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Interactions between panicle size, insect density, and environment for genotypic resistance in sorghum to head bug, *Calocoris angustatus*

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Abstract

Studies were undertaken on interactions between panicle size, insect density, host plant, and the environment for sorghum head bug, *Calocoris angustatus* Lethiery on five sorghum genotypes in terms of bug population increase, grain damage and loss in grain mass across four panicle sizes (5, 10 or 20 branches/panicle and whole panicle), and three infestation levels (5, 10 and 15 pairs of bugs/panicle). Head bug numbers increased and grain damage decreased with an increase in panicle size in the head bug susceptible cultivars, CSH 1 and CSH 5. However, the increase in bug numbers or decrease in grain damage was not significant in head bug resistant genotypes, IS 17610 and IS 17645. Head bug numbers increased with an increase in infestation level in CSH 1 and CSH 5, however, such an increase was not substantial in IS 17610 and IS 17645. Grain damage was significantly lower in IS 17610 and IS 17645 compared with CSH 1 and CSH 5 across infestation levels. Head bug population increased at a greater rate during the rainy season compared with the dry season. Panicle size and infestation levels accounted for greater variation in grain damage and percentage loss in grain mass during the rainy season than in the dry season. To identify reliable sources of resistance to insects, it is important to study insect host plant-interactions across panicle sizes (levels of food availability), infestation levels and seasons.

Introduction

Mirid head bugs, *Calocoris angustatus* Leth., *Eurystylus immaculatus* Odh., *E. bellevoyei* Put. and Reut., *Creontiades pallidus* Ramb., *Taylorilygus vosseleri* Popp., and *Campylomma* spp. are one group of key pests of sorghum which feed on the sorghum grain from initiation of grain development till physiological maturity (Ballard, 1916; Sharma, 1985; Natarajan & Sundara Babu, 1988a, b; Sharma & Lopez, 1990a; Sharma *et al.*, 1992). *C. angustatus* is the predominant head bug species in India (Sharma & Lopez, 1990a). Both adults and nymphs suck the sap from the developing grain, resulting in tanning and shriveling of the damaged grain. This results in a severe loss in grain yield and quality (Sharma & Lopez, 1989).

Plant resistance to insects is an important component in the management of *C. angustatus*. Several lines resistant to *C. angustatus* have been identified (Sharma, 1985; Sharma & Lopez, 1992b). However, environmental conditions change the interactions between the insects and their host plants by influencing the rates of insect development and the physiochemical properties of the plants (Sharma & Lopez, 1991). For measuring genotypic resistance to head bugs, data are recorded on bug numbers, grain damage, loss in grain mass, and seed germination (Sharma & Lopez, 1992a). Panicle size or the amount of grain available for feeding on a panicle has been reported to influence the extent of bug population increase on a susceptible cultivar, CSH 1 under no-choice conditions in the headcage (Sharma, 1985). Also, panicle size or the productivity potential of a genotype is determined by the fertility status of the soil, and the prevailing environmental conditions. Bug abundance and grain damage are also influenced by head bug density, which varies across seasons and locations (Sharma & Lopez, 1991). Therefore, genotypes resistant to bugs should result in low rates of increase in bug numbers, and suffer low grain damage across panicle sizes and infestation levels. We studied such interactions between panicle size and infestation levels in five sorghum genotypes over two seasons to identify reliable sources of resistance to *C. angustatus*.

Materials and methods

Crop. Five sorghum genotypes including three lines (IS 17610, IS 17618, and IS 17645) identified as less susceptible to *C. angustatus* under natural conditions (Sharma, 1985), and two susceptible commercial hybrids (CSH 1 and CSH 5) were tested for their interactions with head bugs under no-choice conditions in the headcage (Sharma & Lopez, 1992a) at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India. The cultivars were planted in eight row plots (4 m long, 75 cm apart) in a randomized block design. There were three replications. Plants were thinned to a spacing of 10 cm 15 days after emergence. Seeds were sown with carbofuran 3G (at 1.2 kg a.i. ha^{-1}) to control the sorghum shoot fly, *Atherigona soccata* Rondani. No insecticide was applied during the reproductive phase of the crop. The crop was grown under rainfed conditions during the rainy season (July-October), and under irrigation during the dry season (December–April).

Insects. Head bugs were reared on panicles of CSH1, a susceptible sorghum hybrid, under field conditions. Adult bugs were confined with the panicles for egg laying at the pre-anthesis stage in a cage covering the panicle. At the dough-stage (15 to 25 days after infestation), newly emerged adults were collected in pairs of 5, 10 or 15 in 200 mL plastic bottle aspirators, and immediately used for infesting the panicles of different genotypes.

Infestation. The bugs collected in plastic bottles were released inside the cages covering sorghum panicles at the pre-anthesis stage (Sharma & Lopez, 1992a). Panicles having all the branches intact (nearly 25 primary branches) or with 5, 10, or 20 primary branches/panicle in the mid-portion were infested with 10 pairs of adult bugs/panicle at the pre-anthesis stage. Extra branches at the top and bottom portion of the panicle were removed with scissors. Five panicles were infested in each treatment. For each panicle size, panicles caged similarly, but without bugs, served as uninfested control. Percentage loss in grain mass in the infested panicles was computed in relation to the grain mass of the uninfested control panicles. Data were recorded on bug numbers 20 days after infestation, and on grain damage, and percentage loss in grain mass at maturity.

In another experiment, randomly tagged panicles were trimmed to a uniform size by retaining 20 primary branches/panicle. Five panicles each were infested with 5, 10, or 15 pairs of bugs/panicle under the headcage to assess the effect of different infestation levels on head bug population increase and grain damage on resistant and susceptible cultivars. Data were recorded on head bug numbers 20 days after infestation, and on grain damage, and percentage loss in grain mass at maturity.

Grain damage. Grain damage in the infested panicles was evaluated visually on a 1 to 5 scale at maturity (1 = grain with a few feeding punctures, 2 = grain with feeding punctures turning red-brown, 3 = most grains with feeding punctures and showing about 40% shriveling, 4 = most grains with feeding punctures and showing about 50% shriveling, and 5 = grain with extensive feeding and > 60% shriveling).

Loss in grain mass. Loss in grain mass (%) in the infested panicles was computed in relation to the average grain mass of similary trimmed or whole panicles of respective genotypes covered with cages but without bugs. The threshed and dried grain from infested and noninfested panicles was weighed, and percentage loss in grain mass computed.

Statistical analysis. Data on bug numbers (converted to square root values), grain damage rating, and percentage loss in grain mass were subjected to analysis of variance. Regression coefficient (b value) and coefficient of determination (R^2) were also computed for each genotype across panicle sizes or infestation levels to identify lines with stable resistance to head bugs. Regresssion coefficients were taken as a measure of the rate of bug population increase or grain damage in relation to panicle size or infestation levels. Genotypes with regression coefficients equal or close to zero and showing low population increase or grain damage across panicle sizes or infestation levels would be stable for their resistance to head bugs. This approach has earlier been used to study the stability of resistance to insects (Sharma & Lopez, 1991).

Results

Effect of panicle size on head bug numbers and grain damage

Head bug numbers. Head bug numbers increased with growth in panicle size, even though an equal number of adults (10 pairs/panicle) were released on each panicle (Fig. 1a).

Across panicle sizes, IS 17610 and IS 17645 had significantly lower bug population increase compared with the susceptible controls CSH 1 and CSH 5 (Table 1).

The regression coefficients were significantly greater for the susceptible controls CSH 1 (0.83**) and CSH 5 (0.94**) compared with those for IS 17610 (0.28*), IS 17618 (0.56), and IS 17645 (0.45) during the rainy season (Table 2).

During the dry season, the b-values were 0.56**, 0.56**, −0.03, 0.43, and 0.06, respectively. Head bug population increased at a greater rate with an increase in panicle size during the rainy season (b = 0.28 to 0.94) compared with the dry season (b = −0.03 to 0.56). Panicle size accounted for >75% of the variation in bug numbers (except IS 17610 during the dry season).

Grain damage. Grain damage rating (GDR) was significantly lower across panicle sizes in IS 17610 and IS 17645 compared with CSH 1 and CSH 5. IS 17618 suffered moderate levels of grain damage across panicle sizes (Table 1). GDR decreased with an increase in panicle sizes (Fig. 1b). IS 17610 and IS 17645 suffered significantly lower grain damage than the susceptible controls across panicle sizes (Table 1). In general, the b values were negative in all cases (b = −0.02 to −0.07) (except CSH 1) during the rainy season when it suffered complete damage (GDR = 9) across panicle sizes (Table 2). Panicle size accounted for 48 to 95 % of the variations in GDR (except CSH 1). R^2 values were greater for data from the rainy season (80 to 95%) compared with the dry season (48 to 83%).

Loss in grain mass. Percentage loss in grain mass was significantly greater in CSH 1 and CSH 5 across panicle sizes compared with IS 17610 and IS 17645 (Table 1). IS 17610 and IS 17645 showed less than 40% loss in grain mass across panicle sizes. Regression coefficients were negative for CSH 1 (−0.98), CSH 5 (−0.56), IS 17618 (−0.70), and IS 17645 (−0.70) and positive for IS 17610 (0.42) (Table 2). Thus, larger panicles suffered lower damage at the same level of infestation (except in IS 17610) (Fig. 2b). During the dry season, the regression coefficients were positive (0.04 to 0.52) (except for CSH 5 (b = −0.02). Coefficient of determination (R^2) was greater during the rainy season (R^2 =23 to 80%) compared with the dry season (R^2 = 1 to 54%).

Effect of infestation levels on head bug numbers and grain damage

Head bug numbers. Head bug numbers were significantly lower in IS 17610 compared with CSH 1 and CSH 5 across infestation levels (Table 3). Generally, bug numbers increased with rise in infestation level (Fig. 3a). Bug numbers explained 32 to 98% variation during the rainy season and 32 to 99% variation during the dry season (Table 4).

Grain damage. GDR increased with rise in infestation level (Fig. 3b), and IS 17610 and IS 17645 suffered lower damage compared with CSH 1 and CSH 5 across infestation levels (Table 3). The susceptible controls suffered high grain damage across infestation levels, and hence, their b values were low (0.02) (except for CSH 1 (0.14*) during the dry season) compared with IS 17610, IS 17618 and IS 17645 (b = 0.14, 0.15 and 0.13 during the rainy season, and 0.00, 0.01 and 0.06 during the dry season, respectively) (Table 4). Rate of increase in grain damage was greater during the rainy season (b = 0.13 to 0.15) compared with the dry season (b = 0.00 to 0.06) in IS 17610, IS 17618 and IS 17645. Coefficients of determination were greater during the rainy season (58 to 91%) compared with the dry season (0 to 75%) (except for CSH 1 99%).

Loss in grain mass. Loss in grain mass was greater in CSH 1 and CSH 5 compared with IS 17610, IS 17618 and IS 17645 (except IS 17618 during the dry season) across infestation levels (Table 3, Fig. 2a). Regression coefficients for loss in grain mass were greater during the rainy season compared with the dry season (Table 4). Bug numbers explained 58 to 96% variation during the rainy season and 6 to 99% variation during the dry season for different cultivars.

Table 1. Head bug population increase, grain damage, and seed germination in eight sorghum genotypes (means across panicle sizes) (ICRISAT Center, 1984–85)

Genotype	Head bug numbers/ panicle		Visual damage rating[1]		% loss in grain mass	
	1984[2]	84/85[3]	1984	84/85	1984	84/85
IS 2761	169(10.9)^{4a}	51(6.7)^{c}	4.8^{f}	4.4^{e}	93^{d}	73de
IS 6984	150(11.7)^{bc}	49(6.4)^{bc}	3.3^{b}	4.7^{ef}	48^{b}	52^{c}
IS 9692	80(8.0)^{a}	48(6.1)^{bc}	4.6^{ef}	5.0^{f}	86^{c}	85de
IS 17610	58(7.1)^{a}	23(4.7)^{b}	2.5^{a}	2.6^{a}	28^{a}	15^{ab}
IS 17610	225(13.9)^{d}	64(6.7)^{cd}	3.9^{c}	3.5^{c}	43^{b}	20^{ab}
IS 17645	136(11.0)^{b}	17(3.9)^{a}	3.4^{b}	3.0^{b}	23^{a}	8^{a}
Susceptible controls						
CSH 1	268(14.7)^{d}	102(8.9)^{e}	5.0^{f}	3.8^{c}	87^{cd}	26^{ab}
CSH 5	249(13.5)^{cd}	235(14.3)^{f}	4.8^{ef}	4.0^{d}	83^{cd}	32^{b}
SE	±(0.57)	±(0.54)	±0.08	±0.11	±4.1	±5.9
LSD at 5%	(1.80)	(1.70)	0.26	0.34	12.8	18.5

[1]See Materials and methods.
[2,3]1984 and 84/85 rainy and dry seasons, respectively.
Head bug numbers in parentheses are $\sqrt{N}$ transformed values.
Figures followed by the same letter within a column are not significantly different at $P \leq 0.05$.

Table 2. Regression coefficient (b value) and coefficient of determination (R^2%) for head bug population increase, grain damage, and percentage loss in grain mass across four infestation levels in five sorghum genotypes (ICRISAT Center, 1984–85)

	Head bug numbers/panicle				Grain damage rating				Loss in grain mass (%)			
	b		R^2		b		R^2		b		R^2	
Genotype	1984 R	1984-85 PR	1984 R	1984-85 PR	1984 R	1984-85 PR	1984 R	1984-85 PR	1984 R	1984-85 PR	1984 R	1984-85 PR
IS 17610	0.28*	−0.03	96	27	−0.04	−0.06	80	83	0.42	0.04	55	1
IS 17618	0.56	0.43	81	77	−0.07	−0.06	91	54	−0.70	0.52	38	39
IS 17645	0.45	0.06	98	82	−0.05*	−0.05	92	77	−0.86	0.24	80	54
Susceptible controls												
CSH 1	0.83**	0.56**	98	99	0.00	−0.05	00	70	−0.56	0.12	23	1
CSH 5	0.94**	0.56**	98	99	−0.02*	−0.04	95	48	−0.98	−0.02	60	1

*,** = Significant at $P<0.05$ and 0.01, respectively.

Table 3. Effect of three infestation levels with *C. angustatus* in eight sorghum genotypes on population increase, grain damage, and loss in grain mass (means across infestation levels) (ICRISAT Center, 1984-85)

Genotype	Head bug numbers/ panicle		Visual damage rating[1]		% loss in grain mass	
	1984[2]	84/85[3]	1984	84/85	1984	84/85
IS 2761	126(10.9)[4bc]	73(7.8)	4.6[ef]	3.9[de]	70[c]	40
IS 6984	212(13.9)[c]	53(6.7)	3.5[bc]	4.5[fg]	64[bc]	59
IS 9692	167(12.3)[bc]	71(7.9)	4.2[de]	4.7[g]	65[bc]	71
IS 17610	63(7.5)[a]	20(4.2)	2.6[a]	2.1[a]	24[a]	11
IS 17618	202(14.1)[bc]	56(6.9)	3.7[cd]	3.1[bc]	34[ab]	25
IS 17645	156(12.4)[bc]	21(4.5)	3.2[b]	2.8[b]	18[c]	7
Susceptible controls						
CSH 1	311(17.1)[d]	83(8.4)	4.9[f]	3.5[ef]	81[c]	17
CSH 5	278(16.7)[d]	207(13.8)	4.9[f]	4.1[ef]	88[c]	30
SE	±(0.81)	±(0.63)	±0.12	±0.15	±10.9	±6.7
LSD at 5%	(2.54)	(1.97)	0.39	0.47	34.2	18.5

[1]See Materials and methods.
[2,3]1984 and 84/85 rainy and dry seasons, respectively.
Head bug numbers in parentheses are $\sqrt{N}$ transformed values.
Figures followed by the same letter within a column are not significantly different at $P \leq 0.05$.

Table 4. Regression coefficient (b value) and coefficient of determination (R^2%) for head bug population increase, grain damage, and percentage loss in grain mass across four infestation levels in five sorghum genotypes (ICRISAT Center, 1984–85)

	Head bug numbers/panicle				Grain damage rating				Loss in grain mass (%)			
	b		R^2		b		R^2		b		R^2	
Genotype	1984 R	1984-85 PR	1984 R	1984-85 PR	1984 R	1984-85 PR	1984 R	1984-85 PR	1984 R	1984-85 PR	1984 R	1984-85 PR
IS 17610	0.20	0.31*	32	99	0.14	0.00	91	0	1.80	−0.69	71	15
IS 17618	0.35	0.28	97	78	0.15	0.01	89	25	1.30	0.47	69	6
IS 17645	0.21	0.08	98	35	0.13	0.06	58	63	1.00	0.40	68	98
Susceptible controls												
CSH 1	0.27	0.52	75	44	0.02	0.14*	75	99	1.30	1.01	58	43
CSH 5	0.30	0.38	96	31	0.02	0.02	89	75	0.30	3.61**	96	99

*= Significant at P<0.05 and 0.01, respectively.

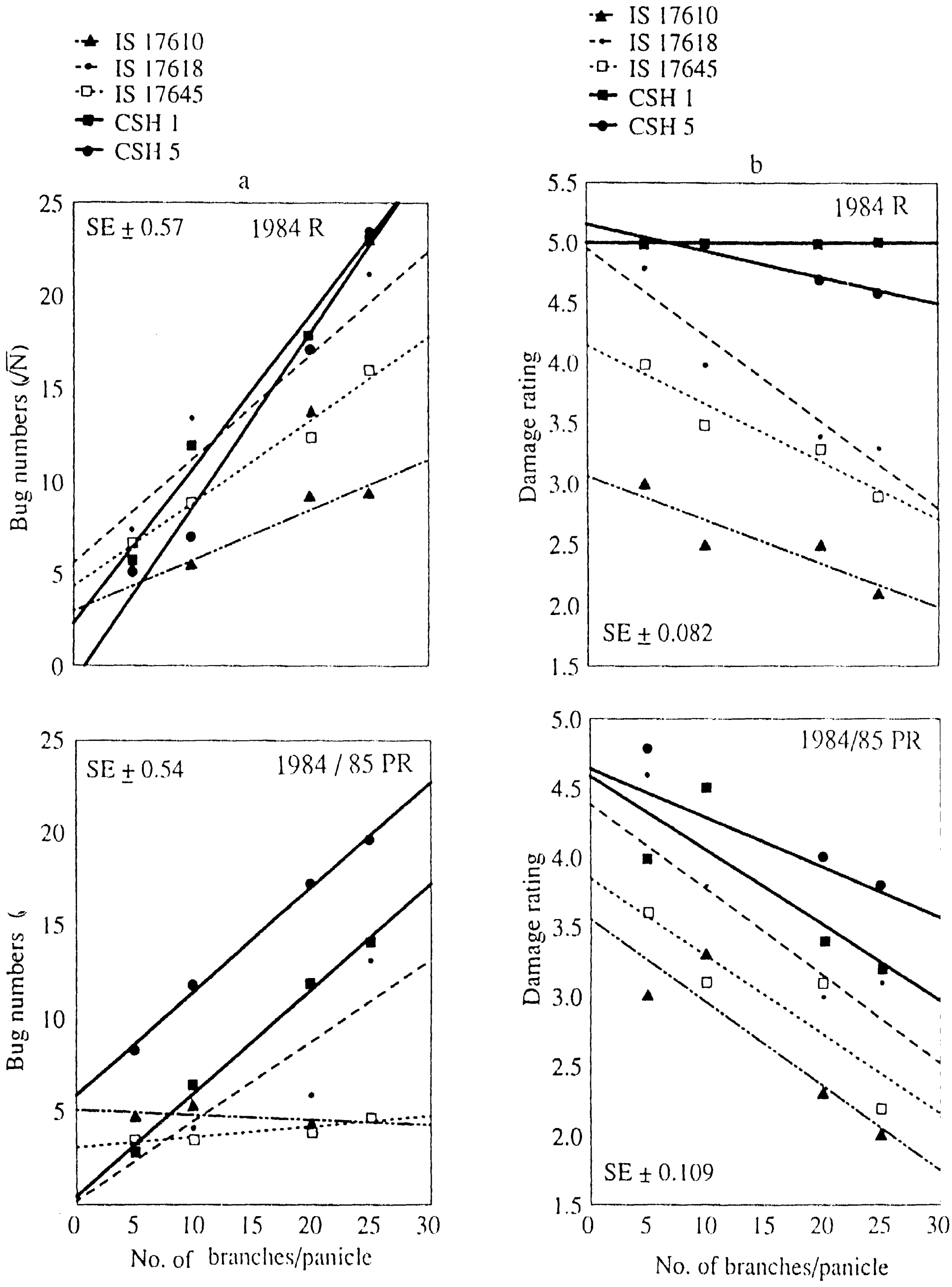

Fig. 1. Head bug population increase (a) and grain damage (b) in five sorghum genotypes infested with 10 pairs of bugs/panicle across four panicle sizes during the 1984 rainy and 1984/85 dry seasons. Damage rating see Materials and methods.

Discussion

Head bug numbers increased linearly with an increase in panicle size, i.e. the amount of space and food available for oviposition and feeding, respectively. Since cultivar nonpreference is excluded under head-cage conditions, lower bug counts on IS 17610 and IS 17645 may be due to low oviposition or antifeedant and/or antibiosis mechanism of resistance (Sharma & Lopez, 1990b). Head bug population increase is influenced by the panicle size or the amount of food available for feeding. Therefore, head bug numbers alone cannot be used as a criterion to select cultivars resistant to *C. angustatus*. IS 17610 and IS 17645 also

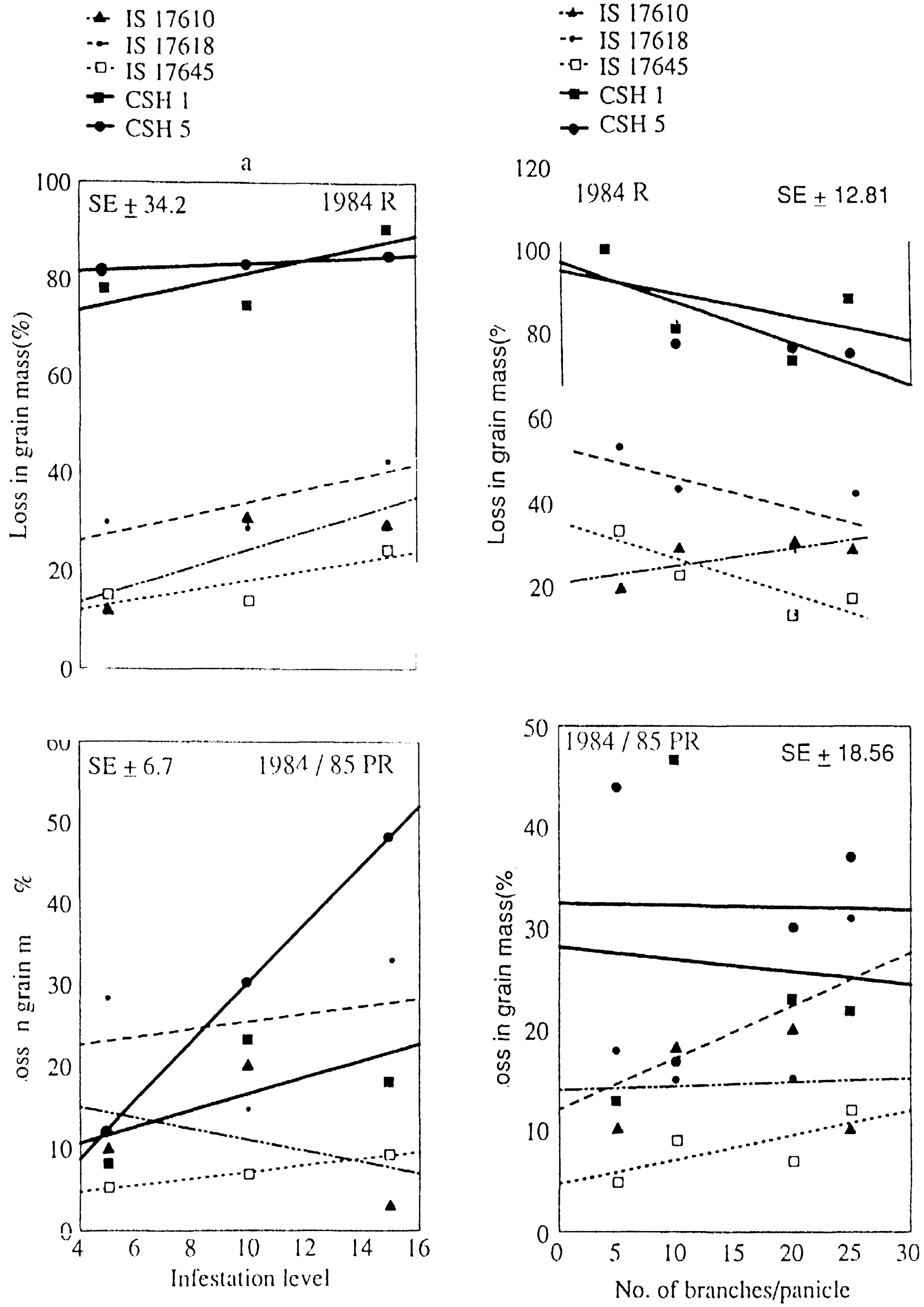

Fig. 2. Loss of grain weight (% in five sorghum genotypes across (a) three infestation levels and (b) four panicle sizes during the 1984 rainy and 1984/85 dry season.

suffered increased grain damage with a growth in infestation level. Greater grain damage in these genotypes at higher levels of in festation (10 and 15 pairs of bugs/panicle) was largely due to initial bug density and not because of the extent of bug population increase

Regression coefficients or the slope of the curve can be taken as a measure of the relationship between panicle size or infestation levels with head bug population increase and grain damage. Genotypes with stable resistance to bugs would have b-values equal or close to zero, and low levels of population increase and grain damage across panicle sizes and infestation levels. Regression coefficients were significant and greater for the susceptible cultivars CSH 1 and CSH 5 for head bug population increase compared with IS 17610 and IS 17645 across panicle sizes. Therefore, the low in-

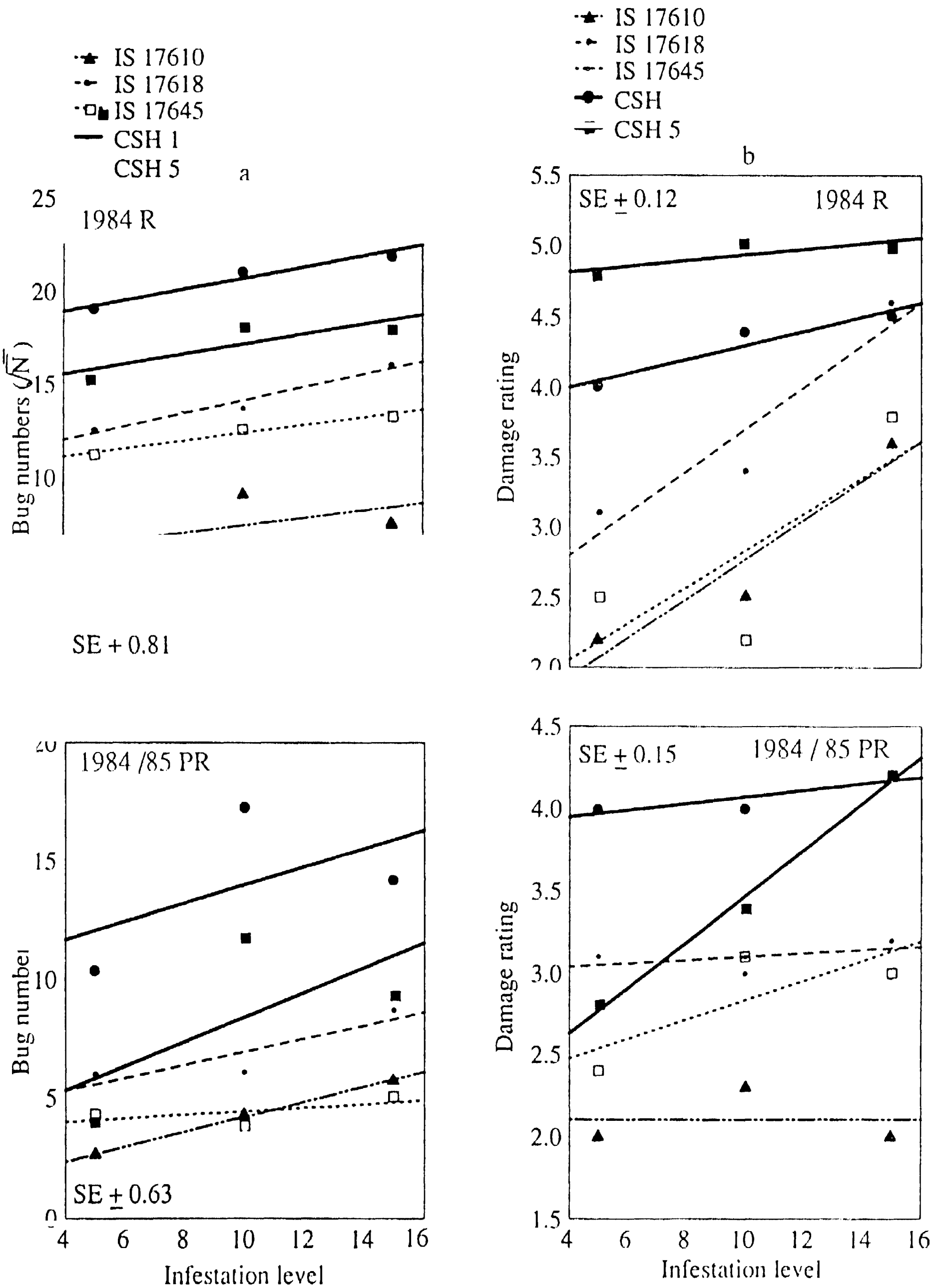

Fig. 3. Head bug population increase (a) and grain damage (b) in five sorghum genotypes across three levels of infestation during the 1984 rainy and 1984/85 dry seasons.

sect numbers recorded on these genotypes were largely because of their resistance to head bugs.

Identification of stable sources of resistance to insects is an important component of an insect resistance breeding program. Stability of resistance is of prime importance in stabilizing crop yields across a wide range of environments (Faris *et al.*, 1979). Not only do the sources need to be stable across environments/seasons. Environmental changes within and across seasons strongly influence genotypic resistance to insects (Faris *et al.*, 1979; Sharma *et al.*, 1988, Sharma & Lopez, 1991).

The headcage technique (Sharma & Lopez, 1992a) can be used to test genotypes against a range of insect densities or under uniform insect pressure across seasons to know their stability of resistance. Regression coefficients and the deviations from the regression of a cultivar on the environmental indices serve as a useful parameter for measuring the stability of performance of a genotype (Eberhart & Russell, 1966). Regression coefficients can serve as a useful parameter to identify lines that would support lower insect numbers or suffer low levels of grain damage across infestation levels and environments (Sharma & Lopez, 1991). In the present studies, the regression coefficients for population increase and grain damage across panicle sizes or infestation levels were greater during the rainy season compared with the dry season. Also, the coefficients of determination (R^2) were greater during the rainy season compared with the dry season. Thus, growing season has a marked effect on the expression of genotypic resistance towards *C. angustatus*. Environmental conditions not only affect the survival and development of bugs, but also affect physio-chemical characteristics of the plants, which in turn may effect the expression of genotypic resistance or susceptibility to *C. angustatus*. Thus, it is important to study the stability of resistance across a range of environments.

Head bug population increase and grain damage are influenced by panicle size, infestation level, and seasons. However, the rates of population increase or grain damage across panicle sizes and infestation levels were significantly lower on the resistant genotypes compared with the susceptible controls. Thus, for identifying reliable sources of resistance to insects, it is important to record insect numbers and extent of damage across levels of food availability and insect density.

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References

Ballard, E., 1916. The *Cholam* capsid (*Calocoris angustatus* Leth.). Pusa Bulletin No. 58. Imperial Department of Agriculture, Pusa, Bihar, India.

Eberhart, S. A. & W. A. Russell, 1966. Stability parameters for comparing varieties, Crop Sci. 6: 36–40.

Faris, M. A., A. M. Lara & F. F. de S. Viega Leao, 1979. Stability of sorghum midge resistance. Crop Sci. 19: 577–580.

Natarajan, N. & P. C. Sundara Babu, 1988a. Damage potential of sorghum earhead bug on sorghum panicle. Insect Sci. Applic. 9: 411–414.

Natarajan, N. & P. C. Sundara Babu, 1988b. Economic injurty level for sorghum earhead bug, *Calocoris angustatus* Lethiery in southern India. Insect Sci. Applic. 9: 395–398.

Sharma, H. C., 1985. Screening for host-plant resistance to mirid head bugs in sorghum. Proceedings, International sorghum entomology workshop, 15–21 July 1984, pp 317–337. Texas A&M University, College Station, Texas USA. Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Sharma, H. C., Y. O. Doumbia & N. Y. Diorisso, 1992. A headcage technique to screen sorghums for resistance to mirid head bug, *Eurystylus immaculatus* Odh. in West Africa. Insect Sci. Applic. 13: 417–427.

Sharma, H. C. & V. F. Lopez, 1989. Assessment of avoidable losses and economic injury levels for the sorghum head bug, *Calocoris angustatus* Leth. (Hemiptera: Miridae) in India. Crop Prot. 8: 429–435.

Sharma, H. C. & V. F. Lopez, 1990a. Biology and population dynamics of sorghum head bugs (Hemiptera: Miridae). Crop Prot. 9: 164–173.

Sharma, H. C. & V. F. Lopez, 1990b. Mechanisms of resistance to sorghum head bug, *Calocoris angustatus*. Entomol. exp. appl. 57: 285–294.

Sharma, H. C. & V. F. Lopez, 1991. Stability of resistance in sorghum to *Calocoris angustatus*(Hemiptera: Miridae). J. econ. Entomol. 91: 1088–1094.

Sharma, H. C. & V. F. Lopez, 1992a. Screening for plant resistance to sorghum head bug, *Calocoris angustatus* Leth. Insect Sci. Appl. 13: 315–325.

Sharma, H. C. & V. F. Lopez, 1992b. Genotypic resistance in sorghum to head bug, *Calocoris angustatus*. Euphytica 58: 193–200.

Sharma, H. C., P. Vidyasagar & K. Leuschner, 1988. No-choice cage technique to screen for resistance to sorghum midge (Diptera: Cecidomyiidae). J. econ. Entomol. 81: 415–422.