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Genotypic resistance in sorghum to head bug, *Calocoris angustatus* Lethiery

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Summary

Sorghum head bug, *Calocoris angustatus* Leth., is an important pest of grain sorghum. We screened nearly 15000 germplasm accessions for resistance to this pest between 1980 and 1990 under natural and headcage conditions. Data were recorded on bug numbers, grain damage (1 = highly resistant the 5 = highly susceptible), and seed germination. Under natural conditions, 34 genotypes suffered moderate levels of grain damage (damage rating (DR) 1.7 to 2.9) compared with a DR of 4.0 to 4.6 in the susceptible controls CSH 1, CSH 5 and CSH 9. IS 17610, IS 17645, IS 21443, IS 21444, IS 19948, IS 25069 and IS 19949 suffered a DR of less than three, and harbored less than 150 bugs/panicle compared with a DR of 4.3 to 4.7, and 248 to 353 bugs/panicle in the susceptible controls CSH 1, CSH 5 and CSH 9 when infested under headcage with 5 pairs of bugs/panicle. IS 18274, IS 20664, IS 20059, IS 25069, and IS 19951 had 150 to 300 bugs/panicle but suffered moderate levels of grain damage (DR less than 3), while the reverse was true in case of IS 8064, IS 19455, IS 19955, IS 20024, IS 20740, IS 23627, IS 2761, and IS 9692. During the 1989 rainy season, IS 14108, IS 17610, IS 17618, IS 17645, IS 19949, IS 19950, IS 19957, IS 20068, IS 25760, IS 27452, IS 27477 and IS 27329 suffered moderate levels of grain damage when infested with 5 and 10 pairs of bugs/panicle, and recorded more than 80% seed germination compared with a DR of 3.9 to 5.0, and seed germination of 15–18% in the susceptible controls CSH 1, CSH 5 and CSH 9. There is a considerable diversity in the genotypes resistant to head bugs, and attempts should be made to transfer the resistance into agronomically acceptable cultivars.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is an important cereal crop in Asia, Africa and Latin America. Over 150 insects have been reported as pests of sorghum, of which shoot fly (*Atherigona soccata* Rond.), stem borers (*Chilo partellus* Swin. and *Busseola fusca* Fuller), midge (*Contarinia sorghicola* Coq.), head bugs (*Calocoris angustatus* Leth., *Eurystylus immaculatus* Odh., *Campylomma* spp. and *Creontiades pallidus* Ramb.), and head caterpillars (*Helicoverpa* (*Heliothis*) *armigera* Hb.), *Pyroderces simplex* Wsm. and *Eublemma* spp.) are the key pests of sorghum world wide (Sharma, 1985a).

Yield losses caused by panicle feeding insects vary from 5.8 to 84.3%, and avoidable losses have been estimated at nearly Rs. 100 million per annum in India (Leuschner & Sharma, 1983). Head bugs account for a considerable part of these losses. *C. angustatus* is predominant in India (Ballard, 1916; Sharma, 1985b), and *E. immaculatus* in Africa (Sharma et al., 1991).

Head bugs feed mainly on the developing grain, which shrivel, and under severe infestations, become completely chaffy. The damaged grain shows

red-brown feeding punctures, and under heavy infestation, becomes completely tanned. Head bug damage also increases the severity of mold incidence, results in poor seed germination, and renders the grain unfit for human consumption (Sharma & Lopez, 1989; 1990a; Sharma et al., 1991). At the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), major emphasis has been placed on developing sorghum cultivars with resistance to insect pests. We screened a large proportion of the world sorghum germplasm collection to identify genotypes resistant to *Calocoris angustatus*.

Material and methods

Germplasm accessions flowering in less than 85 days during the rainy season were obtained from the genetic resources unit, ICRISAT. Over 15000 accessions were screened at the ICRISAT Center, Patancheru, India, between 1981 and 1990. Selected entries were also evaluated at Bhavanisagar (Tamil Nadu, India). Entries were planted on ridges (75 cm apart), and the plants were thinned to a 10 cm spacing within a row, 15 days after germination. Carbofuran 3G (@ 1.2 Kg a.i. (active ingredient)/ha) was applied at the time of sowing to protect the crops against the sorghum shoot fly, *A. soccata*. No insecticide was applied during the reproductive phase of the crop. The material was evaluated under natural (free-choice) and headcage (no-choice) conditions (Sharma & Lopez, 1991b).

Preliminary screening. In preliminary screening, the entries were tested under infester row technique (Sharma & Lopez, 1991b). Because of staggared flowering of sorghum genotypes, and variation in head bug density over time (Sharma, 1985b), each experiment was planted twice at an interval of 15 days to reduce the chances of escape from head bug damage. The crop was sown during the second and fourth weeks of July so that most of the genotypes flower during September, when the head bug density is greatest (Sharma & Lopez, 1990a). Each entry was planted in a single row (4 m long). Resistant (IS 17610) and susceptible (CSH 1, CSH 5 and CSH 9) checks were planted at regular intervals (after every 50 entries) (Sharma, 1985b). The entries were evaluated for grain damage at maturity on a 1 to 5 scale (1 (highly resistant) = grain with a few feeding punctures, 2 (resistant) = grain with feeding punctures turning brown-red, 3 (moderately resistant) = grain showing slight tanning and about 25% shriveling, 4 (susceptible) = grain showing 50% shriveling and highly tanned appearance, and 5 (highly susceptible) = grain with more than 75% shriveling, slightly visible outside the glumes, and highly tanned). Genotypes with a damage rating of less than three in both sowings were selected for further testing.

Advanced screening. In the advanced trials, entries were planted in 2-row plots, and replicated twice in a randomized block design. Test entries were planted along with suitable resistant and susceptible checks. The entries were evaluated for head bug damage at maturity as described above. Selected entries were tested under no-choice conditions using the headcage technique (Sharma & Lopez, 1991b).

Genotypes which showed low susceptibility to head bugs at ICRISAT Center during the rainy season (July–Oct) were also tested at Bhavanisagar during the summer (Feb-May). Coefficient of variation (%) was computed for each genotype across seasons to determine the stability of resistance to head bugs. Data were also recorded on days to flowering, plant height, grain color, glume length, panicle type and 1000 grain mass.

Headcage screening. To confirm the resistance observed under field conditions, the selected entries were tested under headcage at two levels of infestation (5 and 10 pairs of bugs/panicle). Experimental design was the same as in the advanced trials. Five panicles were infested with 5 and 10 pairs of bugs/panicle in each replication under the headcage (Sharma & Lopez, 1991b). Head bug numbers in the cages were counted 20-days-after infestation. Infested panicles were also rated for grain damage on a 1 to 5 scale. These tests were conducted for four seasons between 1986 and 1989.

Table 1. Head bug damage[1] in 37 sorghum genotypes at two locations in India

Genotype	Patancheru[2]					Bhavanisagar[3]		Mean ± SE	CV (%)
	1986	1987	1988	1989	1990	1988	1989		
IS 8064	3.0^{ab}	1.5^{ab}	1.0^{bc}	2.2^{ab}	0.8^{a}	1.8^{a}	1.8^{bc}	1.7 ± 0.28	16
IS 14317	3.0^{ab}	3.0^{de}	2.5^{fg}	2.7^{bc}	1.4^{ab}	1.8^{a}	2.7^{c}	2.4 ± 0.23	10
IS 14334	3.0^{ab}	2.5^{cd}	2.4^{fg}	3.1^{c}	2.5^{cd}	1.8^{a}	1.8^{bc}	2.4 ± 0.19	8
IS 14380	3.3^{ab}	3.0^{d}	2.8^{gh}	–	1.9^{bc}	1.2^{a}	–	2.4 ± 0.39	16
IS 16357	3.0^{ab}	1.5^{ab}	2.7^{fg}	2.7^{b}	1.1^{a}	–	2.2^{bc}	2.2 ± 0.31	14
IS 19455	3.0^{ab}	3.0^{de}	2.2^{ef}	3.1^{c}	1.9^{bc}	1.8^{a}	2.0^{bc}	2.4 ± 0.22	9
IS 19945	3.0^{ab}	1.0^{a}	2.1^{ef}	–	1.1^{a}	1.2^{a}	–	1.7 ± 0.38	22
IS 19948	3.0^{ab}	1.5^{ab}	0.8^{a}	3.5^{cd}	2.5^{cd}	2.2^{ab}	2.8^{d}	2.3 ± 0.35	15
IS 19949	3.0^{ab}	2.5^{cd}	1.4^{cd}	–	1.4^{a}	1.8^{a}	0.5^{a}	1.8 ± 0.36	20
IS 19950	3.0^{ab}	1.5^{a}	1.3^{cd}	2.9^{b}	2.2^{cd}	1.2^{a}	2.8^{d}	2.1 ± 0.30	14
IS 19951	2.8^{ab}	2.5^{cd}	2.2^{ef}	3.2^{c}	–	2.2^{ab}	1.8^{bc}	2.5 ± 0.20	8
IS 19955	3.0^{ab}	2.5^{cd}	1.3^{cd}	3.5^{cd}	–	1.8^{a}	1.8^{bc}	2.3 ± 0.34	15
IS 19957	3.0^{ab}	1.5^{ab}	0.8^{a}	2.7^{bc}	1.4^{a}	1.2^{a}	1.8^{bc}	1.8 ± 0.30	17
IS 20024	3.0^{ab}	3.0^{d}	1.3^{cd}	2.8^{bc}	2.2^{cd}	1.8^{a}	2.5^{c}	2.4 ± 0.29	12
IS 20059	2.5^{a}	1.0^{a}	2.1^{ef}	2.8^{bc}	1.9^{bc}	1.2^{a}	3.1^{d}	2.1 ± 0.30	14
IS 20068	2.5^{a}	2.5^{cd}	1.1^{b}	1.8^{a}	0.8^{a}	1.8^{a}	2.8^{d}	1.9 ± 0.28	15
IS 20664	3.0^{ab}	3.0^{de}	1.8^{d}	3.2^{c}	–	2.8^{b}	2.8^{d}	2.8 ± 0.20	7
IS 20740	3.0^{ab}	3.0^{de}	2.2^{ef}	3.3^{c}	1.4^{a}	2.2^{ab}	1.3^{a}	2.3 ± 0.30	13
IS 21443	3.0^{ab}	2.5^{cd}	1.7^{d}	3.2^{c}	2.8^{de}	1.8^{a}	2.0^{bc}	2.4 ± 0.23	9
IS 21444	3.0^{ab}	3.0^{de}	2.1^{ef}	3.3^{c}	2.5^{c}	1.2^{a}	2.0^{bc}	2.4 ± 0.28	12
IS 21485	3.5^{bc}	3.5^{e}	1.9^{c}	3.5^{cd}	2.2^{c}	2.8^{bc}	3.1^{d}	2.9 ± 0.25	9
IS 21574	3.3^{b}	2.0^{b}	1.3^{c}	3.1^{c}	2.8^{de}	1.8^{a}	3.1^{d}	2.5 ± 0.29	12
IS 22284	3.0^{ab}	3.0^{de}	2.4^{fg}	2.9^{bc}	–	3.3^{cd}	2.2^{bcd}	2.8 ± 0.17	6
IS 23627	3.0^{ab}	–	2.4^{fg}	·	–	1.8^{a}	2.2^{bcd}	2.4 ± 0.25	10
IS 23748	2.5^{ab}	1.0^{a}	1.9^{c}	2.7^{bc}	1.4^{a}	1.2^{a}	1.3^{a}	1.7 ± 0.25	15
IS 25069	2.5^{a}	1.5^{a}	3.5^{f}	–	1.7$_{bc}$	4.0^{d}	–	2.6 ± 0.49	19
IS 25098	2.3^{a}	2.0^{b}	2.7^{fg}	–	1.1^{a}	2.2^{a}	–	2.1 ± 0.27	13
IS 25760	3.0^{ab}	1.0^{a}	2.9^{gh}	2.7^{bc}	–	1.8^{a}	1.8^{bc}	2.2 ± 0.32	15
IS 27329	–	–	0.5^{a}	3.1^{c}	–	–	2.5^{cd}	2.0 ± 0.79	39
IS 27452	–	–	0.5^{a}	3.5^{cd}	–	–	2.5^{cd}	2.2 ± 0.88	40
IS 27477	–	–	1.7^{d}	2.9^{bc}	–	–	1.2^{a}	1.9 ± 0.50	26
IS 17610	2.5^{a}	2.0^{b}	1.4^{c}	2.9^{bc}	1.1^{a}	3.3^{cd}	1.2^{a}	2.1 ± 0.33	19
IS 17618	3.0^{ab}	2.5^{cd}	1.4^{c}	2.2^{a}	1.7^{bc}	–	–	2.2 ± 0.38	17
IS 17645	2.5^{a}	2.0^{b}	1.1^{b}	2.2^{a}	1.1^{a}	–	1.2^{a}	1.7 ± 0.25	15
CSH 1	4.0^{cd}	4.3^{f}	4.8^{i}	3.9^{d}	3.6^{c}	–	4.2^{c}	4.1 ± 0.17	4
CSH 5	4.5^{de}	5.0^{f}	4.9^{i}	4.1^{d}	–	–	4.5^{c}	4.6 ± 0.16	4
CSH 9	5.0^{e}	5.0^{f}	3.3^{fg}	4.2^{d}	3.3^{c}	–	4.0^{c}	4.0 ± 0.31	8
SE ±	0.21	0.27	0.17	0.27	0.50	0.27	0.31	–	–
LSD at 5%	0.58	0.75	0.47	0.75	1.38	0.75	0.86	–	–

[1] Damage rating (1 = grain with a few feeding punctures, 2 = grain with feeding punctures turning red-brown, 3 = grain showing about 25% shriveling, 4 = grain showing about 50% shriveling and highly tanned appearance, and 5 = grain showing > 75% shriveling, slightly visible outside the glumes, and highly tanned appearance).

[2] Screened at Patancheru during rainy season (Jul. to Oct.).

[3] Screened at Bhavanisagar during summer (Feb. to May).

Figures followed by the same letter within a column are not significantly different at $P < 0.05$.

Data on head bug numbers was plotted against grain damage ratings for each genotype to identify genotypes with lower population increase and/or low levels of head bug damage under the no-choice conditions in the headcage.

During the 1989 rainy season, the selected genotypes were evaluated for head bug damage under natural and headcage conditions (5 or 10 pairs of bugs/panicle). Data were recorded on head bug numbers and grain damage under natural and headcage conditions, and seed germination (%) under natural conditions. Data were subjected to analysis of variance.

Results

Under natural conditions, 34 genotypes showed grain damage rating (DR) of less than three over seasons and locations (Table 1). IS 8064, IS 19945, IS 19949, IS 19950, IS 20068, IS 23745, IS 25098, IS 27329, IS 27477, IS 17610, and IS 17645 were resistant to head bugs over seasons (DR less than 3). Based on coefficient of variation (%) for grain damage (which can be taken as a measure of stability of resistance), IS 14334, IS 19455, IS 19951, IS 20664, IS 21443, and IS 22284 were stable in their reaction to head bug damage across seasons. Most of these genotypes are tall (nearly 300 cm), and flower in 54–110 days (Table 2). Grain color varies from brown to red, purple, straw, white and grey. Grain mass ranges from 12 to 28.8 g/1000 grains. Most of these genotypes are *guinense* sorghums from West Africa (except IS 14108 and IS 20740 (*bicolor*) and IS 16357 (*caudatum*)).

Results on genotypic reaction to head bugs under headcage are given in Fig. 1a and b. At an infestation level of 5 pairs/panicle, IS 17610, IS 17645, IS 21444, IS 19948, IS 21443, IS 25069 and IS 19949 suffered a mean grain damage rating (DR) of less than three and had less than 150 bugs/panicle compared with 248 to 353 bugs/panicle, and a DR of 4.3 to 4.7 in the susceptible controls CSH 1, CSH 5, and CSH 9.

At an infestation level of 10 pairs of bugs/panicle, IS 17610 and IS 20740 had lower population increase (less than 150 bugs/panicle) and suffered a DR of less than three compared with 243 to 336 bugs/panicle and a DR of 4.8 to 5.0 in the susceptible controls, CSH 1, CSH 5, and CSH 9. IS 25069, IS 20059, IS 17618, IS 19948, IS 25098, and IS 17645 had 150 to 300 bugs/panicle, but suffered moderate levels of grain damage (DR less than 3.0). Genotypes showing grain damage severity of less than 3.5 and having less than 150 bugs/panicle included IS 21444, IS 21443, IS 17645, IS 14380, and IS 14334.

Twenty-six lines showing low susceptibility to head bugs under natural infestation, were tested under natural and headcage conditions during the 1989 rainy season (Table 3). IS 14108, IS 27452, IS 27477, IS 17610, and IS 17618 had 18–123 bugs/panicle and showed a DR of 0.6 to 2.8 compared with 177 to 202 bugs/panicle and a DR 4.4 to 5.0 in the susceptible controls CSH 1, CSH 5, and CSH 9 under headcage. Under natural infestation, IS 14108, IS 14317, IS 19949, IS 19957, IS 20068, IS 20664, IS 20740, IS 21574, IS 25760, and IS 27329 had less than 100 bugs/10 panicles and suffered a DR of less than three compared with 195–605 bugs/10 panicles and a DR of 4.2 to 4.7 in the susceptible controls CSH 1, CSH 5, and CSH 9. Genotypes having low bug numbers or showing a grain DR of less than three showed more than 78% seed germination compared with 15–18% seed germination in the susceptible controls.

Discussion

Head bug numbers and grain damage under natural conditions are influenced by cultivar preference/nonpreference and antibiosis (Sharma, 1985b; Sharma & Lopez, 1990b). Resistance to bugs is also influenced by head bug density and the prevailing environmental conditions, which affect both population increase and grain damage (Sharma & Lopez, 1991a). A number of these factors vary over time and space, and therefore, it is important to know the levels and expression of resistance to head bugs across seasons/locations, and under controlled conditions (headcage screening) to identify stable sources of resistance for use in a breeding program.

Table 2. General characteristics of 38 sorghum genotypes less susceptible to the sorghum head bug, *C. angustatus*

Genotype	Origin	Classification[1]	Plant height (cm)	Days to 50% flowering	Panicle type[2]	Grain color[3]	1000 grain mass (g)
IS 8064	Japan	G	380^{klm}	68^{b-d}	L	LR	12.0^{a}
IS 14108	USSR	B	218^{a}	54^{a}	L	B	25.9^{kl}
IS 14317	Swaziland	G	308^{ghi}	74^{e}	L	LR	18.9^{d}
IS 14334	South Africa	G	245^{cd}	65^{b}	L	W	22.4^{ghij}
IS 14380	Zimbabwe	G	290^{f}	65^{b}	L	LR	22.6^{ghij}
IS 16357	Cameroon	C	214^{a}	68^{b}	SL	RB	24.4^{ijk}
IS 19455	Botswana	G	267^{def}	71^{cde}	SL	W	15.5^{bc}
IS 19945	Senegal	G	310^{gh}	83^{ghi}	L	S	19.7^{def}
IS 19948	Senegal	G	305^{ghi}	76^{ef}	SL	S	18.8^{d}
IS 19949	Senegal	G	285^{efg}	81^{fg}	L	S	23.7^{ijk}
IS 19950	Senegal	G	329^{hij}	78^{f}	L	S	23.0^{hij}
IS 19951	Senegal	G	370^{kl}	82^{gh}	L	CW	25.5^{kl}
IS 19955	Senegal	G	410^{mn}	82^{gh}	L	S	22.0^{ghij}
IS 19957	Senegal	G	308^{fg}	78^{f}	SL	W	18.5^{cde}
IS 20024	Senegal	G	320^{hij}	82^{gh}	L	S	15.0^{b}
IS 20059	Senegal	G	348^{jk}	72^{cd}	SL	S	20.9^{fgh}
IS 20068	Senegal	G	329^{hij}	73de	SL	P	21.6^{ghij}
IS 20664	USA	G	300^{fgh}	77^{ef}	L	W	19.7^{def}
IS 20740	USA	B	255^{cde}	75^{e}	L	B	18.6^{cde}
IS 21443	Malawi	G	268^{def}	72^{cde}	SL	W	18.0^{d}
IS 21444	Malawi	G	258^{def}	71^{cde}	SL	W	21.2^{fgh}
IS 21485	Malawi	G	390^{lm}	83^{ghi}	SL	W	20.3^{efg}
IS 21574	Malawi	G	384^{lm}	75^{e}	SL	W	17.4^{cd}
IS 22284	Botswana	GC	252^{cd}	88^{i}	L	S	17.5^{cd}
IS 23627	Gambia	G	390^{lm}	84^{hi}	SL	B	13.4^{b}
IS 23748	Burkina Faso	GC	287^{defg}	73^{def}	SL	RB	33.5^{n}
IS 25069	Ghana	GC	350^{jk}	71^{cde}	SL	R	28.2^{l}
IS 25098	Ghana	G	310^{gh}	73^{def}	SL	R	28.0^{l}
IS 25760	Mali	G	296^{defgh}	72de	L	S	22.7^{hij}
IS 27329	Burkina Faso	G	326^{hij}	74^{ef}	SL	W	24.3^{ijk}
IS 27452	Burkina Faso	G	332^{ij}	85^{hi}	L	G	24.3^{ijk}
IS 27477	Burkina Faso	GC	332^{ij}	82^{ghi}	SL	RB	28.8^{lm}
IS 17610	Ghana	G	425^{n}	110^{j}	L	W	23.6^{ijk}
IS 17618	Ghana	G	392^{lm}	110^{j}	SL	R	22.8^{hij}
IS 17645	Ghana	G	425^{n}	110^{j}	SL	R	24.0^{ijk}
CSH 1	India	B	120^{a}	66^{bc}	SC	S	30.6^{mn}
CSH 5	India	B	165^{b}	74^{ef}	SC	S	30.6^{mn}
CSH 9	India	B	129^{a}	76^{ef}	C	S	32.2^{n}
SE ±	–	–	11.9	1.9	–	–	0.82
LSD at 5%	–	–	33.1	5.2	–	–	2.25

[1] Classification (B = bicolor; G = guinense; C = caudatum; GC = guinense-caudatum).

[2] Panicle type (C = compact; SC = semi-compact; SL = semi-loose; L = loose).

[3] Grain color (B = brown; G = grey; P = purple; R = red; S = straw; W = white; CW = chalky white; LR = light red; RB = reddish brown).

Figures followed by the same letter within a column are not significantly different at $P < 0.05$.

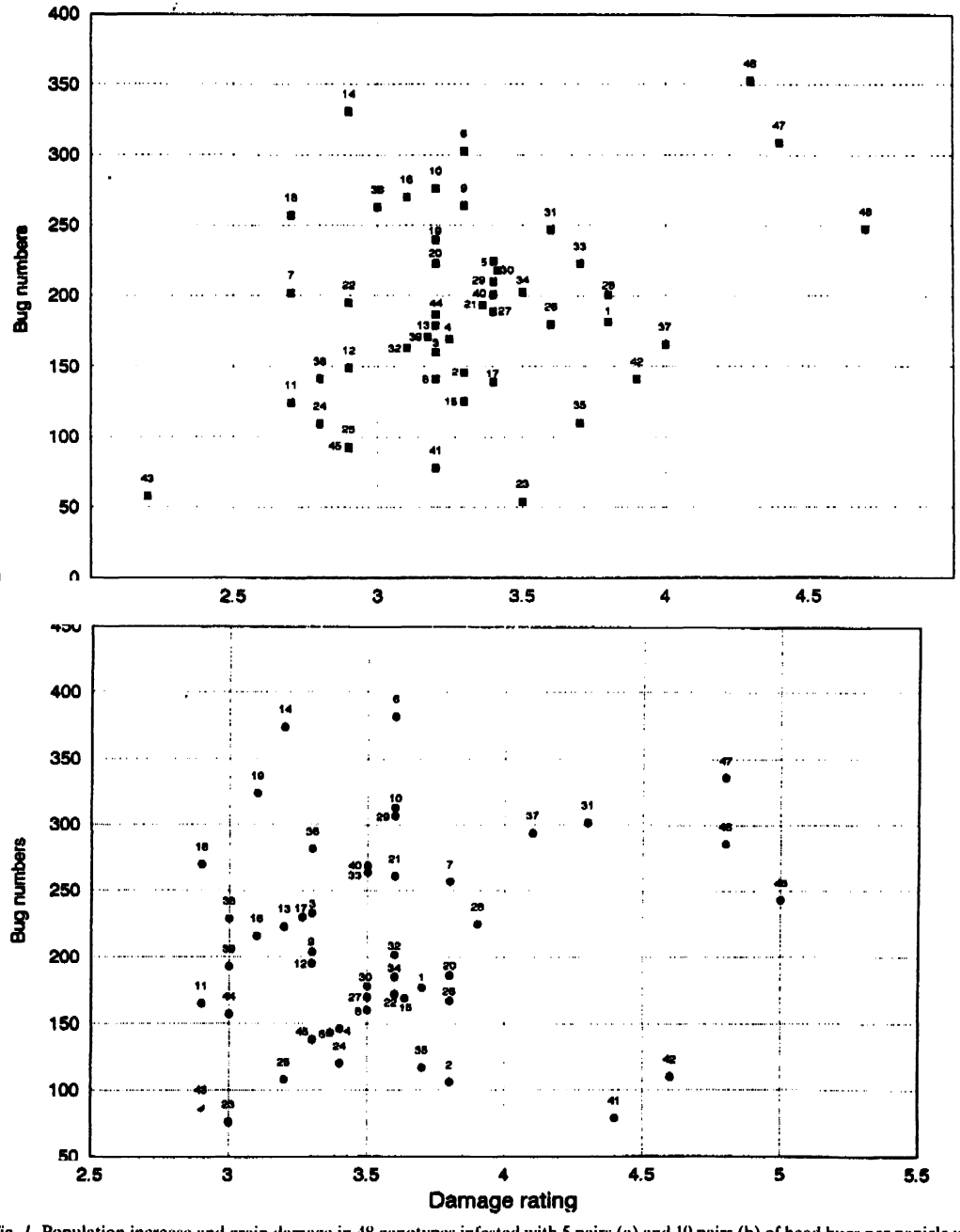

Fig. 1. Population increase and grain damage in 48 genotypes infested with 5 pairs (a) and 10 pairs (b) of head bugs per panicle under head cage (1 = IS 6983, 2 = IS 8064, 3 = IS 14317, 4 = IS 14334, 5 = IS 14380, 6 = IS 16357, 7 = IS 18274, 8 = IS 19455, 9 = IS 19945, 10 = IS 19946, 11 = IS 19948, 12 = IS 19949, 13 = IS 19950, 14 = IS 19951, 15 = IS 19955, 16 = IS 19957, 17 = IS 20024, 18 = IS 20059, 19 = IS 20068, 20 = IS 20226, 21 = IS 20638, 22 = IS 20664, 23 = IS 20740, 24 = IS 21443, 25 = IS 21444, 26 = IS 21468, 27 = IS 21485, 28 = IS 21525, 29 = IS 21527, 30 = IS 21574, 31 = IS 21621, 32 = IS 22284, 33 = IS 22289, 34 = IS 22291, 35 = IS 23627, 36 = IS 23748, 37 = IS 23968, 38 = IS 25069, 39 = IS 25098, 40 = IS 25125, 41 = IS 2761, 42 = IS 9692, 43 = IS 17610, 44 = IS 17618, 45 = IS 17645, 46 = CSH 1, 47 = CSH 5, 48 = CSH 9).

IS 19948, IS 20740, IS 21443, IS 21444, IS 17610, and IS 17645 were most resistant to head bugs, and had lower bug numbers and suffered low levels of grain damage (DR less than 3). Bug population increase on IS 18274, IS 20664, IS 20059, IS 25069, and IS 19951 was greater than 150 bugs/panicle, and suffered moderate levels of grain damage under headcage (DR less than 3). These genotypes possibly have some degree of tolerance to head bug feeding. On the contrary, bug population increase was low (less than 150 bugs/panicle) on IS 8064, IS 19455, IS 19955, IS 20024, IS 20740, IS 23627, IS 2761, and IS 9692, but they suffered greater grain damage (DR 3 to 4). Some of these genotypes may have antibiosis as one of the mechanisms of resistance to bugs.

Twenty-two genotypes suffered moderate levels of grain damage (DR less than 3) under natural infestation, of which 14 genotypes had low (less than 150 bugs/10 panicles) head bug numbers as well. Under no-choice conditions in the headcage, IS 14317, IS 20059, IS 20068, IS 20664, IS 20740,

Table 3. Response of 26 sorghum genotypes to the head bug, *C. angustatus*, under natural and headcage conditions (1989 rainy season)

Genotype	No. of bugs/panicle with		Grain damage[1] rating with		Natural conditions	Damage[1] rating	Germination (%) under natural infestation
	5 pairs	10 pairs	5 pairs	10 pairs	No. of bugs/10 panicles	Threshed grain	
IS 14108	70 (8.2)^{2bc}	39 (6.1)^{2b}	2.7	2.8^{bcd}	19 (5.1)^{2a}	1.9^{abc}	–
IS 14317	119 (10.5)^{d}	122 (11.0)^{de}	4.3^{g}	3.6^{de}	72 (7.8)^{bc}	1.4^{a}	96^{cd}
IS 16357	308 (16.7)^{i}	191 (13.2)^{gh}	2.1^{bcd}	3.2^{cde}	355 (17.4)^{h}	2.2^{abcd}	71^{b}
IS 19455	315 (17.6)^{j}	160 (12.3)^{fg}	3.5^{f}	3.6^{de}	226 (12.1)^{ef}	2.8^{cde}	84^{bcd}
IS 19948	116 (9.6)^{cd}	152 (11.2)^{ef}	3.3^{ef}	3.2^{cde}	178 (12.0)^{ef}	2.2^{abcd}	96^{cd}
IS 19949	143 (11.3)^{de}	208 (12.8)^{fg}	2.5^{cde}	2.9^{bcd}	38 (5.7)^{ab}	2.2^{abcd}	86^{bcd}
IS 19950	147 (12.1)^{ef}	242 (15.4)^{ij}	2.0^{bc}	2.8^{bcd}	59 (6.1)^{ab}	3.1^{de}	95^{cd}
IS 19957	167 (11.5)^{e}	261 (15.7)^{ij}	2.5	2.2^{b}	64 (6.7)^{ab}	2.8^{cde}	99^{d}
IS 20059	164 (12.5)^{ef}	157 (12.5)^{fg}	2.9^{def}	3.3^{cde}	122 (9.7)^{cd}	3.1^{de}	91^{bcd}
IS 20068	255 (15.3)^{hi}	156 (11.9)^{efg}	3.1^{ef}	3.1^{cde}	81 (7.9)^{bc}	1.9^{abc}	92^{d}
IS 20664	237 (14.3)^{gh}	113 (9.5)^{cd}	2.8^{def}	3.7^{e}	66 (6.5)^{ab}	2.5^{bcde}	92^{d}
IS 20740	47 (5.8)^{a}	18 (4.1)^{a}	2.6^{cde}	3.8^{e}	96 (7.9)^{bc}	2.5^{bcde}	–
IS 21443	154 (12.2)^{ef}	202 (13.5)^{gh}	3.3^{ef}	3.9^{e}	164 (10.9)^{de}	3.1^{de}	93^{cd}
IS 21444	159 (12.3)^{ef}	124 (11.0)^{def}	3.6^{f}	3.3^{cde}	115 (9.7)^{c}	3.3^{ef}	82^{bcd}
IS 21574	162 (12.6)^{ef}	126 (10.7)^{de}	2.9^{def}	3.6^{de}	61 (6.9)^{ab}	2.8^{cde}	96^{cd}
IS 22284	166 (11.2)^{de}	112 (10.2)^{cd}	3.2^{ef}	3.4^{de}	223 (10.7)^{d}	1.9^{abc}	96^{cd}
IS 25760	215 (13.3)^{fg}	250 (14.5)^{hi}	2.6^{cde}	2.6^{bc}	59 (7.0)^{ab}	2.8^{cde}	29^{a}
IS 27329	252 (15.3)^{hi}	96 (9.0)^{c}	2.9^{def}	2.8^{bcd}	67 (6.2)^{ab}	1.9^{abc}	97^{d}
IS 27452	64 (7.8)^{b}	110 (10.3)^{cd}	2.2^{bcd}	2.5^{bc}	166 (11.9)^{def}	2.8^{cde}	78^{bc}
IS 27477	72 (8.2)^{bc}	105 (9.0)^{c}	1.8^{bc}	2.1^{ab}	161 (12.1)^{ef}	2.5^{bcde}	92^{c}
IS 17610	78 (8.2)^{bc}	122 (10.3)^{cd}	0.6^{a}	1.5^{a}	211 (13.2)^{fg}	1.4^{a}	100^{d}
IS 17618	34 (5.4)^{a}	123 (10.7)^{def}	1.3^{a}	2.8^{bcd}	347 (16.3)^{h}	2.2^{abcd}	98^{cd}
IS 17645	234 (14.2)^{gh}	204 (13.2)^{gh}	2.9^{def}	–	– (–)	1.7^{ab}	96^{cd}
CSH 1	177 (12.7)^{e}	306 (16.2)^{i}	4.9^{g}	5.0^{f}	195 (13.1)^{fg}	4.7^{g}	15^{a}
CSH 5	267 (16.0)^{hij}	241 (15.2)^{ij}	4.4^{g}	5.0^{f}	291 (15.3)^{gh}	4.2^{fg}	15^{a}
CSH 9	282 (16.2)^{ij}	254 (15.4)^{ij}	4.4^{g}	5.0^{f}	605 (10.4)^{de}	4.2^{fg}	18^{a}
Mean	169 (12.5)	161 (11.7)	2.9	3.3	161 (10.4)	2.6	79
SE	± (0.6)	± (0.5)	± 0.31	± 0.30	± (0.8)	± 0.35	± 7.4
LSD at 5%	(1.7)	(1.5)	0.86	0.83	(2.2)	0.90	20.4

[1] Damage rating – see Table 2.

[2] Figures in parentheses are square root transformed values.

Figures followed by the same letter within a column are not significantly different at $P < 0.05$.

and IS 21574 suffered greater grain damage (DR more than 3.0) when infested with 10 pairs of bugs/panicle during the 1989 rainy season. These genotypes may not be stable in their reaction to head bugs. IS 19959, IS 19950, IS 19957, IS 25760, IS 27329, IS 17610, IS 17618, and IS 17645 suffered low levels of grain damage (DR less than 3) despite having greater number of bugs under natural and/or headcage conditions. These genotypes possibly have greater tolerance to head bug feeding.

The levels of resistance to head bugs in sorghum germplasm accessions are moderate. However, the interactions between sources of resistance and head bug populations are diverse. There is also a considerable diversity in resistance sources in plant height, days to flower, grain size, grain color, panicle type and glume characteristics. Most of the genotypes resistant to head bugs have long glumes which cover the grain upto 20 days after flowering compared with 6 to 8 days in the susceptible controls (Sharma, 1985b; Sharma et al., 1991). This possibly restricts the effective feeding period of the bugs on the exposed surface of the grains. Efforts should be made to increase the level of head bug resistance by involving diverse genotypes in breeding programs, and to transfer the resistance from germplasm lines into photo-period insensitive agronomically acceptable cultivars.

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