No-choice Cage Technique to Screen for Resistance to Sorghum Midge (Diptera: Cecidomyiidae)

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ABSTRACT A cage technique to screen sorghum cultivars for resistance to sorghum midge, *Contarinia sorghicola* (Coquillett), under no-choice conditions was developed and standardized. Forty adult midges collected during morning hours (0800–1100 hours) from flowering sorghum panicles and introduced into the cage at the top- to half-anthesis stage for 2 consecutive d resulted in maximum midge damage in the susceptible cultivar 'CSH 1'. Wire-framed cage covered with a blue bag caused the most damage in 'CSH 1'. This technique is useful for verification of midge resistance observed under field conditions. Resistance of 21 sorghum cultivars to sorghum midge was compared under no-choice cage and natural conditions for four seasons. Of 15 cultivars reported to be resistant to sorghum midge under natural conditions, only three ('DJ 6514', 'TAM 2566', and 'IS 12666C') showed repeatable levels of resistance under no-choice conditions during the four seasons. 'TAM 2566' and 'IS 12666C' were less attractive to the midges (<4 midges per five panicles) than the midge-susceptible hybrid sorghum 'CSH 1' (19 midges per five panicles) under field conditions. Fourteen cultivars that were either less attractive to adult midges or had ≤12% florets with midge larvae under natural conditions showed a susceptible reaction under no-choice testing in the cage. Cultivar reactions to midge were stable under the cage over four seasons (except 'IS 2328'). Using first two principal component cluster analysis, 'TAM 2566' and 'DJ 6514' were grouped together as the most resistant cultivars. Sources of resistance to midge thus placed in different groups can be used to increase levels of midge resistance by hybridization among cultivars belonging to different groups.

KEY WORDS Insecta, *Contarinia sorghicola*, no-choice screening, cage screening

SORGHUM MIDGE, *Contarinia sorghicola* (Coquillett), is the most destructive pest of grain sorghum, *Sorghum bicolor* (L.) Moench, in Asia, Africa, the Americas, and Australia (Harris 1976). Host-plant resistance is one of the most effective, economical, and practical means of maintaining midge populations below economic thresholds. Reference to midge resistance was first made by Ball & Hastings (1912). Bowden & Neve (1953) reported 'Nunaba' (a cliestogamous sorghum) to be resistant to the sorghum midge, although Harris (1961) and Passlow (1965) later found that this cultivar became susceptible in the absence of a more favorable host. Recent efforts to screen for resistance to sorghum midge have been reviewed by Sharma & Davies (1981). Testing cultivars under a standard and uniform level of infestation is essential for identifying resistant cultivars. This criterion cannot be met under natural conditions because the midge density varies from day to day and the flowering of sorghum genotypes is not synchronous. Caging adult midges on sorghum panicles has been suggested by Rossetto et al. (1975), Jotwani (1978), and Page (1979).

At the ICRISAT Center, we developed and standardized a technique for large-scale screening of sorghum lines for midge resistance under no-choice conditions. The technique was standardized with respect to the optimum number of adult midges to be released in the cage, the number of infestations required, optimum stage of the panicle for infestation, and color of the cloth bag used to cover the wire-framed cage.

Materials and Methods

Cage. The cage (Fig. 1) consisted of a cylindrical wire frame made of 1.5-mm diameter galvanized iron wire. The wire-framed cage can be tied around the sorghum panicle and covered with a muslin or any similar thin cloth bag. The cylindrical wire-framed cage had two rings (16 cm diameter), 20 cm apart, that were supported by three vertical wire bars. The wire bars at the top ring were bent to hold a 2-cm loop 8 cm below the top ring. The wire bars at the lower ring were bent so that they could be tied around the peduncle with a piece (10 cm) of galvanized iron wire (0.5 mm diameter) or an electric wiring clip. The loop attached to the top ring (which rested around the tip of the panicle) and the extensions of the verticle bars at the lower ring (which were tied around the peduncle) prevented the cage from slipping when disturbed by wind or other factors. The wire frame was covered with a thin blue cloth bag (20 cm diameter, 30 cm long) (Fig. 2). The cloth bag at the top had an

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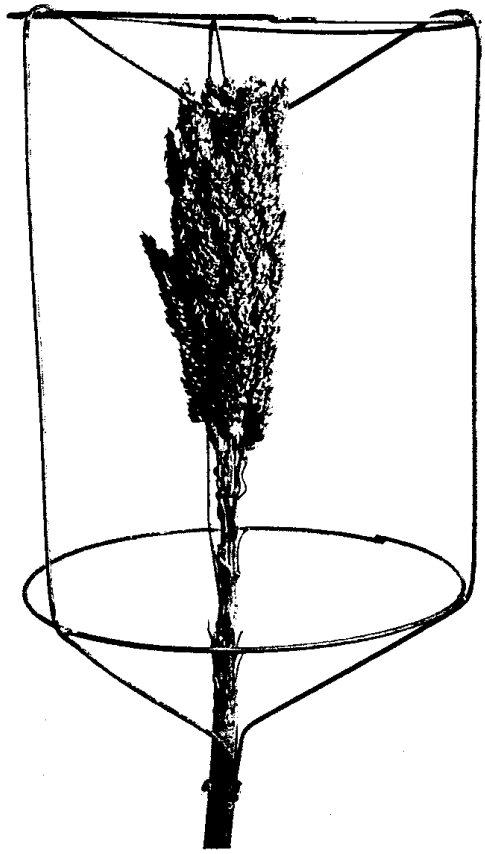

Fig. 1. Wire-framed cage tied around the sorghum panicle.

Fig. 2. Wire-framed cage covered with cloth bag and infested with sorghum midges for resistance screening.

extension (5 cm diameter, 10 cm long) for the introduction of midges.

Experimental Design, Midge Collection, and Damage Evaluation. All experiments were conducted in plots of 'CSH 1' (a commercial sorghum hybrid). Cage treatments were arranged in a randomized block design. Each experiment was replicated five times and one panicle was caged in each replication. While caging the panicles, the branches on the lower 5-cm portion were removed from panicles that were flowering at the top, while the branches on the top 5 cm were removed from panicles that were at the 50% anthesis stage to expose the panicles to midges at the most susceptible stage (Sharma et al. 1983). Adult female midges were collected in plastic bottles (200 ml) between 0800 and 1100 hours from flowering sorghum panicles with an aspirator (only female midges visit the flowering sorghum panicles and these were collected for conducting the experiments). Except as indicated below, 40 midges were released into each cage for 2 consecutive d. The wire cages were covered with a thin blue bag. In the experiment to determine the effect of bag color on midge damage to sorghum, the wire cages were covered with bags of different colors.

The number of midge larvae in the florets and the number of midge-damaged chaffy florets that failed to produce grain were recorded from a sample of 500 florets taken randomly from the infested panicles. Three primary branches were taken at random from the top, middle, and lower portion of each panicle. Primary branches in a sample were mixed and then separated into smaller secondary branches. Five hundred florets were examined from each caged panicle. Midge-damaged chaffy florets were pressed between the tips of a blunt forceps; those producing a red ooze contained midge larvae. Midge-damaged chaffy florets were counted in mature sorghum panicles and the samples were taken as described for the florets infested by midge larvae.

Adult Midge Number. To determine the optimum number of midges required to obtain maximum damage, 20, 30, 40, and 50 adult midges were released into the cage for 2 consecutive d. Numbers of midge larvae in the florets and numbers of midge-damaged chaffy florets were recorded from a sample of 500 florets as previously described.

Number of Infestations. Anthesis in the sorghum panicle proceeds from the top to the bottom and is completed in 6–7 d. Oviposition by the sorghum midge is confined to anthesis. An adult midge survives for 4–24 h after emergence (Sharma et al. 1983). Therefore, adult midges must be released more than once so that all florets of a panicle are exposed to oviposition during anthesis. To deter-

mine the optimum number of infestations required, 40 midges were released into the cages for 1, 2, and 3 consecutive d. Numbers of florets with midge larvae were recorded from a sample of 500 florets as previously described.

Time of Collection and Release. Adult female midges emerge in the morning hours, mate, begin ovipositing in the sorghum panicles at anthesis, and finally die in 4–24 h. Number of eggs laid and survival decrease over time. To determine the time up to which adult midges could be collected and released into the cages for resistance screening, 40 adult midges were collected and released in the cages at 2-h intervals between 0830 and 1430 hours. During the 1980–81 postrainy season, only 20 midges were released in the cages for 1 d. Numbers of florets with midge larvae and numbers of midge-damaged chaffy florets were recorded as previously described.

Midge Damage from Cage-emerged Versus Field-collected Midges. Damage to florets caused by adult midges emerging from milk-stage (15-d-old) sorghum panicles kept in a cage (30 cm^3) in the laboratory was compared with damage to florets by midges collected from flowering sorghum panicles in the field. The cages were covered with black paper, and a transparent plastic jar (16 cm diameter, 20 cm long) with a muslin cloth bag at the end was placed on the top of the cage. After emergence, adults moved into the plastic jar, from which they were collected in plastic bottles (200 ml) with aspirators. In the field, adult midges were collected from flowering sorghum panicles between 0800 and 1100 hours. Field- and laboratory-collected midges were released into the cages in the field. The number of florets with midge larvae and the number of midge-damaged chaffy florets were counted from a sample of 500 florets as described previously.

Stage of Panicle Development. To determine the optimum stage of the panicle for infestation necessary to obtain maximum damage in the cage, sorghum panicles at pre-, top-, half-, and complete anthesis were exposed to 40 midges for 2 consecutive d. The number of florets with midge larvae and the number of midge-damaged chaffy florets were recorded from a sample of 500 florets as described previously.

Bag Color. Sorghum midge behavior is influenced by different colors. Yellow, red, and white are particularly attractive to the midges (Sharma et al. 1983). To test the effect of different cage cover colors on midge damage to sorghum in the cage, blue, black, red, yellow, or white muslin cloth was used to cover the wire-framed cages. Forty midges were introduced into the cages for 2 consecutive d. Number of florets with midge larvae and the number of midge-damaged chaffy florets were recorded from a sample of 500 florets.

Midge Damage to Panicles of 21 Cultivars Under Natural and Cage Conditions. A set of 21 sorghum cultivars, including 15 reported as midge resistant ('DJ 6514' [Shyamsunder et al. 1975]; 'EC 92792', 'EC 92793', and 'EC 92794' [Jotwani 1978]; 'IS 2816C', 'IS 2579C', 'IS 12608C', 'IS 12612C', 'IS 12664C', 'TAM 2566' ['SC 108C'], and 'IS 12666C' [Johnson et al. 1973]; 'IS 1151', 'IS 1510', and 'IS 6195' [Pradhan 1971]; and 'SGIRL-MR-1' [Wiseman et al. 1973]), was tested using the cage technique for four seasons. The cultivars were planted in two rows (4 m long, 75 cm apart) in a randomized block design. Blocks were replicated three times. The cultivars were planted with carbofuran 3 granules (1.2 kg [AI]/ha) to control sorghum shoot fly, *Atherigona soccata* Rondani, and spotted stem borer, *Chilo partellus* Swinhoe. No insecticide was applied during the reproductive stage of the crop. Five panicles of each cultivar at top-anthesis were infested in each replication. Female midges were collected from flowering sorghum panicles between 0800 and 1100 hours in plastic bottles (200 ml). Twenty midges were released for 3 consecutive d at the top-anthesis stage during the 1980 rainy and the 1980–81 postrainy season, and 40 midges were released for 2 consecutive d during the 1981 rainy and the 1981–82 postrainy season. The wire-framed cages were covered with blue bags. Data on numbers of florets with midge larvae and numbers of midge-damaged chaffy florets were recorded from a sample of 500 florets as described earlier.

Data on cultivar susceptibility to midge under natural conditions were recorded for three seasons. Numbers of florets with midge larvae and numbers of midge-damaged chaffy florets were recorded 15 d after anthesis from a sample of 500 florets drawn from five randomly selected panicles in each replication as described before. Numbers of adult midges on five randomly selected panicles of each cultivar in each replication were recorded visually between 0900 and 1000 hours for 3 consecutive d at top- to half-anthesis stage.

Statistical Analysis. Data on number of florets with midge larvae and the number of midge-damaged chaffy florets were expressed as the percentage of total number of florets examined. Data were transformed to arcsine$\sqrt{\%}$ values (except the data on number of midges per panicle, which were converted to square root values) for analysis of variance. Treatment means of the transformed data were compared by least significant difference (LSD) (Snedecor & Cochran 1967). The stability of the genotypes under cage testing and over the seasons (based on the number of florets with midge larvae) was assessed by the method of Finlay & Wilkinson (1963) using modified joint regression analysis (Digby 1979). The stability of genotypes for midge resistance across seasons was assessed from the significance of t value of the regression coefficient. The genotypes tested were grouped using the first two principal components cluster analysis of Snedecor & Cochran (1967) based on the number of florets with midge larvae and the number of midge-damaged chaffy florets.

Table 1. Number of florets with midge larvae and chaffy florets in earheads at different levels of infestation

No. of midges[a]	No. of florets with midge larvae (%)[b]				No. of chaffy florets (%)[b]			
	1981R	1980–81P	1982R	1982–83P	1981R	1980–81P	1982R	1982–83P
20	32.6 (34.3)	37.3 (37.2)	43.8 (41.2)	25.0 (29.8)	55.0 (47.9)	62.0 (52.1)	79.6 (62.2)	50.8 (45.4)
30	28.6 (32.1)	41.3 (39.7)	50.4 (45.0)	26.4 (30.8)	55.6 (48.2)	67.7 (56.1)	77.8 (63.7)	44.0 (41.5)
40	67.4 (55.4)	58.0 (49.7)	64.6 (53.6)	28.2 (31.9)	77.2 (61.9)	71.4 (58.1)	83.6 (68.0)	49.0 (44.4)
50	60.2 (50.9)	54.7 (47.7)	64.6 (53.7)	59.4 (50.6)	77.0 (57.7)	70.6 (57.3)	85.8 (66.4)	74.6 (60.5)
SEM	(±1.89)	(±3.15)	(±3.76)	(±3.28)	(±2.09)	(±2.47)	(±2.41)	(±3.21)
LSD	(5.81)	(9.18)	(NS)	(10.11)	(6.45)	(NS)	(NS)	(9.90)
CV%	(9.77)	(21.66)	(17.37)	(20.51)	(8.68)	(13.26)	(8.29)	(14.97)

R, rainy season; P, postrainy season; NS, not significant; LSD, least significant difference ($P < 0.05$) for comparing treatment means of transformed values; CV%, coefficient of variance (%).

[a] Midge flies were released in the cages for 2 consecutive days.

[b] Figures in parentheses are arcsine$\sqrt{\%}$ transformed values.

Results and Discussion

Adult Midge Number. Florets with midge larvae and midge-damaged chaffy florets were maximum in panicles infested with 40 midges for 2 consecutive d during the 1981 rainy season and the 1981–82 postrainy season (Table 1). A further increase in the midge numbers to 50 per panicle often resulted in a slight reduction in the number of florets with midge larvae and the number of midge-damaged chaffy florets (except during the 1982–83 postrainy season). The decrease in midge damage in panicles infested with 50 midges per panicle may have been due to overcrowding in the cage. During the 1982 rainy season, midge damage of panicles infested with 40 or 50 midges did not differ. Increased midge damage during the 1982–83 postrainy season may have reflected decreased activity or death of some midges because of low relative humidity (<30%) and high temperatures (>40°C), resulting in reduced competition for oviposition. Variation in midge damage over seasons probably resulted from different temperatures and relative humidities. High temperatures (>40°C), lower relative humidity (<30%), and rainfall affect both midge emergence and oviposition adversely (Sharma 1985).

Number of Infestations. Releasing midges for 1, 2, and 3 consecutive d resulted in 28, 44, and 49% florets with midge larvae, respectively. Releasing midges for 3 consecutive d produced only a slight increase in midge damage compared with the 2-d release.

Time of Collection and Release. The number of florets with midge larvae and the number of midge-damaged chaffy florets decreased as the time of collection and release advanced from 0830 to 1430 hours (Table 2). However, the differences in the number of midge-damaged chaffy florets were not significant during the 1982 rainy season. The progressive decrease in midge damage possibly resulted from a decrease in the number of eggs a midge could lay over time. Natural death of adults (midges die at between 4 and 24 h) and reduced activity because of increasing temperatures and decreasing relative humidity may have also accounted for decreased midge damage.

Midge Damage from Cage-emerged Versus Field-collected Midges. Sorghum panicles infested with field-collected midges suffered higher damage (Fig. 3). However, differences were negligible during the 1980 rainy season and the 1980–81 postrainy season. Less damage by midges collected from cages under laboratory conditions probably was due to the problem of adaptation to the variable environmental conditions in the field and the inability of midges to mate inside the emergence cages.

Stage of Panicle Development. Panicles infested at the top- and half-anthesis stages generally suffered greater damage (except during the 1980 postrainy season) compared with those infested at the

Table 2. Effect of time of collection and infestation on percent florets with midge larvae and chaffy florets

S. no.	Time of collection	No. of florets with midge larvae (%)			No. of chaffy florets (%)		
		1980–81P	1982R	1982–83P	1980–81P	1982R	1982–83P
1	0830 hours	11.0 (3.4)[a]	47.8 (43.7)[b]	81.6 (64.6)[b]	39.8 (39.1)[b]	67.0 (55.2)[b]	87.8 (69.7)[b]
2	1030 hours	8.0 (3.0)	36.2 (36.9)	44.0 (41.5)	34.2 (35.7)	58.4 (49.9)	53.2 (46.9)
3	1230 hours	7.0 (2.8)	37.2 (37.4)	10.0 (18.0)	29.8 (32.9)	74.0 (59.8)	27.6 (31.7)
4	1430 hours	0.8 (1.3)	17.4 (23.9)	7.4 (15.4)	21.8 (27.6)	66.4 (55.2)	39.4 (38.9)
SEM		(±0.28)	(±2.89)	(±1.67)	(±2.32)	(±3.67)	(±1.14)
LSD		(0.85)	(8.90)	(5.14)	(7.16)	(NS)	(3.51)
CV%		(23.74)	(18.21)	(10.69)	(15.38)	(14.93)	(5.45)

R, rainy season; P, postrainy season; NS, not significant; LSD, least significant difference ($P < 0.05$) for comparing treatment means of transformed values; CV%, coefficient of variance (%).

[a] $\sqrt{n + 1}$ transformed values.

[b] Arcsine$\sqrt{\%}$ transformed values.

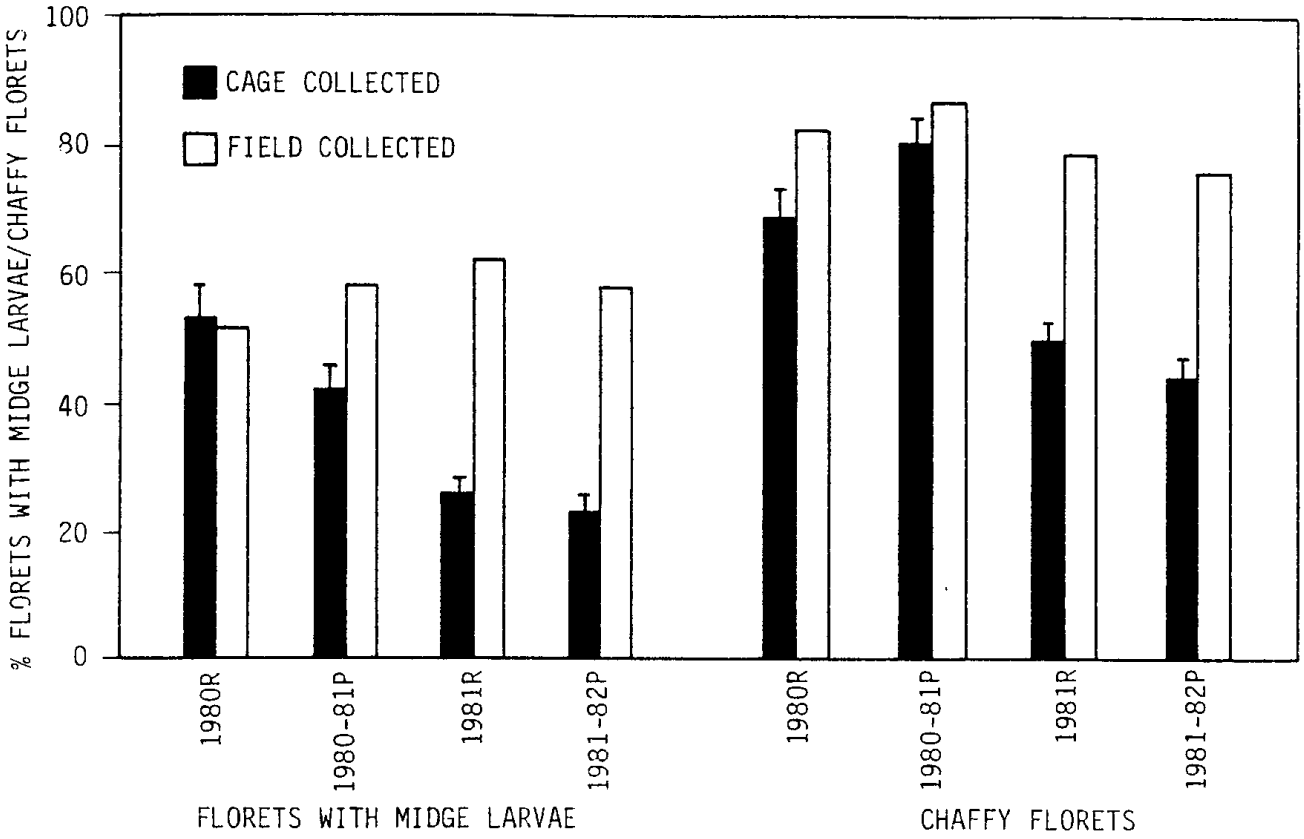

Fig. 3. Florets with midge larvae and midge-damaged chaffy florets in sorghum panicles infested with cage-emerged and field-collected midges.

pre- and complete-anthesis stages (Table 3). Panicles infested at complete anthesis suffered the least damage due to reduced chemical stimuli from the dried anthers and stigmas or an absence of a physical stimulus because of the closed flowers and the initiation of ovary development (Sharma et al. 1983).

Bag Color. Maximum florets with midge larvae and midge-damaged chaffy florets were recorded from panicles covered with blue and black bags (Table 4). However, the differences were not significant during the 1981–82 postrainy season. Differences in midge damage in panicles covered with bags of different colors were probably the result of attraction of the midges to yellow, red, and white, which are closer to the colors of the panicles (Wiseman et al. 1972, Sharma et al. 1983). As a consequence of nonattraction to blue and black, the midges confined themselves to the sorghum panicles for oviposition, with resultant higher damage. Blue bags were selected to cover the cages because the black bags may cause very high temperatures inside the cage during the hot, dry summer season in the semi-arid tropics.

Midge Damage to Panicles of 21 Sorghum Cultivars Under Natural and Cage Conditions. The number of florets with midge larvae and the number of midge-damaged chaffy florets differed significantly among the cultivars under no-choice conditions in the cage over the four seasons (df = 40; $P = 0.05$) (Table 5). 'DJ 6514', 'TAM 2566', and 'IS 12666C' were the most resistant and suffered

Table 3. Number of florets with midge larvae and chaffy florets in earheads infested at different stages of development

Head stage	No. of florets with midge larvae (%)[a]				No. of chaffy florets (%)[a]	
	1980–81P	1981R	1982R	1982–83P	1982R	1982–83P
Pre-anthesis	43.0 (40.9)	24.7 (29.4)	32.6 (34.5)	14.4 (22.2)	66.0 (54.7)	36.8 (37.3)
Top-anthesis	37.6 (37.8)	38.3 (38.0)	40.4 (39.4)	24.4 (29.4)	76.2 (61.2)	46.2 (42.8)
Half-anthesis	30.8 (33.3)	30.0 (33.2)	50.8 (45.5)	27.0 (31.3)	84.6 (67.3)	46.4 (42.9)
Post-anthesis	8.4 (16.7)	3.3 (10.5)	26.8 (31.0)	14.0 (21.5)	80.6 (63.9)	30.4 (33.1)
SEM	(±1.91)	(±3.40)	(±3.22)	(±1.65)	(±3.21)	(±2.34)
LSD	(5.90)	(11.76)	(9.93)	(5.08)	(NS)	(7.21)
CV%	(13.31)	(21.19)	(19.18)	(14.12)	(11.61)	(13.42)

R, rainy season; P, postrainy season; NS, not significant; LSD, least significant difference ($P < 0.05$) for comparing treatment means of transformed values; CV%, coefficient of variance (%).

[a] Figures in parentheses are arcsine$\sqrt{\%}$ transformed values.

Table 4. Effect of bag color on number of florets with midge larvae and chaffy florets in the cage

S. no.	Bag color	No. of florets with midge larvae (%)		No. of chaffy florets (%)
		1981–82P	1982R	1981–82P
1	Blue	71.8 (58.2)[a]	77 (61.4)	82.0[b]
2	Black	70.3 (57.2)	76 (60.1)	83.0
3	Red	66.9 (55.1)	61 (51.6)	67.0
4	Yellow	66.0 (54.4)	63 (52.7)	76.0
5	White	69.8 (56.7)	66 (54.7)	75.0
SEM		(±1.84)	(±2.11)	—
LSD		(NS)	(6.34)	—
CV%		(9.22)	(8.43)	

R, rainy season; P, postrainy season; NS, not significant; LSD, least significant difference ($P < 0.05$) for comparing treatment means of transformed values; CV%, coefficient of variance (%).

[a] Figures in parentheses are arcsine$\sqrt{\%}$ transformed values.

[b] Based upon 2,000 florets taken from five heads.

less midge damage (≤26.9% florets with midge larvae and ≤49.3% midge-damaged chaffy florets) in no-choice screening in the cage. Differences in midge damage among these cultivars were not significant. 'IS 12573C' had 28.9% florets with midge larvae, but the percentage of midge-damaged florets was high (63.5%). The genotype × environment interaction was significant. 'IS 12573C', 'IS 2579C', and 'IS 2816C' suffered more damage during the postrainy season than in the rainy season, but the converse was true for 'DJ 6514' and 'IS 12666C'.

Under natural conditions, 11 cultivars harbored less than four adult midges per five panicles at flowering; of these, three cultivars ('TAM 2566', 'IS 12666C', and 'SGIRL-MR-1') were less damaged (5.0–11.2% florets with midge larvae). Five cultivars ('DJ 6514', 'IS 1151', 'IS 12612C', 'EC 92792', and 'EC 92793'), which did not show nonpreference to adult midges, also suffered less midge damage (<12% florets with midge larvae).

Midge damage under cage screening over seasons was stable for all cultivars (except for 'IS 2328' and 'EC 92793', for which the b value was significant at $P < 0.01$) (Table 6). 'TAM 2566', 'IS 6195', 'IS 12612C', 'CSH 1', and 'IS 12666C' were most stable in their reaction to midge damage (florets with midge larvae) over four seasons under no-choice cage conditions. The cultivars were divided into nine groups using the first two principal components cluster analysis (Fig. 4). 'DJ 6514' and 'TAM 2566' were grouped together as the most resistant cultivars.

The identification of stable sources of resistance to sorghum midge is difficult under natural infestation because of varying midge density and staggered flowering of sorghum cultivars. Twelve out of the 15 reported sources of resistance showed a susceptible reaction in the cage testing, although some cultivars were still relatively less damaged

Table 5. Florets with midge larvae and chaffy florets under cage and natural conditions in 21 sorghum cultivars

Cultivar	Cage[a]		Natural[b]		No. of midges per five panicles[b]
	% florets with midge larvae	% chaffy florets	% florets with midge larvae	% chaffy florets	
'DJ 6514'	13.3 (18.9)[c]	33.9 (34.0)[c]	5.0 (11.5)[c]	23.7 (28.6)[c]	7.3 (2.3)[d]
'TAM 2566'	18.9 (25.2)	34.9 (35.3)	7.0 (13.2)	17.3 (23.9)	2.8 (1.7)
'IS 12666C'	26.9 (30.9)	49.3 (44.0)	11.0 (17.7)	15.8 (22.9)	2.7 (1.5)
'IS 12573C'	28.9 (32.7)	63.5 (53.3)	3.5 (10.2)	28.2 (31.1)	1.2 (1.1)
'IS 2579C'	40.2 (40.0)	70.3 (56.0)	19.2 (21.3)	25.0 (29.4)	5.0 (2.0)
'IS 12664C'	40.6 (40.4)	55.9 (49.6)	20.3 (23.6)	20.7 (26.9)	2.8 (1.6)
'IS 1151'	42.2 (41.9)	54.6 (48.1)	9.7 (15.8)	14.2 (21.0)	9.5 (2.8)
'IS 12612C'	42.6 (40.3)	70.6 (59.0)	11.2 (17.1)	20.2 (25.6)	6.2 (2.4)
'IS 92792'	43.1 (40.9)	54.3 (47.8)	8.8 (15.4)	11.2 (20.6)	7.2 (2.4)
'IS 12611'	46.1 (43.6)	61.9 (52.9)	15.8 (21.7)	13.5 (21.2)	7.5 (2.7)
'SGIRL-MR-1'	46.9 (43.1)	64.6 (53.9)	8.2 (15.4)	13.7 (21.6)	3.0 (1.6)
'IS 2327'	49.3 (43.0)	59.1 (50.5)	23.8 (24.9)	18.7 (25.0)	9.3 (2.6)
'IS 1510'	51.6 (47.4)	75.8 (60.9)	9.5 (15.8)	23.3 (28.3)	3.3 (1.8)
'EC 92793'	52.1 (46.7)	63.0 (53.0)	8.7 (15.5)	14.3 (21.2)	8.7 (2.3)
'ENTM.3'	52.2 (46.7)	67.8 (56.3)	20.2 (23.3)	27.7 (29.4)	6.8 (2.3)
'IS 12608C'	52.7 (48.3)	69.9 (58.6)	14.0 (18.2)	24.7 (28.3)	3.7 (1.8)
'IS 2328'	52.8 (46.9)	73.6 (59.6)	17.0 (20.2)	31.5 (32.6)	12.8 (3.3)
'EC 92794'	53.4 (46.9)	66.6 (55.9)	14.5 (18.8)	21.8 (27.2)	4.8 (2.0)
'IS 2816C'	55.6 (49.2)	53.0 (48.9)	11.2 (17.6)	22.0 (32.4)	2.3 (1.4)
'IS 6195'	57.9 (49.5)	65.1 (56.6)	16.2 (19.9)	30.3 (32.9)	6.0 (2.1)
'CSH 1'	60.0 (51.8)	75.5 (62.3)	18.7 (25.5)	23.8 (28.5)	18.7 (4.1)
SEM	(±5.26)	(±6.31)	(±3.64)	(±3.72)	(±0.47)
LSD	(14.55)	(17.29)	(9.96)	(10.20)	(1.28)
CV%	(17.8)	(17.0)	(28.1)	(19.7)	(30.0)

[a] Based upon four seasons' data.

[b] Based upon three seasons' data.

[c] Arcsine$\sqrt{\%}$ transformed values.

[d] Square root transformed values.

LSD, least significant difference ($P < 0.05$) for comparing treatment means of transformed values. CV%, coefficient of variance (%).

Table 6. Stability of midge resistance of 21 sorghum cultivars under no-choice cage screening over four seasons

Cultivar	*b* value of regression coefficient
'DJ 6514'	−0.26
'TAM 2566'	1.11
'IS 12666C'	0.35
'IS 12573'	−1.16
'IS 2612C'	1.59
'EC 92792'	2.20
'SGIRL-MR-1'	2.09
'IS 2327'	0.17
'EC 92794'	1.96
'IS 2579C'	0.23
'IS 6195'	1.34
'IS 12664C'	1.85
'EC 92793'	2.76[a]
'ENT.3'	−0.48
'IS 12608C'	2.28
'IS 2328'	−3.33[a]
'IS 12611C'	2.46
'IS 2816C'	−1.04
'IS 1151'	2.20
'IS 1510'	1.84
'CSH 1'	0.40

[a] Significant at $P < 0.05$.

than the susceptible control 'CSH 1'. Insect escape, nonpreference, and antibiosis contribute to lower levels of midge damage under natural conditions. Of the 11 cultivars that were less attractive to adult midges under natural conditions, only two cultivars ('TAM 2566' and 'IS 12666C') were less damaged under no-choice conditions. Nonpreference, thus, seems to be one of the components of resistance to the sorghum midge, but this may be of little importance when such cultivars are planted over large areas. Nonpreference as a mechanism of resistance breaks down in the absence of a more favorable host (Harris 1961, Passlow 1965).

Cultivar reaction to sorghum midge is also influenced by the environment. Faris et al. (1979) reported that 'AF 28' was the most stable line over several sowing dates, whereas the reaction of other cultivars such as 'IS 12666C', 'IS 2579C', and 'SGIRL-MR-1' changed with increasing midge density. In our studies, the genotype × environment interaction was significant and some cultivars suffered higher damage in the postrainy season than in the rainy season and vice versa. Thus, the sources of resistance to sorghum midge should be identified not only under no-choice conditions, but also by growing them over several testing environments. Sources of resistance to the sorghum midge belonging to different groups can be utilized to increase levels of midge resistance by hybridization among cultivars belonging to the different groups.

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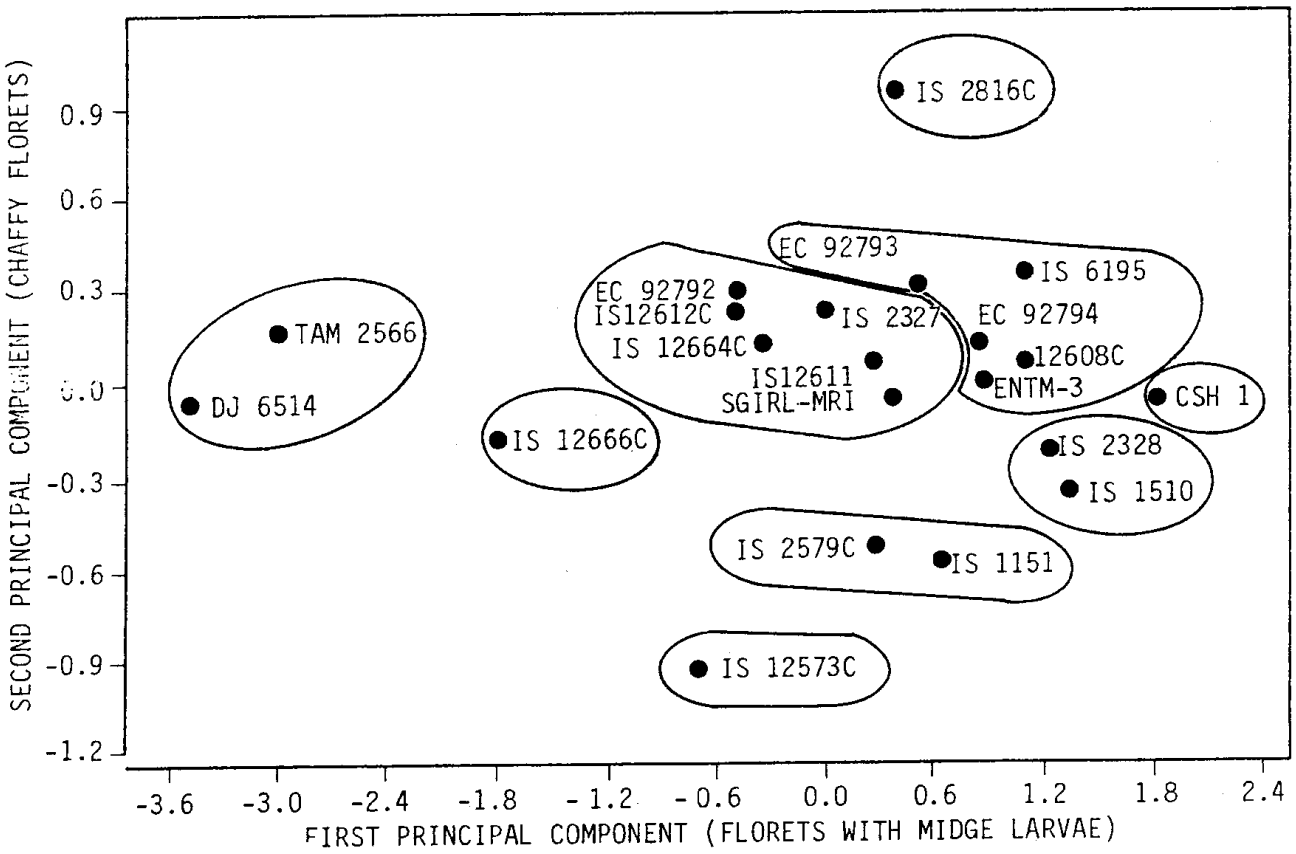

Fig. 4. Clusters of 21 sorghum cultivars for midge resistance based on first two principal components analysis of Snedecor & Cochran (1967).

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