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SCREENING FOR PLANT RESISTANCE TO SORGHUM HEAD BUG, *CALOCORIS ANGUSTATUS* LETH.*

H. C. SHARMA and V. F. LOPEZ
Cereals Entomology, ICRISAT, Patancheru, A.P. 502 324, India

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Abstract—Sorghum head bug, *Calocoris angustatus* Leth. (Hemiptera: Miridae) is an important insect pest of sorghum in the semi-arid tropics. A technique to screen for resistance to head bugs under field conditions was tested. Planting infester rows of susceptible cultivars (CSH 1 or CSH 5), 20 days before the test material or planting early (40–45 days) flowering lines (IS 802, IS 13429 and IS 24439) along with the test material, split planting of test material at 15-day intervals, grouping test material according to maturity, and use of sprinkler irrigation to maintain high humidity, were found effective in increasing the efficiency of screening and selecting for resistance to head bugs.

A headcage technique to screen for resistance under no-choice conditions has also been developed. Panicles infested with 10 pairs of bugs at pre- and half-anthesis, result in maximum population build-up and grain damage under headcage. This technique is useful for confirming the resistance observed under field conditions.

Under natural infestation, five genotypes harboured relatively lower head bug numbers than the susceptible checks, but only three (IS 17610, IS 17618 and IS 17645) maintained their level of resistance under the headcage. Seed germination was > 70% in these genotypes compared to < 10% in CSH 1 and CSH 5.

Key Words: Sorghum, *Calocoris angustatus*, resistance screening, host-plant resistance

Résumé—La punaise des panicules du sorgho, *Calocoris angustatus* Leth. (Hémiptères: Miridés), constitue un insecte ravageur important des régions tropicales semi-arides. Une technique de criblage au champ pour la résistance aux punaises des panicules a été normalisée. Le semis des rangs infestants de cultivars sensibles (CSH 1 ou CSH 5), 20 jours avant le matériel d'essai, ou le semis des lignées (IS 802, IS 13429 et IS 24439) à floraison hâtive (40–45 jours) au même temps que le matériel d'essai, le semis échelonné du matériel d'essai aux intervalles de 15 jours, le regroupement du matériel d'essai selon la maturité, ainsi que la mise en place de l'irrigation par aspersion pour maintenir un niveau élevé d'humidité sont des moyens qui se sont avérés efficaces dans l'augmentation de l'efficacité du criblage et de la sélection pour la résistance aux punaises des panicules.

Une technique de panicule encagée a également été mise au point pour le criblage pour la résistance dans des conditions de choix unique. Les panicules infestées avec 10 paires de punaises avant l'anthèse ont provoqué le maximum de pullulation et de dégâts aux grains sous la cage. Cette technique est utile pour la confirmation de la résistance observée en milieu réel.

En conditions naturelles, cinq génotypes entretenaient des nombres de punaises relativement inférieurs par rapport aux témoins sensibles. Mais seulement trois génotypes (IS 17610, IS 17618 et IS 17645) ont pu maintenir leur niveau de résistance sous la cage. La

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germination des semences était > 70% pour ces génotypes par rapport à < 10% chez CSH 1 et CSH 5.

Mots Clés: Sorgho, *Calocoris angustatus*, criblage pour la résistance, résistance de la plante-hôte

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is an important cereal crop in the semi-arid regions of Asia and Africa. Over 150 species of insects have been reported as pests of sorghum, of which panicle infesting mirid head bugs (*Calocoris angustatus* Leth., *Eurystylus immaculatus* Odh., *Creontiades pallidus* Ramb. and *Campylomma* spp.) are important in Asia and Africa. *C. angustatus* is the predominant species in India, while *Eurystylus immaculatus* is more serious in Africa (Sharma, 1985a, b).

Head bugs feed mainly on the developing grain, and occasionally on other tender parts of the plant. The nymphs and adults suck sap from developing kernels causing them to be unfilled, shrivelled, and in severe cases completely chaffy. Damage during the early stages of grain development results in heavy yield losses, while later infestations largely result in a quality loss (Ballard, 1916). Damaged grains show red-brown feeding punctures, and under severe infestation become completely tanned. Head bug damage increases the incidence and severity of grain moulds (Sharma, 1985c) that further deteriorates the grain quality and reduces seed germination. Low to moderate levels of damage render the grain unfit for human consumption in most food preparation methods.

Information on the extent of losses due to head bugs in different regions is not available. At ICRISAT Center, 54–89% loss in grain yield has been recorded in the commercial cultivars, CSH 1, CSH 5 and ICSV 1 (Sharma and Lopez, 1989) and in India, yield losses of 5.8–84.3% have been recorded (Leuschner and Sharma, 1983). Because of high levels of head bug incidence and damage during the rainy season in West Africa and in the Deccan Plateau of India, farmers traditionally plant photoperiod sensitive cultivars which flower in October–November when head bug numbers are quite low.

At ICRISAT, a major emphasis has been placed on developing cultivars resistant to insect pests. Pest resistant cultivars are an important component in pest control strategies in the semi-arid tropics. Within this framework, a major exercise was undertaken to standardize the screening methodology, and to identify head bug resistant lines for developing head bug resistant cultivars for use by the farmers.

MATERIALS AND METHODS

All the experiments were carried out at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) between 1981 and 1988.

Field screening technique (multi-choice conditions)

Planting date. In order to determine an optimum date of planting to screen for resistance to bugs, we studied the fluctuations in head bug abundance between 1982 and 1986 at ICRISAT Center. Head bug abundance was monitored at fortnightly intervals in sorghum fields at the milk stage of development at different locations on the ICRISAT farm. Experimental details are described by Sharma and Lopez (1990).

Infester rows. Infester rows of susceptible mixed maturity cultivars (CSH 1 and CSH 5 in a ratio of 1:1), planted 20 days before the test material, were used to increase head bug density in field trials of screening for head bug resistance. Alternatively, early flowering lines (< 45 days to flower) such as IS 802, IS 13429 and IS 24439 were planted along with the test material. Four infester rows were planted after every 16 rows of test material. Head bugs collected from other fields were spread in the infester rows to increase subsequent insect density and to ensure uniform head bug infestation. During the 1981/82 postrainy season, we evaluated the effect of infester rows on head bug abundance levels in large unreplicated plots (0.5 ha) of CSH 1 and TAM 2566. Similar plots, but without infester rows, served as untreated controls for comparison. Twenty-five randomly selected panicles were sampled in the centre of each plot at the milk stage. Mean and standard error of estimate for mean was computed for head bug density in each plot.

Split-planting. Head bug abundance fluctuates over time and sorghum genotypes flower from 45 to > 90 days after planting. Normally, cultivars flowering at the beginning and end of the cropping season escape insect damage, while those flowering in the mid-season suffer the most damage. Therefore, lines selected as less susceptible under natural conditions are often not resistant lines, but early- and late-flowering escapes. To reduce the chances of escape, test material was planted 2–3 times at an interval of 15–20 days. To test the usefulness of split plantings in increasing the efficiency of screening for head bug resistance, we evaluated 88, 44 and 44 lines in the preliminary, advanced and multilocation nurseries, respectively, in two sequential plantings at an interval of 15 days during the 1988 rainy season. Entries were rated for head bug damage on a 1–5 scale (1 = grain with a few feeding punctures, and 5 = grain showing >75% shrivelling and highly tanned) at maturity, and the number of lines showing resistance to head bugs in the first and second planting were compared.

Placing material in different maturity groups of early (45–55 days), medium (56–70 days) and late (> 70 days), and sowing each group so that flowering occurs during the period of greatest head bug density is useful for resistance screening. Suitable resistant and susceptible checks are included in each group to ensure proper comparisons. During the 1985 rainy season, the influence of flowering period on head bug damage was evaluated under natural infestation in a trial comprising 62 entries. Sorghums in the trial were rated for grain damage at maturity. The entries were grouped according to maturity and their damage ratings compared.

Sprinkler irrigation. High relative humidity is an important component for development and survival of bugs (Sharma and Lopez,1990). Maximum bug density generally occurs during periods of high relative humidity (> 75%) and moderate temperatures (28–35°C) during the rainy season. During the post-rainy season (Oct.–April), when relative humidity falls below 40%, use of overhead sprinkler irrigation for an hour (1500–1600 hr) daily helps to increase the relative humidity (> 65%). We compared head bug density in fields with and without sprinkler irrigation to study the effect of high humidity on head bug populations.

Headcage technique (no-choice conditions)

Under natural conditions, it is difficult to maintain uniform head bug numbers because of fluctuating bug abundance and staggered flowering of sorghum genotypes. To overcome this problem, the wire-framed headcage developed to screen for sorghum midge (*Contarinia sorghicola* Coq.) resistance (Sharma et al., 1988b) was tested to screen for resistance to head bugs. The susceptible cultivars CSH 1 and ICSV 1 were used to determine the optimum infestation levels and stage of the panicle at infestation, time interval for taking head bug counts, and effect of panicle size, source of head bugs, and infestation levels on head bug abundance and grain damage.

Experimental procedure. All experiments, unless otherwise mentioned, were conducted using CSH 1, a head bug susceptible sorghum hybrid. Normal agronomic practices were followed for raising the crop (Sharma and Lopez, 1990). Experiments were conducted in large plots of 0.05–1.0 ha. Panicles were selected randomly for infestation. There were 10 replications for each experiment in a randomized block design. Headcages were fixed around the sorghum panicles at panicle emergence or as indicated in each experiment. The wire-framed cages were covered with a white muslin cloth bag. Specially designed cloth bags (40 x 16 cm) with an inlet for introducing head bugs can also be used for this purpose (Sharma et al., 1988b). Head bugs were collected in aspirators made of plastic bottles (200 ml capacity), and were introduced into the cages through a small inlet hole. The latter was closed with a galvanized iron wire or a piece of thread.

Head bugs were counted 20 days after infestation (unless otherwise indicated), and panicles rated for grain damage at harvest on a 1–5 scale (1 = grain with a few feeding punctures, and 5 = grain showing > 75% shrivelling and highly tanned).

Infestation level and stage of panicle development. The number of pairs of adult head bugs needed to obtain optimum damage (damage rating > 4) under the headcage to the susceptible cultivar CSH 1 was studied at four infestation levels (5, 10, 15 and 20 pairs/panicle), and at four stages of panicle development (pre-anthesis, half-anthesis, complete-anthesis, and milk stage), during the 1983/84 post-rainy season. All panicles were cut to a uniform size by retaining 20 primary branches per panicle. There were 10 replications in a randomized block design. Bug numbers and damage rating were recorded.

In another experiment during the same season, increase in head bug abundance was studied in five cultivars at four stages of panicle development, and at four levels of infestation. There were five replications in a split plot design. Bug numbers were counted and panicles rated for bug damage.

Panicle size. In experiments on screening for resistance to head bugs, we observed that lower head bug counts in some cultivars were quite often associated with smaller panicles. To study the influence of panicle size (or amount of food available to the head bugs) on increase in head bug abundance under headcages, we retained 5, 10 and 20 primary branches/panicle of CSH 1. Full panicles served as a control. There were 10 replications in a randomized block design. Panicles were infested with 10 pairs of head bugs at pre-anthesis. Head bug numbers and damage ratings were recorded.

Increase in head bug abundance and grain damage over time. To determine the optimum duration for exposing the panicles to head bugs under the headcage, we infested 30 panicles of CSH 1 with 10 and 15 pairs/panicle at the pre-anthesis stage during the 1981/82 post-rainy season. Head bugs were removed and counted from 10 panicles each at 20, 25 and 30 days after infestation. Seed germination (%) and 1000 kernel weight were recorded after harvest. In another experiment during the 1983 rainy season, 40 panicles of ICSV 1 were infested with 10 pairs/panicle at pre-anthesis, and the head bugs were counted at 11, 14, 17 and 20 days after infestation to determine if maximum head bug density occurred earlier than 20 days after infestation. There were 10 replications in a randomized block design.

A large proportion of grain damage under the headcage may result from feeding by adult bugs introduced into the cage, leaving inadequate amount of food for survival and development of nymphs. Therefore, to get a more realistic estimate of nymph emergence and avoid excessive damage by the adults, we studied the nymph emergence across infestation levels (15, 20, 30, 40 and 50 pairs/panicle) by confining bugs on panicles of ICSV 1 for 3 days for oviposition. After 3 days, the adults were removed, and the number of nymphs was recorded every day between 7 and 12 days after infestation. There were 10 replications in a randomized block design.

Laboratory reared vs. field collected bugs. During the 1983/84 post-rainy season, we compared the increase in population density from field collected bugs with those of 2-day-old adults reared under laboratory conditions at 5, 10, 15 and 20 pairs of bugs/panicle. Panicles were infested at pre-anthesis. There were 10 replications in a split plot design. Head bug numbers and damage ratings were recorded.

Genotypic resistance to head bug damage under natural and headcage conditions. We evaluated eight lines, selected as less susceptible under natural conditions, and two susceptible checks during 1982/83 in the rainy and the post-rainy seasons. There were three replications in a randomized block design. Under natural conditions, head bug numbers were estimated from five randomly selected panicles at the pre-anthesis and milk stages. Under headcages, five panicles of each genotype were infested with 10 pairs of adults at the pre-anthesis stage. Bug numbers and damage ratings were recorded. 100-kernel samples drawn at random from each replication were subjected to a germination test as described earlier.

During the 1983 rainy season, a set of 15 genotypes was tested under headcages with five and 15 pairs/panicle to test the level of head bug resistance in different genotypes. There were three replications in a randomized block design. Head bug numbers were counted and panicles rated for damage. Seeds were subjected to a germination test after harvest under laboratory conditions.

Statistical analysis. Data on head bug numbers were converted to square root values, and all data subjected to analysis of variance to test the significance of differences in treatment effects. Least significant differences were calculated to compare the treatment means.

RESULTS

Field screening (multi-choice conditions)

Planting date. During the rainy season, maximum head bug density at ICRISAT Center was recorded during the second fortnight of September and the first fortnight of October (Fig. 1). A small peak was also recorded in July on summer planted sorghum. During the post-rainy season, a smaller peak was observed during March. Our observations indicate that to screen material for resistance to sorghum head bugs, the crop should be planted between 10–25 July during the rainy season, and in the first fortnight of December during the post-rainy season.

Infester rows. We recorded 27 head bugs/panicle in CSH 1 plots with infester rows compared to <1 bug/panicle in plots without infester rows. Similarly, there were eight and < 1 bugs/panicle in plots of TAM 2566 with and without infester rows, respectively (Fig. 2). To increase the initial population in the infester rows, head bugs can be collected from other fields and spread uniformly in the infester rows as a starter infestation.

Split-planting. We selected 44, 28 and 37 entries in the first planting, and 14, 13 and 28 entries in the second planting as less susceptible to head bugs in the preliminary, advanced, and multilocation trials, respectively (damage rating < 3). Entries selected as less susceptible in the second planting also suffered less damage in the first planting. Thus, sequential plantings are useful to discard a number of escapes. Grouping the material according to maturity and height were also found to be effective. In the trial composed of 62 entries, early flowering lines received a mean damage rating of > 4 compared to 3 in the medium and later maturity groups. Thus, for proper comparisons, trials should be arranged according to maturity.

Sprinkler irrigation. High humidity is essential for survival and multiplication of head bugs (Sharma and Lopez, 1989). In most of our observations/studies, we recorded higher head bug numbers in fields under sprinkler irrigation than mean head bug numbers at ICRISAT Center without sprinklers (Fig. 3). Thus in situations or seasons of low relative humidity, sprinkler irrigation can be used to increase head bug abundance.

Headcage technique (no-choice conditions)

Infestation level and stage of panicle development. Maximum head bug numbers were recorded in panicles infested with 10 pairs of head bugs across all stages of panicle development (except milk stage) (Table 1). Head bug numbers were significantly lower in panicles infested with

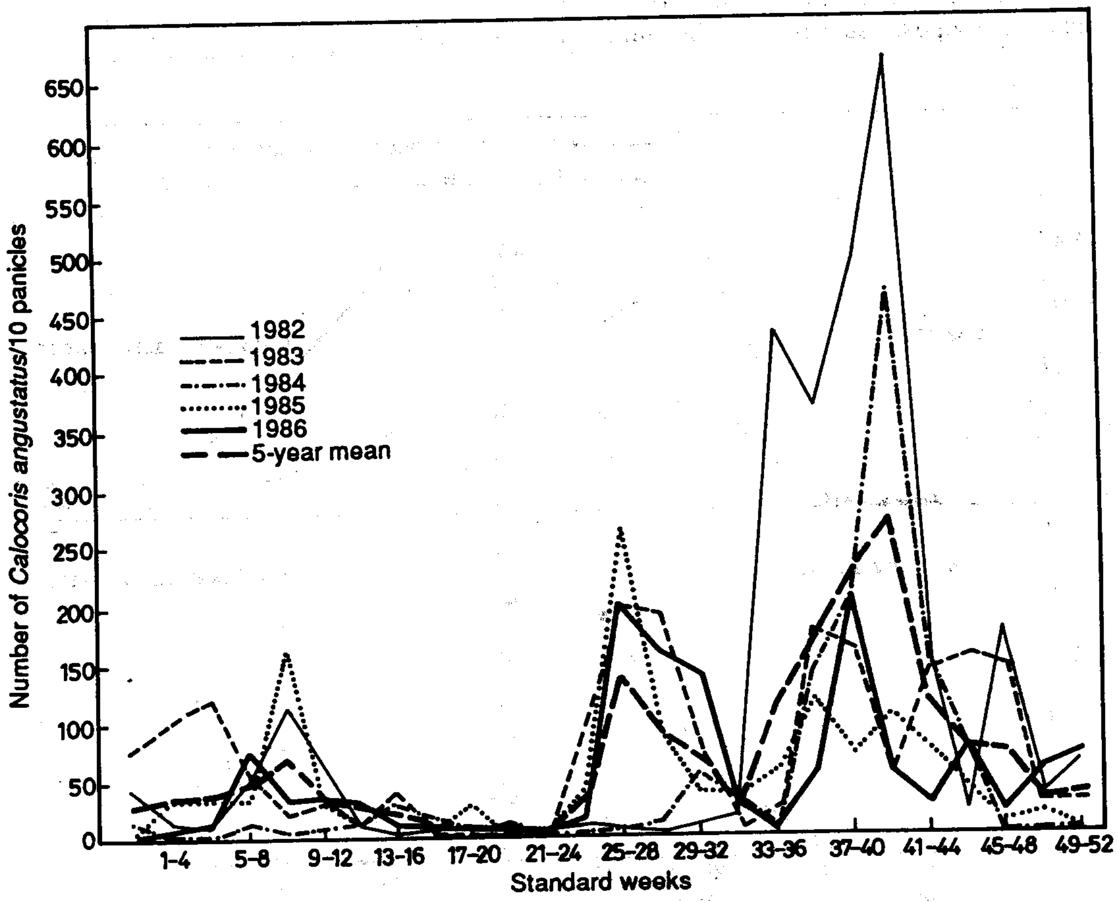

Fig. 1. Population dynamics of the sorghum head bug, *Calocoris angustatus*.

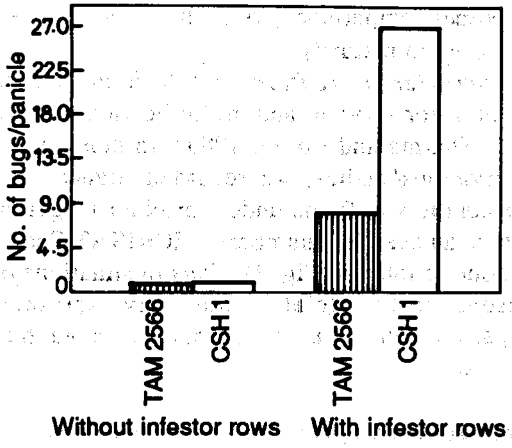

Fig. 2. Effect of infester rows on population build-up of the sorghum head bugs, *C. angustatus*.

20 pairs/panicle at pre-anthesis than those infested with 10 pairs/panicle. Head bug numbers were also lower in panicles infested at complete-anthesis, and declined significantly in those infested at the milk stage. Less head bug numbers at these stages may be due to inability of the females to oviposit successfully in spikelets where grain development has initiated, and the decreased suitability of the grain for feeding and development of nymphs.

Head bug damage was higher (damage rating > 4) in panicles infested with 5–20 pairs of bugs at the pre- to complete-anthesis. Panicles infested at pre- and half-anthesis had the maximum bug numbers, and 5–10 pairs result in sufficient grain damage in the susceptible cultivar, CSH 1. There was a significant reduction in grain damage in panicles infested at the milk stage, and a slight decrease in those infested at complete-anthesis. A similar trend was also evident in increase in head bug abundance across stages of panicle development.

In a set of five cultivars, three less susceptible (IS 2761, IS 9692 and IS 17645) and two susceptible checks (CSH 1 and CSH 5), mean head bug abundance decreased as the stage of panicle development advanced at the time of infestation (Fig. 4). Bug numbers were significantly lower in panicles infested with five adult pairs, than those infested with 10–20 pairs/panicle.

Panicle size. We recorded 20 ± 6, 63 ± 17 and 375 ± 53 bugs/panicle in panicles of CSH 1 with

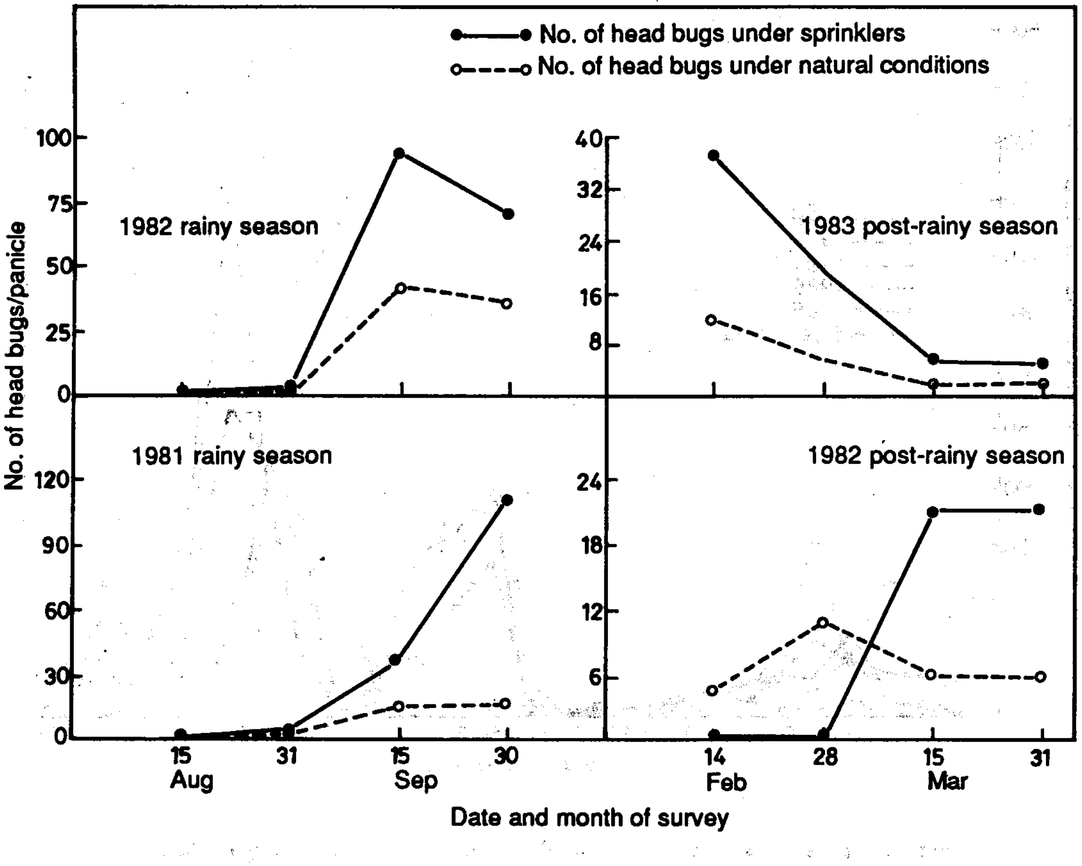

Fig. 3. Effect of overhead sprinkler irrigation on population build-up of the sorghum head bug, *C. angustatus*.

Table 1. Population build-up and grain damage by *Calocoris angustatus* under the headcage at four levels of infestation and four stages of panicle development (cv. CSH 1) (ICRISAT Center, 1982/83 post-rainy season)

	No. of head bugs/panicle				Damage rating⁺			
No. of pairs released	Pre-anthesis	Half anthesis	Complete anthesis	Milk stage	Pre-anthesis	Half anthesis	Complete anthesis	Milk stage
5	200 (13.9)*	338 (18.2)	285 (16.8)	220 (14.4)	5.0	4.5	4.2	2.5
10	468 (21.5)	503 (22.4)	516 (22.7)	157 (12.0)	5.0	5.0	4.7	3.2
15	328 (18.1)	481 (21.8)	456 (21.2)	265 (15.7)	5.0	5.0	4.8	3.2
20	151 (12.3)	412 (20.1)	321 (17.7)	170 (12.8)	5.0	5.0	5.0	3.3
Mean	151 (16.5)	434 (20.6)	395 (19.6)	203 (13.7)	5.0	4.9	4.7	3.1

S.E. and LSD for comparing	S.E.	LSD at 5%
No. of bugs		
Pairs	(± 0.81)	(2.17)
Stage of panicle development	(± 1.34)	(2.93)
Damage rating		
Pairs	(± 0.07)	(0.22)
Stage of panicle development	(± 0.12)	(0.25)

*Figures in parentheses are √*N* transformed values.

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

5, 10 and 20 primary branches, respectively, and 611 ± 86 in a full panicle 20 days after infestation. Head bug damage was complete in all panicles. Thus, panicle size has a great influence on head bug abundance under headcage. It is important to maintain uniformity in panicle size of genotypes under testing.

Increase in head bug numbers and grain damage over time. Maximum head bug numbers were recorded on 20 and 25 days after infestation (Table 2). Differences in 1000 kernel weight and % seed germination were not substantial in panicles confined with head bugs for 20 to 30 days. In the second experiment where bugs were removed and counted 11, 14, 17 and 20 days after infestation (Fig. 5), maximum bug numbers were recorded 20 days after infestation. There was some reduction in head bug numbers in panicles sampled at 14 days after infestation.

Nymph emergence in panicles infested for 3 days was recorded between 7th and 11th day after infestation. Peak nymph numbers occurred on the 9th day after infestation (Table 3). There were 570–632 nymphs/panicle in panicles infested with 15–25 pairs of adults for 3 days. These numbers are closer to head bug numbers resulting from 10 pairs over a period of 20 days (Table 1). Therefore, to avoid excessive feeding by adults used for infestation in the headcage, 15–20 pairs of adults can be confined with panicles for 3 days, and then removed thereafter.

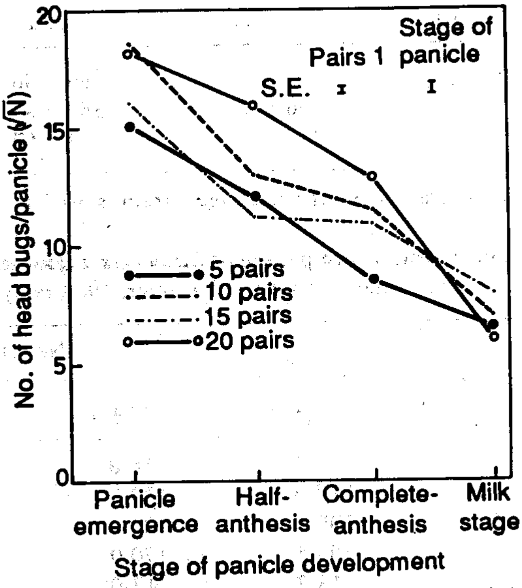

Fig. 4. Head bug, *C. angustatus*, population build-up under the headcage across four stages of panicle development and four infestation levels.

Table 1. Population build-up and grain damage by *Calocoris angustatus* under the headcage at four levels of infestation and four stages of panicle development (cv. CSH 1) (ICRISAT Center, 1982/83 post-rainy season)

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S.E. and LSD for comparing	S.E.	LSD at 5%
No. of bugs		
Pairs	(± 0.81)	(2.17)
Stage of panicle development	(± 1.34)	(2.93)
Damage rating		
Pairs	(± 0.07)	(0.22)
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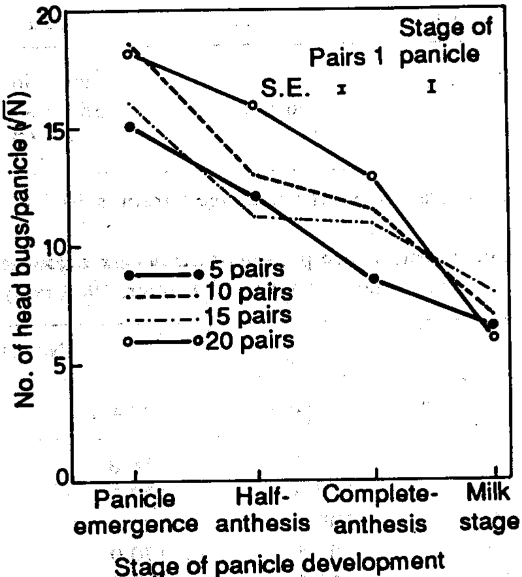

Fig. 4. Head bug, *C. angustatus*, population build-up under the headcage across four stages of panicle development and four infestation levels.

Laboratory reared vs. field collected bugs. Head bug numbers were higher in panicles infested with field collected bugs than those reared in cages under laboratory conditions (Fig.6). This difference may be due to possible difficulties in mating under laboratory conditions, and adaptability of laboratory reared bugs to field conditions.

Genotypic resistance to head bugs under natural and headcage conditions. Head bug numbers and grain damage in eight less susceptible genotypes and two susceptible checks are given in Tables 4 and 5. Under natural conditions, < 14 bugs/panicle were recorded at pre-anthesis on panicles of IS 1335, IS 17610, IS 17618 and IS 17645 during the 1982 rainy season compared to 20 and 30 bugs on CSH 1 and CSH 5, respectively. Maximum bugs (40) were recorded on IS 4686. At the milk stage, bug numbers were significantly lower in IS 17610, IS 17618, IS 17645, IS 2761 and IS 61 (< 96 bugs/panicle) compared to the susceptible checks CSH 1 and CSH 5 (264 and 217 bugs/panicle). Under headcages, IS 17610, IS 17618 and IS 17645 had lower bug numbers than the susceptible checks CSH 1 and CSH 5. These cultivars also suffered moderate damage (damage rating < 3) under the headcage. Seed germination was > 75% in IS 61, IS 2761, IS 17610, IS 17618 and IS 17645 compared to < 7% in CSH 1 and CSH 5 (Table 5).

In the post-rainy season, which is relatively less favourable for survival and development of head bugs, there were < 2 bugs/panicle in IS 17610, IS 17618 and IS 17645 at pre-anthesis and milk stage. Under headcage test, IS 2761, IS

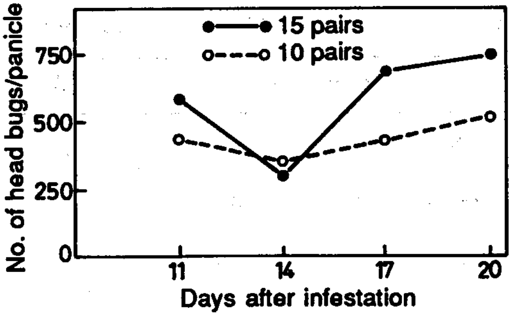

Fig. 5. Emergence pattern of the head bug, *C. angustatus*, in panicle infested for a 3-day period under headcage.

Table 2. Head bug population build-up and grain damage under headcage over time in CSH 1 (ICRISAT Center, 1981/82 post-rainy season)

Days after infestation	No. of head bugs/panicle		1000 grain mass (g)*		% Germination	
	10 pairs	15 pairs	10 pairs	15 pairs	10 pairs	15 pairs
20	352 ± 32	396 ± 86	10.2	9.8	36	32
25	366 ± 55	367 ± 87	9.7	8.1	11	24
30	267 ± 57	317 ± 57	11.0	9.2	26	17

*1000 grain mass of undamaged grain is 30.0 g.

Table 3. Emergence pattern of *Calocoris angustatus* nymphs in panicles infested for a 3-day period at four levels of infestation (ICRISAT Center, 1983 rainy season)

Days after infestation	No. of nymphs emerged/panicle					
	15 pairs	20 pairs	25 pairs	30 pairs	40 pairs	50 pairs
7	18.3	16.6	6.8	203.2	157.0	70.2
8	117.0	177.2	86.8	370.8	321.0	732.7
9	239.6	189.4	236.2	457.4	517.8	723.0
10	209.5	170.0	272.8	254.4	168.6	552.0
11	18.2	17.0	29.6	40.8	45.6	111.0
Total	602.2	570.2	632.2	1350.4	1210.2	2189.0
S.E.	±49.1	±52.0	±107.8	±172.0	±166.5	±109.6

Table 4. Population build-up and grain damage by *Calocoris angustatus* in 10 cultivars under natural and headcage conditions (ICRISAT Center, 1982 rainy season)

Cultivar	No. of head bugs/panicle under natural conditions		No. of head bugs/panicle under headcage (10 pairs/panicle)	Grain germination (%)	Damage+ rating
	Pre-anthesis	Milk stage			
IS 61	19 (4.3)*	96 (9.7)	226 (14.7)	76	2.9
IS 1335	7 (2.6)	418 (20.3)	200 (14.1)	4	3.8
IS 2761	23 (4.8)	81 (8.9)	147 (12.0)	81	2.5
IS 4686	40 (6.3)	348 (18.5)	163 (12.1)	34	2.5
IS 7790	25 (4.7)	271 (16.4)	169 (12.9)	35	3.7
IS 17610	7 (2.5)	36 (5.8)	111 (10.5)	90	2.3
IS 17618	14 (3.7)	38 (6.0)	85 (9.2)	76	2.5
IS 17645	11 (3.3)	26 (5.1)	52 (7.2)	95	2.4
CSH 1	21 (4.3)	204 (14.3)	283 (16.7)	7	4.2
CSH 5	36 (5.3)	217 (14.7)	374 (19.3)	7	4.0
S.E.	± (0.59)	± (1.13)	± (1.45)	±10	±0.2
LSD at 5%	(1.76)	(3.37)	(4.31)	29	0.7

*Figures in parentheses are $\sqrt{N}$ transformations.
+Damage rating — see Table 1.

Table 5. Population build-up and grain damage in 10 cultivars under natural and headcage conditions (ICRISAT Center, 1982–1983 post-rainy season)

Cultivar	No. of head bugs/panicle under natural conditions		No. of head bugs/panicle under headcage (10 pairs/panicle)	Damage+ rating
	Pre-anthesis	Milk stage		
IS 61	4 (1.8)	7 (2.6)	342 (18.0)*	4.0
IS 1335	7 (2.7)	129 (9.9)	143 (11.8)	5.0
IS 2761	1 (1.1)	6 (2.4)	71 (8.4)	4.8
IS 4686	9 (2.8)	48 (6.4)	455 (21.3)	4.8
IS 7790	11 (3.2)	42 (6.3)	153 (11.9)	4.2
IS 17610	1 (0.4)	1 (0.8)	66 (8.1)	3.3
IS 17618	2 (1.4)	1 (1.0)	92 (9.6)	3.5
IS 17645	1 (0.7)	1 (0.9)	22 (4.7)	3.0
CSH 1	6 (2.4)	8 (2.9)	276 (16.6)	4.2
CSH 5	6 (2.4)	13 (3.1)	316 (17.7)	4.2
S.E.	± (0.36)	± (1.52)	± (1.41)	± 0.19
LSD at 5%	(1.06)	(4.53)	(4.20)	0.57

*Figures in parentheses are $\sqrt{N}$ transformations.
+Damage rating — see Table 1.

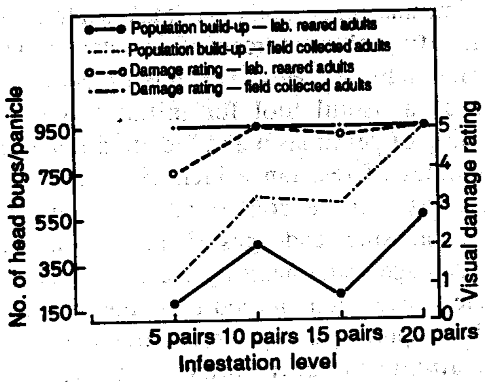

Fig. 6. Population build-up and grain damage from laboratory-reared versus field-collected adults of *C. angustatus* under headcage.

17610, IS 17618 and IS 17645 had significantly lower head bug numbers than CSH 1 and CSH 5, and except for IS 2761, suffered a moderate grain damage (damage rating < 3.5).

Of the 15 cultivars evaluated under headcage at two infestation levels during the 1983 rainy season (Table 6), eight genotypes (IS 2761, IS 6983, IS 6984, IS 9639, IS 9692, IS 14476, IS 17610 and IS 17618) had lower head bug numbers at both infestation levels, while IS 4544, IS 21217 and IS 17645 became susceptible when infested with 15 pairs/panicle. Of these, three genotypes (IS 17610, IS 17618 and IS 17645) suffered moderate grain damage. Seed germination was >70% in 5 genotypes (IS 4544, IS 9639, IS 17610,

Table 6. Population build-up and grain damage in 15 cultivars infested with 5 and 15 pairs of *Calocoris angustatus*/panicle (ICRISAT Center, 1983 rainy season)

Cultivar	No. of head bugs/panicle		Damage rating⁺		Germination %	
	5 pairs	15 pairs	5 pairs	15 pairs	5 pairs	15 pairs
IS 2761	44(6.6)*	204(14.3)	3.9	4.3	86	37
IS 4544	119(10.8)	374(19.3)	2.3	3.2	70	72
IS 6983	34(5.8)	57(7.1)	4.1	4.0	71	42
IS 6984	123(11.0)	50(7.0)	4.8	5.0	57	30
IS 9639	25(4.3)	204(14.2)	3.0	3.9	78	80
IS 9692	83(8.9)	232(15.2)	4.2	4.7	67	66
IS 14476	47(6.8)	63(7.9)	4.2	5.0	64	46
IS 17610	104(10.1)	84(9.0)	3.3	3.0	72	85
IS 17618	132(11.5)	312(17.7)	3.5	3.5	83	76
IS 17645	83(8.9)	174(13.2)	3.0	3.2	74	84
IS 21217	88(9.3)	297(17.1)	3.8	4.7	64	42
CSH 1	281(16.7)	625(25.0)	4.5	4.6	37	6
CSH 5	178(13.3)	394(19.8)	4.1	3.7	4	15
CSH 9	279(16.7)	495(22.2)	4.4	4.9	9	3
Swarna	226(15.0)	277(16.6)	5.0	5.0	7	0

S.E. and LSD for comparing:

	No. of head bugs		Damage rating		Grain germination	
	S.E.	LSD at 5%	S.E.	LSD at 5%	S.E.	LSD at 5%
Cultivar	±0.83	2.55	±0.06	0.52	±7.4	15.9
Infestation levels	±0.33	0.99	±0.12	0.38	±2.4	5.0

*Figures in parentheses are √*N* transformations.
⁺Damage rating — see Table 1.

IS 17618, and IS 17645) compared with < 12% in CSH 5 at 15 pairs/panicle.

DISCUSSION

Under natural conditions, screening for head bug resistance can be carried out efficiently with a combination of timely planting, use of infester rows, sequential plantings, and grouping of material according to maturity and height. In situations/seasons of low r.h., sprinkler irrigation can be used to increase bug abundance. This system was primarily evaluated and used to screen for resistance to sorghum midge in the post-rainy season (Sharma et al., 1988a), and has been found to be useful in increasing head bug abundance and damage. A combination of these techniques and practices was found useful for screening large numbers of entries for resistance to head bugs. However, under multi-choice conditions in the field, bug counts and grain damage are influenced by cultivar preference/nonpreference, and physical characteristics of the panicle (size, compactness, length and tightness of glumes, and days for glume opening and grain hardening). The extent of bug damage is also influenced by days to flowering, head bug population density and environmental conditions. These factors change over time and space, and thus, it takes a long time to identify stable sources of resistance under natural conditions. However, this procedure can serve as a useful tool for initial large scale screening of germplasm and breeding material.

Sources of resistance identified under field conditions can be confirmed under uniform infestation using headcages. Head bug counts and grain damage under headcages are influenced by panicle size (amount of food available for feeding and development) and environmental conditions. By maintaining uniformity in panicle size (clipping the panicles to same size at the time of infestation) and completing infestation within a short period of time, headcages can give a useful measure of genotypic resistance to bugs. However, this technique excludes cultivar non-preference and effect of panicle type on population build-up and grain damage.

Under natural conditions, five genotypes (IS 61, IS 2761, IS 17610, IS 17618 and IS 17645) harboured relatively lower head bug numbers at the milk stage compared to the susceptible checks CSH 1 and CSH 5. Only three of them showed relatively lower bug numbers, under headcages in both seasons of testing. However, bug numbers were comparatively higher in IS 61 and IS 2761 under headcage in one or both the seasons, while IS 4686 and IS 7790 had relatively higher head bug numbers under natural conditions. These differences in bug numbers may be because of the variation in panicle size (amount of food available for feeding) or the influence of environmental factors on survival and development of bugs. Thus, it is important to confirm the resistance of field selected genotypes under uniform infestation using the headcage. Apart from confirming the resistance observed under field conditions, the headcage technique can also serve as a useful tool to differentiate between non-preference and other mechanisms (difficulties in oviposition and antibiosis) of resistance by comparing the bug numbers under natural (choice) and headcage (no-choice) conditions, and studying the oviposition, survival and duration of development under headcage conditions.

Headcage technique can also be used to determine the levels of resistance by varying insect density/panicle. Nine genotypes had relatively lower head bug numbers at five pairs/panicle, and of these, six had relatively lower population build-up at 15 pairs/panicle as well. However, only three of them (IS 17610, IS 17618, and IS 17645) showed moderate levels of grain damage and >70% seed germination. Five genotypes suffered higher grain damage at 15 pairs/panicle compared with five pairs/panicle.

Thus, the headcage technique not only allows for confirming and differentiating the types of resistance, but can also be used as a tool to evaluate resistance levels and the nature of interactions between the insect and the host-plant.

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