76 and rated as promising during 1978-79	AICSIP, 1979, 1976
4	E 302	Showed promise at Parbhani	AICSIP, 1975
5	E 63-3	< 20% incidence at Dharwar	AICSIP, 1980
6	E 1839-1	< 10% incidence	AICSIP, 1970
7	EC 92792	Promising at Parbhani and Delhi	AICSIP, 1975, 1976, 1977 & 1979
8	EC 92793	< 15% incidence at Coimbatore, least damage at Delhi	AICSIP, 1975, 1973 & 1977
9	EC 92794	Promising at Parbhani, less damaged at Delhi	AICSIP, 1975, 1976 & 1977
10	EM 3402	< 10% incidence	AICSIP, 1970
11	4-Glue	Promising under artificial conditions at Dharwar	AICSIP, 1979
12	IS 149	< 10% incidence	AICSIP, 1970
13	IS 419	Less damaged at 3 centers	AICSIP, 1973
14	IS 420-13	< 10% incidence during 1969-70 and < 20% during 1979-80	AICSIP, 1970, 1980
15	IS 703	< 10% incidence	AICSIP, 1970
16	IS 705	< 10% incidence	AICSIP, 1970
17	IS 1002	No incidence at Delhi	AICSIP, 1967
18	IS 1004	"	"
19	IS 1032	"	"

S.No.	Line	Remarks	Remarks
20	IS 1151	< 15% incidence at Coimbatore, promising at Parbhani & Delhi; < 10% incidence during 1969-70	AICSIP, 1975 AICSIP, 1973 & 1970
21	IS 1182	< 20% incidence at Parbhani	AICSIP, 1974
22	IS 1202	< 5% incidence at Akola	AICSIP, 1980
23	IS 1202B	"	AICSIP, 1980
24	IS 1474	No incidence at Delhi	AICSIP, 1967
25	IS 1501	Promising at Parbhani	AICSIP, 1975
26	IS 1510	Promising at Parbhani, less damaged during 1972-73 & 76-77. < 20% incidence during 1978-79 and promising at Dharwar	AICSIP, 1975, 1973 1977 & 1979
27	IS 1542	No incidence at Delhi	AICSIP, 1967
28	IS 2134	<5% incidence at Akola	AICSIP, 1980
29	IS 2205	< 15% incidence at Coimbatore, promising at Parbhani & less damaged during 1972-73	AICSIP, 1975,, 1973
30	IS 2307	No incidence at Delhi	AICSIP, 1967
31	IS 3472	Less damaged during 1972-73, < 10% incidence during 1970	AICSIP, 1973 & 1970
32	IS 3915	< 10% damage	AICSIP, 1970
33	IS 4114	Suffered < 15% incidence at Coimbatore, less damaged during 1972-73	AICSIP, 1975, 1973
34	IS 4307	< 10% incidence	AICSIP, 1970
35	IS 4308	"	"
36	IS 4411	< 10% incidence	"
37	IS 4416	3.3 midge flies/head compared to 18.7 on Swarna & no incidence at Delhi	AICSIP, 1973
38	IS 4477	< 10% incidence	AICSIP, 1970

S.No.	Line	Remarks	Reference
39	IS 4511	No incidence at Delhi	AICSIP, 1967
40	IS 4524	"	"
41	IS 4832	< 10% incidence at Coimbatore, less damaged during 1972-73, < 10% incidence during 1969-70	", 1975, 1973, 1970
42	IS 4870	< 10% incidence	AICSIP, 1975, 1970
43	IS 4876	"	AICSIP, 1975, 1970
44	IS 4890	No incidence at Delhi	AICSIP, 1967
45	IS 4955	Promising at Parbhani	AICSIP, 1967
46	IS 5230	< 15% damage at Coimbatore, less damaged during 1972-73 at 3 Centers	AICSIP, 1975, 1973
47	IS 5367	No incidence at Delhi	AICSIP, 1967
48	IS 5475	"	"
49	IS 5653	"	"
50	IS 5656	"	"
51	IS 5977	Promising at Delhi, < 10% incidence during 1969-70	AICSIP, 1973, 1970
52	IS 5990	< 10% incidence	AICSIP, 1970
53	IS 6035	No incidence at Delhi	AICSIP, 1967
54	IS 6040	"	"
55	IS 6146	"	"
56	IS 6170	< 10% damage	AICSIP, 1970
57	IS 6179	3.3 midge flies/head compared to 18.7 on Swarna. Showed least damage at 3 Centers during 1972-73	AICSIP, 1973
58	IS 6199	< 15% incidence	AICSIP, 1975
59	IS 6810	< 20% incidence at Dharwar	AICSIP, 1980

S.No.	Line	Remarks	Reference
60	IS 9333	<20% incidence	AICSIP, 1980
61	IS 9530	<10% incidence during 1969-70 and <20% during 1979-80	AICSIP, 1980 & 1970
62	IS 11025	<20% incidence at Parbhani	AICSIP, 1979
63	IS 12573	Promising	AICSIP, 1977, 1979
64	MSH-33, 37	<20% damage	AICSIP, 1979
65	Nanded local	<10% incidence	AICSIP, 1970
66	NJ 1944	<20% incidence at Dharwar	AICSIP, 1980
67	NJ 1989/2	<10% incidence	AICSIP, 1970
68	ODC-19	Promising at Delhi	AICSIP, 1973
69	Philippine	<10% incidence	AICSIP, 1970
70	Pickett-3	<20% incidence at Dharwar	AICSIP, 1980
71	Pickett-4-8	< 5% incidence at Akola	AICSIP, 1980
72	PJ-22K	<20% incidence at Akola	AICSIP, 1980
73	S-Giri-MR-1	1.7% incidence at Coimbatore, promising at Hyderabad & Parbhani, less damaged during 1975-76 & 1976-77; <20% damage at Parbhani during 1978-79 & 1979-80	AICSIP, 1975, 1976 1977, 1980 & 1979
74	Sonna-1	<5% incidence at Akola	AICSIP, 1980
75	SPH-94	<20% damage	AICSIP, 1979
76	SPV-35	"	"
77	SPV-96	"	"
78	SPV-233	"	"
79	TAM 428	<25% damage at Akola	AICSIP, 1980
80	TAM 2566	Promising at Parbhani and Akola	AICSIP, 1979
81	Tx2536	<5% incidence at Akola	AICSIP, 1980

S.No.	Line	Remarks	Reference
82	Uch-H1	Less susceptible	AICSIP, 1977
83	Uch-V1	"	"
84	Uch-V3	"	"
85	X-422 E	<20% incidence	AICSIP, 1979
86	575-1/F3	Promising	AICSIP, 1977
87	575-3/F3	"	"
88	148-BG-J	<5% incidence	AICSIP, 1980
89	575-2	Promising at Dharwar	AICSIP, 1979

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