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SOURCES AND MECHANISMS OF RESISTANCE TO SORGHUM HEAD BUG, *EURYSTYLUS IMMACULATUS* ODH. IN WEST AFRICA

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Abstract—Sorghum is one of the most important cereal crops in West Africa, and the head bug, *Eurystylus immaculatus* Odh. (Hemiptera: Miridae) is the key pest of grain sorghum in this region. A range of sorghum genotypes were evaluated for resistance to sorghum head bug at Sotuba (Mali) and Kamboinse (Burkina Faso). Genotypes CSM 388, IS 14332, Malisor 84-7, Sakoika, S 29 and Kamboinse local were resistant to head bugs, both under natural and headcage screening. Head bug resistant genotypes had a lower percentage of head bug damaged grain. The food quality of head bug damaged grain was very poor and unacceptable.

Cultivar non-preference was identified as a component of resistance to head bugs, and CSM 388 was non-preferred compared to E 35-1. Panicle compactness was positively associated with head bug numbers and grain damage. However, genotypes with loose panicles were also susceptible to bugs. Long glumes (>5 mm), days to glume opening (>20 days after anthesis), >50% covering of the grain by the glumes, and grain hardness contribute towards resistance to *Eurystylus immaculatus*. This information will be useful for developing a programme to breed for resistance to this insect in West Africa.

Key Words: *Eurystylus immaculatus*, Miridae, sorghum, host-plant resistance, mechanisms of resistance, head bugs

Résumé—Divers génotypes de sorgho ont été évalués pour la résistance à la punaise des panicules du sorgho, *Eurystylus immaculatus* Odh. à Sotuba (Mali) et à Kamboinsé (Burkina Faso). Les génotypes CSM 388, IS 14332, Malisor 84-7, Sakoika, S 29 et Kamboinsé local étaient relativement résistants aux punaises en criblage naturel ou en cage. Les génotypes résistants à la punaise avaient un pourcentage moins élevé de grains endommagés par les punaises. La qualité alimentaire des grains endommagés était très faible et inacceptable.

La non préférence des cultivars était identifiée comme une composante de la résistance aux punaises. Le CSM 388 était non préféré par rapport au E 35-1. La densité de la panicule était positivement associée avec les nombres de punaises et les dégâts aux grains. Cependant, les génotypes avec des panicules lâches étaient également susceptibles aux punaises. Les glumes longues (>5 mm), le nombre de jours à l'ouverture des glumes (>20 jours après l'anthese), >50% de couverture de la graine par les glumes, ainsi que la dureté de la graine contribuent à la résistance à *Eurystylus*.

INTRODUCTION

Sorghum, *Sorghum bicolor* (L.) Moench is an important cereal crop in West Africa, and insect pests are among the major factors limiting production (Nwanze, 1985). Over 100 species of insects have been reported as serious pests of sorghum in the Sahel, of which the mirid head bug, *Eurystylus immaculatus* Odh. is a key pest (McFarlane, 1989; Sharma et al., 1992; Doumbia and Bonzi, 1985).

Efforts to breed and introduce medium maturity high yielding cultivars into West Africa have largely been unsuccessful, because of head bug damage, which adversely affects the grain quality, and renders the grain unfit for food preparations such as "to" (a thick porridge prepared from sorghum flour) and "Cous-Cous". Hard and vitreous grain is preferred for these food preparations, while head bug damage renders the grain soft and starchy. Head bug eggs are laid inside the developing grain and the oviposition site turns red-to-black due to decomposition of starch and accumulation of tannins. This changes the colour of food preparations. Head bug damage also leads to greater incidence of grain moulds (Sharma et al., 1992), which adversely affect the appearance and germination of the grain as well as food quality.

Crop improvement efforts in the sub-Saharan zone, therefore, need to focus on developing cultivars less susceptible to head bugs. There is no available information on host plant resistance to this insect. The present studies were therefore undertaken to identify sources of resistance, and understand the factors associated with resistance to *E. immaculatus* in sorghum.

MATERIALS AND METHODS

Screening for resistance

Cultivar susceptibility to head bugs was evaluated in 11 cultivars at Sotuba, Mali during the 1985 rainy season. There were three replications in a randomized complete block design. The crop was planted on ridges 75 cm apart, and the seedlings were thinned to a 10-cm spacing within the row, 15 days after emergence. Plot size was 4 x 3 m. Normal agronomic practices were followed for raising the crop. No insecticide was applied during the reproductive phase of the crop.

Five randomly marked panicles were screened for head bug resistance in each genotype under no-choice conditions in a headcage (Sharma et al., 1992). Each panicle was infested with 20 pairs of bugs at the milk stage i.e., 12 days after anthesis. Head bug numbers in the infested panicles were recorded 20

days after infestation. The panicles were rated for head bug damage at maturity on a 1 to 5 scale (1 = grain with a few feeding punctures; and 5 = grain showing >60% shrivelling and discoloration to brownish-red) (Sharma et al., 1992). Head bug numbers under natural infestation in different genotypes were recorded in five panicles sampled at random in a polyethylene bag (45 x 30 cm) at the dough stage as described by Sharma and Lopez (1992a). Cultivars were also evaluated for grain damage by the bugs at maturity on a 1 to 5 scale as described before.

Data were also recorded on 1000 grain weight of light and heavy grain separated in sodium nitrate solution with a specific density of 1.31 (Hallgren and Murty, 1983), % light grain, grain hardness (1 = grain hard and corneous, and 5 = grain soft and floury); and "to" quality (1 = "to" light-olive and granular, and 5 = "to" dark-brown in colour and pasty) (Da et al., 1982).

During the 1988 rainy season, four cultivars were evaluated for resistance to head bugs under natural and headcage conditions at Sotuba and Samanko, Mali. Each plot measured 6 x 9 m. There were three replications in a randomized complete block design. Normal agronomic practices were followed for raising the crop as described before. Head bug numbers under natural conditions were recorded in five panicles sampled at random in each replication. Cultivars were also screened in a headcage using 20 pairs of adults or 100 third-instar nymphs/panicle at the complete-anthesis stage. Head bug numbers in the cages were counted 20 days after infestation. Panicles were rated for grain damage at maturity as described before. Data were also recorded on 1000 grain weight and seed germination as described earlier (Sharma et al., 1992).

During the 1986 rainy season, four cultivars were evaluated for head bug resistance under headcage at Kamboinse, Burkina Faso. Normal agronomic practices were followed for raising the crop. No insecticide was applied during the reproductive phase of crop. Each plot measured 4 x 3 m, and there were three replications in a randomized complete block design. Five randomly marked panicles were caged with 20 pairs of bugs/panicle at the complete-anthesis stage in each cultivar. Head bug numbers in the infested panicles were recorded 20 days after infestation. Panicles were rated for grain damage at maturity as described before.

Mechanisms of resistance

Non-preference. Cultivar preference by adult bugs was studied both under field and laboratory conditions

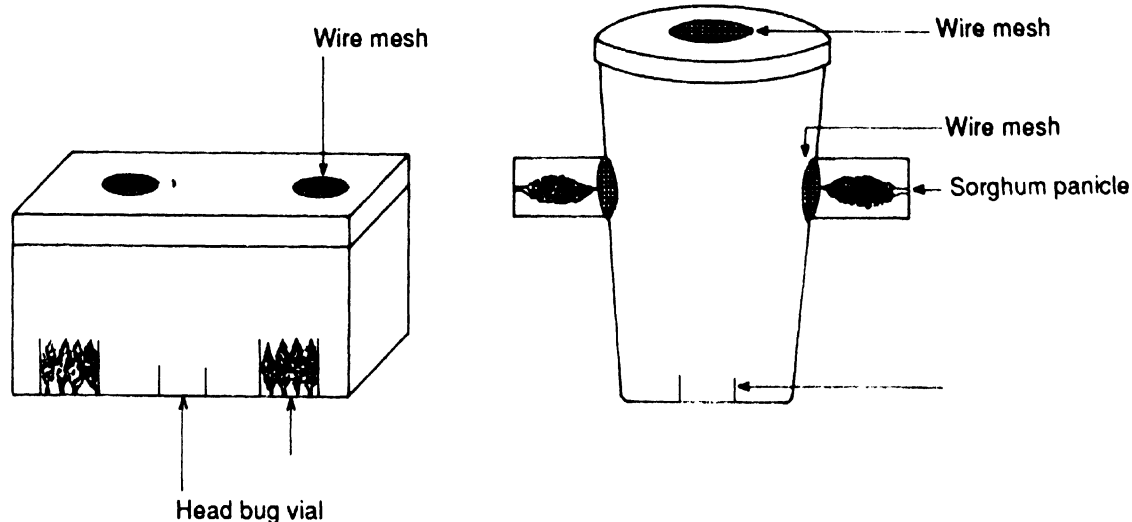


Fig. 1. Olfactometers to study cultivar preference of sorghum head bug with (A) and without (B) contact with the host plant.

during the 1985 rainy season at Sotuba. Under field conditions, the number of bugs attracted to the panicles of different genotypes for feeding and oviposition were recorded at the early milk stage i.e., 12 days after anthesis. Five panicles were randomly sampled individually in a polyethylene bag as described before. The number of bugs recorded on each genotype was taken as a measure of genotypic preference by the head bugs.

Under laboratory conditions, cultivar non-preference by the adults was studied through olfactometer tests, which allowed the orientation of head bugs to be monitored with and without contact with the host plant (Fig. 1). Three cultivars were evaluated for relative preference as described above. Milk grains of the susceptible cultivar, E 35-1 were used as a standard check. Twenty bugs were released in the centre of the olfactometer. The number of bugs (% of the total released) responding to each genotype was recorded after 4 hr. The experiment was repeated five times for each comparison.

Effect of removing glume G1 on egg laying and grain damage

During the 1986 rainy season at Kamboinse, Burkina Faso, the role of glumes in head bug resistance was studied by removing glume G1 from seeds of S 29 at the milk stage with a pair of forceps. Glume G1 was removed from all spikelets of five randomly marked panicles having five primary branches. This cultivar has long glumes, and the grains are covered by the glumes for up to 20 days after anthesis. The removal

of glume G1 exposed the developing grain for feeding and oviposition. Five panicles of SPV 35 with exposed grain, but of the same age after anthesis, served as an undisturbed control. The panicles were infested with five pairs of bugs under a headcage. Data were recorded on feeding punctures and eggs laid/100 grains sampled at random 10 days after infestation. During the 1988 rainy season, the experiment was repeated on another *guinense* cultivar, CSM 388 at Sotuba, Mali. Observations on feeding punctures and egg laying were recorded on 25 grains sampled at random.

Role of panicle and glume characteristics in resistance to head bugs

Panicle and glume characteristics were evaluated in 11 genotypes during the 1985 rainy season at Sotuba, Mali. Data were recorded on number of days required for glume opening, glume length, glume hairiness, glume covering of the grain, and panicle compactness. Days to glume opening were recorded by tagging three branches in three panicles in a genotype at anthesis. The number of days required for the grain to be visible outside the glumes was recorded as the period for glume opening. Glume length and breadth were recorded in mm in 10 spikelets sampled at random. Samples were drawn from five panicles at anthesis and three branches were sampled from each panicle. Glume covering of the grain was evaluated visually on a 1 to 5 scale (1 = <20% grain surface covered by the glumes; and 5 = >60% grain surface covered by the glumes). Glume hairiness was

rated on a 1 to 3⁺ scale (1 = glume shining and without hairs; and 3 = glume completely covered with long hairs) under a microscope (x40). Panicle compactness was evaluated on a 1 to 3 scale (1 = compact, 2 = semi-compact, and 3 = loose). Data on panicle compactness and glume length was also recorded in genotypes screened under headcage during 1986 in Burkina Faso, and during 1988 in Mali.

Statistical analysis

Data on bug numbers were converted to square root values, and were subjected to analysis of variance to test the significance of difference between treatment effects. Treatment means were compared by the least significant difference (LSD). Association of head bug numbers and grain damage with panicle, and glume characteristics was determined through correlation analysis.

RESULTS

Screening for resistance

Head bug numbers were significantly lower at the milk stage in IS 14332, CSM 388, Malisor 84-7, 83F6-16, 83F6-148, and 83F6-87 as compared to A 13120 and E 35-1; of which IS 14332, CSM 388, Malisor 84-7, and 83F6-87 suffered lower grain damage than 83F6-16 and 83F6-148 (Table 1). IS

14332, CSM 388, E 35-1, 83F6-87, and ICSV 197 were also less damaged by grain moulds (damage

Table 1. Head bug numbers and grain damage in 11 sorghum cultivars under natural infestation (1985 rainy season, Mali)

Cultivar	No. of head bugs/panicle	Grain damage	Grain mould severity
IS 14332	5*(2.1) [†] a	1.1 [‡] ab	1.0 a
CSM 388	9(2.7) ab	1.0 a	1.0 a
Malisor 84-7	20(4.2) bc	1.4 b	2.1 c
83F6-87	26(4.8) cd	2.2 c	1.6 b
A 13120	62(7.7) g	2.4 cd	1.8 bc
83F6-111	45(6.6) e	2.6 de	2.6 de
ICSV 197	49(6.5) f	2.8 ef	1.6 b
E 35-1	100(9.8) h	3.0 g	1.0 a
83F6-16	27(4.3) cd	3.0 g	2.8 e
83F6-42	38(5.8) def	4.4 g	2.2 cd
83F6-148	39(6.2) def	4.4 g	2.8 e
SE ±	1.89	0.12	0.13
LSD at 5%	2.67	0.35	0.37

* Grain mould severity (1 = <10%, 2 = 11–25%, 3 = 26–40%, 4 = 41–60%, and 5 = >60% mould infected grains).

[†] Figures in parentheses are square root transformed values. Figures followed by the same letter within a column are not significantly different at $P < 0.05$.

[‡] Grain damage rating (1 = grain with a few feeding punctures, 2 = grain with feeding punctures and 10% grain with eggs, 3 = grain slightly tanned and 25% grains with eggs, 4 = grain slightly shrivelled and 50% grains with eggs, and 5 = grain showing >60% shrivelling and >60% grains with eggs).

Table 2. Head bug numbers in 11 sorghum cultivars infested with 20 pairs of bugs/panicle under headcage and their panicle and glume characteristics (1985 rainy season, Sotuba, Mali)

Cultivar	No. of head bugs/panicle	Grain* damage	Panicle type**	Days to glume ⁺ opening	Glume length (mm)		Glume hairiness ^{††}	Glume covering [‡]
					G1	G2		
IS 14332	56(7.5) ^{‡‡} a	1.0 a ^{***}	1	23	5.9 h	5.9 h	1.7 d	2.8 f
CSM 388	118(10.7) ab	1.0 a	1	20	5.1 g	5.3 f	0.7 a	2.3 e
Malisor 84-7	78(8.2) ab	2.0 b	3	8	4.3 e	4.2 c	2.1 f	2.1 d
83F6-87	95(9.6) ab	3.0 c	1	16	5.1 g	5.0 e	2.1 f	2.0 d
83F6-16	186(13.4) ab	4.0 e	3	6	4.5 f	4.7 d	1.5 e	1.5 c
83F6-42	262(15.9) b	3.5 d	1	8	3.6 b	3.8 b	1.9 e	1.3 b
83F6-148	165(12.4) ab	4.0 e	2	7	3.8 c	3.9 b	2.8 g	1.6 c
83F6-111	131(11.1) ab	3.0 c	2	14	5.8 h	5.6 g	1.2 b	2.4 e
ICSV 197	101(10.1) ab	3.0 c	2	7	3.4 a	3.4 a	1.2 b	1.2 b
A 13120	182(12.9) ab	2.0 b	2	8	4.0 d	3.9 b	1.3 b	1.2 b
E 35-1	175(13.0) ab	3.0 c	3	8	4.6 f	4.3 c	1.3 b	0.7 a
SE ±	2.93	0.14			0.04	0.06	0.03	0.02
LSD at 5%	8.10	0.39			0.12	0.18	0.09	0.06

* Grain damage see Table 1.

** Panicle compactness (1 = loose, 2 = semi-compact and 3 = compact).

⁺ Number of days for grain to be visible outside the glume.

^{††} Glume hairiness (1 = glume slightly hairy, 2 = glume medium hairy and 3 = glume highly hairy).

[‡] Glume covering (1 = 30% grain surface covered by glumes, 2 = 50% grain surface covered by glumes, and 3 = 75% grain surface covered by glumes).

^{‡‡} Figures in parentheses are square root transformed values.

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

Table 3. Effect of head bug feeding on grain weight/panicle, 1000 grain weight, and grain hardness in 11 sorghum cultivars infested with 20 bug pairs/panicle under headcage conditions (1985 rainy season, Sotuba, Mali)

Cultivar	Grain weight/panicle (g)		%	1000 grain weight (g)		Grain hardness	
	Heavy grain	Light grain		light grain	Heavy grain	Light grain	Heavy grain
IS 14334	22.3 b	1.0 a	4.3	14.0 a	12.0 a	2.2 a	2.5 a
CSM 388	31.7 c	5.0 ab	13.6	22.5 e	15.6 b	2.8 b	3.5 b
83F6-87	19.2 b	11.7 cd	26.3	25.8 g	23.0 e	3.1 bc	3.8 b
83F6-148	12.8 a	32.7 f	75.8	22.3 e	19.3 d	3.1 bc	3.8 b
Malisor 84-7	34.9 c	6.1 abc	14.8	19.4 c	13.2 a	3.4 de	4.0 c
A 13120	32.9 c	11.7 cd	26.3	21.7 de	15.3 b	3.2 cd	4.0 c
ICSV 197	39.9 d	9.0 bcd	18.5	17.6 b	12.4 a	3.0 bc	4.6 d
83F6-16	22.4 b	14.2 d	38.8	23.5 f	19.9 d	3.9 f	4.6 d
E 35-1	22.1 b	14.6 d	39.8	26.9 h	22.2 e	3.6 ef	4.8 d
83F6-42	10.9 a	26.8 e	70.8	21.2 d	17.0 c	3.5 de	4.8 d
83F6-111	12.8 a	32.7 f	75.8	26.0 gh	20.8 d	3.4 de	5.4 e
SE \pm	2.22	1.99	—	0.30	0.43	0.10	0.16
LSD at 5%	6.27	5.62	—	0.83	1.22	0.28	0.45

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

Table 4. Food quality of 11 sorghum cultivars infested with 20 pairs of head bugs/panicle under headcage (1985 rainy season, Sotuba, Mali)

Cultivar	"To" keeping quality*		"To" colour†	
	Heavy grain	Light grain	Heavy grain	Light grain
83 F6-16	2.3	4.5	Dark red	Dusky red
83 F6-87	3.0	4.0	Dark brown	Dusky red
E 35-1	3.3	5.0	Light olive brown	Light olive brown
83 F6-148	4.0	4.3	Dark grayish brown	Black
83 F6-42	4.0	5.0	Light olive brown	Dark red
A 13120	3.5	4.3	Dark yellowish brown	Light yellowish brown
83 F6-111	3.6	4.0	Dark reddish brown	Dusky red
Malisor 84-7	1.3	4.5	Light olive brown	Dark brown
ICSV 197	2.3	4.0	Light olive brown	Olive brown
CSM 388	2.6	3.0	Dark yellowish	Dark brown
IS 14332	1.0	—	Olive	—

* Scores above 3 indicate poor food quality.

† According to Munsell soil colour chart.

rating, DR < 1.6). Except E 35-1 and 83F6-83, cultivars susceptible to head bugs also suffered a greater incidence of grain moulds.

Under no-choice conditions in the headcage, the bug population increase was high (Table 2). 83F6-42 had significantly greater number of bugs than the other genotypes tested. Head bug numbers were < 100/panicle in IS 14332, Malisor 84-7, and 83F6-87. IS 14332, CSM 388, A 13120, and Malisor 84-7 suffered lower DR < 2.0 compared with 83F6-16 and 83F6-148 with DR = 4. These cultivars were also less susceptible to bugs under natural conditions. However, 83F6-16 and 83F6-148 had low bug numbers under natural infestation, but were highly susceptible under headcage screening.

The percentage of light grain was lower in IS 14332, CSM 388, and Malisor 84-7 when infested with 20 pairs of bugs/panicle in the headcage (Table 3). 83F6-42 and 83F6-148 had > 70% light grain and

suffered greater bug damage (DR = 4). Differences in 1000 grain weight were also less between the heavy and light grain fractions in IS 14332, 83F6-87, 83F6-148, 83F6-16 and E 35-1, of which the last three genotypes had a damage rating of 3.5. These differences in visual damage rating and 1000 grain weight may be because of genotypic differences in tanning caused by bug feeding and oviposition. Non-tan genotypes show red-brown feeding spots while in the tan genotypes, the feeding spots are light-brown and this may affect visual rating of grain for head bug damage. Grain hardness for heavy grain was higher (score < 3.1) in IS 14332, CSM 388, 83F6-87, 83F6-148, and ICSV 197 compared with 83F6-16. Only IS 14332 had an acceptable grain hardness rating for the light grain fraction.

Food quality ("to" quality) was acceptable for heavy grain (score < 3) in 83F6-16, 83F6-87, Malisor 84-7, ICSV 197, CSM 388, and IS 14332 (Table 4).

Table 5. Head bug numbers on four sorghum genotypes under natural conditions at two locations (Mali, 1988 rainy season)

Cultivar	No. of head bugs/five panicles		Panicle type*	Glume length**
	Sotuba	Samanko		
S 34	412 (20.1) ^{+c}	278(16.2) ^{++b}	2	1
Malisor 84-7	91 (9.5) a	91(9.5) a	3	2
CSM 388	37 (5.9) b	37(5.9) a	1	3
Sakoika (local)	36 (5.5) b	83(8.8) a	1	3
SE ±	(0.76)	(1.86)		
LSD at 5% t	(2.47)	(6.05)		

⁺Figures in parentheses are square root transformed values.
^{*}Panicle type (1 = Loose, 2 = Semi-compact and 3 = Compact).
^{**} Glume length (1 = Short, 2 = Medium and 3 = Long).
⁺⁺Figures followed by the same letter within a column are not significantly different at $P < 0.05$.

Light grain damaged by the head bugs generally had very poor food quality (score > 3.0). Only light grain of CSM 388 had acceptable "to" quality. Thus, head bug damage rendered the grain unfit for food purpose although the effect on grain weight may not be substantial. Head bug damaged grain of resistant cultivars was also unfit for food purposes. However, bug-resistant cultivars had a relatively lower proportion of head bug damaged light grain.

Under natural infestation at Sotuba and Samanko (Mali) during the 1988 rainy season, CSM 388, Sakoika and Malisor 84-7 had <91 bugs/five panicles compared with 278–412 bugs/five panicles for S 34 (Table 5). Malisor 84-7, CSM 388, and Sakoika, also had lower bug population in the headcage and suffered low grain damage (DR <2.7) (Table 6). Differences in nymphal survival between the resistant and susceptible genotypes were not significant. Lowest bug survival was recorded in Malisor 84-7 followed by CSM 388. These results suggest that non-preference for oviposition may be one of the major components of resistance to *Eurystylus* in sorghum. Grain weight was significantly reduced by head bug feeding only in S 34. Seed germination was >75% in CSM 388, Sakoika and Malisor 84-7 (except under adult infestation) compared with <15% seed germination in the susceptible check, S 34. Seed germination in the uninfested control panicles was 84 to 96%.

During the 1986 rainy season, Kamboinse local and S 29 showed lower bug population increase and suffered low grain damage (DR <1.5) than SPV 35. Head bug increase was very low on *guinense* sorghums (four nymphs from 20 pairs/panicle) as compared with SPV 35 (46 nymphs/panicle) (Table 7).

Cultivar	Number of bugs/panicle from 20 pairs	Nymphs survived per 100 nymphs	Grain damage (%)		Seed germination (%)
			Adult infestation	Nymph infestation	
Malisor 84-7	27(5.1) ^{**a}	37(6.0) ^{**a}	2.7 ^{±b}	2.1 a	31.8 a
CSM 388	37(5.5) a	45(6.3) a	2.1	2.7 a	24.7 a
Sakoi	57(7.3) a	55(7.3) a	2.0 a	2.3 a	32.3 a
S 34	07(10.3) b	54(7.3) a	4.8 c	5.0 b	23.8 a
SE	±(0.85)	±(0.8)	±0.20	±0.39	±3.55
LSI	(2.35)	(2.25)	5.5	1.08	9.81
Untreated control			23.1	22.4	23.2
Nymph infestation			27.7 b	31.4 b	22.1 a
Adult infestation			66(55) b	90(72) c	93(75) c
Untreated control			34(60)	96(77)	95(77)
Nymph infestation			76(61) ^{++t}	93(75) c	86(70) c
Adult infestation			15(15) a	0.1(0.1) a	15(15) a
Untreated control			±(5.7)	±1.68	±(5.7)
Nymph infestation			11.83	11.83	11.83
Adult infestation			19.7	19.7	19.7
Untreated control			4.64	4.64	4.64

*Cont = uninfested panicles, covered with cloth bag at p.
^{**}Figt in parentheses are square root transformed value.
⁺Figw followed by the same letter within a column are not significant.
⁺⁺Figl in parentheses are angular transformed values

Table 7. Population increase of *E. immaculatus* on three sorghum cultivars under headcage (20 pairs/panicle) (Kamboinse, Burkina Faso, 1986)

Cultivar	No. of head bugs/panicle			Damage rating	Panicle* type	Glume length (mm)
	Adults	Nymphs	Total			
Kamboinse local	40(6.2)** a	1(0.7) a	41(6.4) a	1.4 a	1	7.0 c
S 29	38(6.2) a	4(1.7) b	42(6.5) a	1.2 a	1	6.4 b
SPV 35	40(6.3) a	46(6.8) c	86(9.3) b	4.0 b	3	4.0 a
SE	±(0.09)	±(0.26)	±(0.19)	±0.24	-	±0.11
LSD at 5% t	(0.27)	(0.80)	(0.58)	0.74	-	0.34

*Panicle type (1 = loose, 2 = semi-compact and 3 = compact).

**Figures in parentheses are square root transformed values.

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

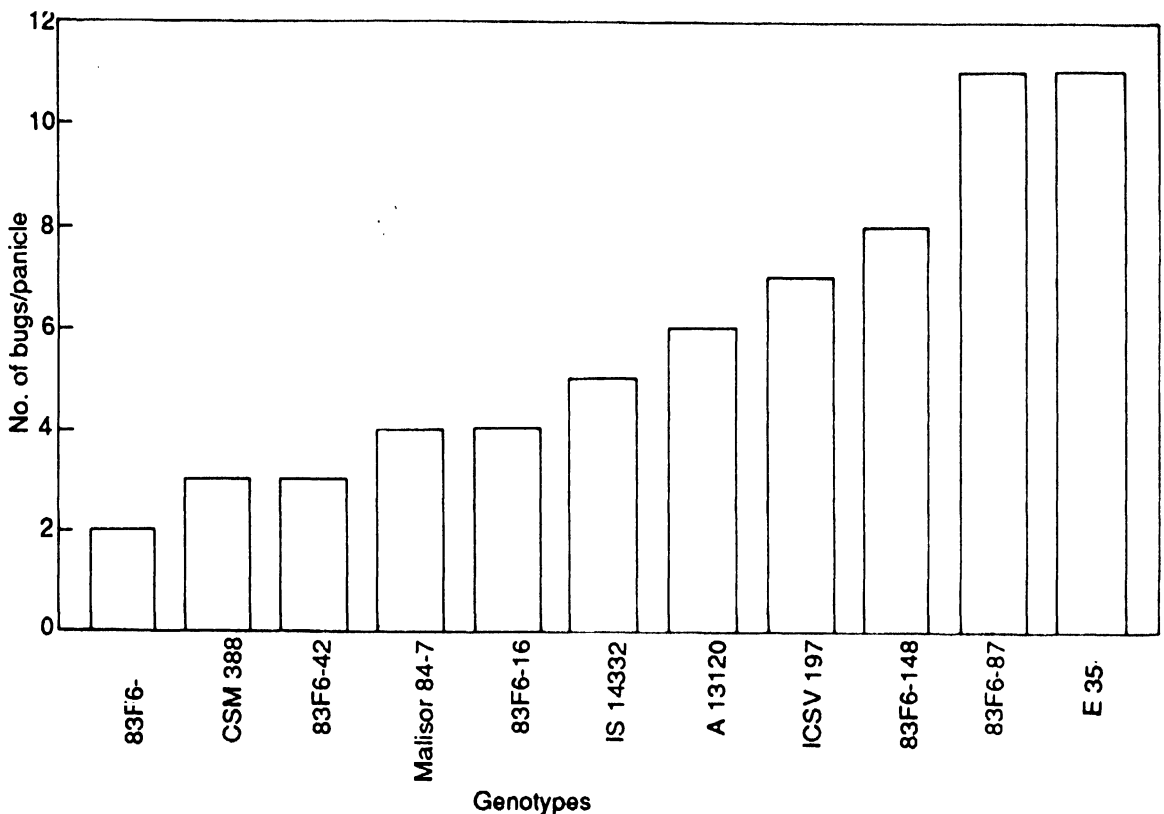


Fig. 2. Cultivar non-preference of 11 sorghum genotypes to head bugs at the complete-anthesis stage under field conditions.

Mechanisms of resistance

Host plant preference. Under field conditions, IS 14332, CSM 388, Malisor 84-7, 83F6-16 and 83F6-111 had < five females/panicle at the complete-anthesis stage compared with 11 females on E 35-1 (Fig. 2). Most of the bugs found at this stage were females. These genotypes also had fewer head bugs at the dough stage (Table 1). Thus, cultivar non-preference at the initial stages seems to be an important factor in determining bug population increase and

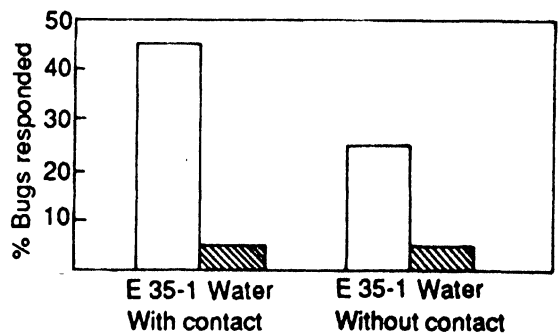


Fig. 3. Relative preference of milk grain and water to head bugs.

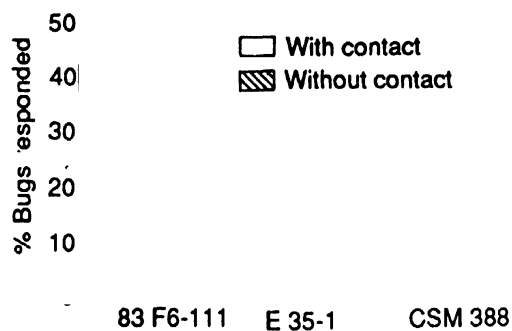


Fig. 4. Cultivar non-preference to sorghum head bugs with and without contact with the host plant.

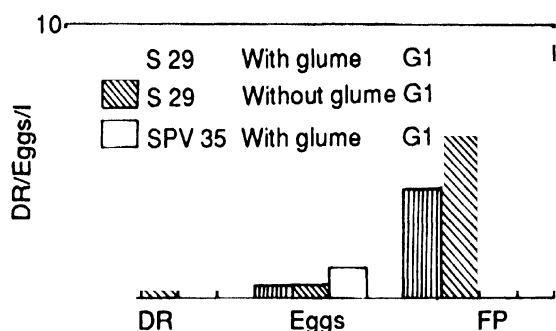


Fig. 5. Effect of removing glume G1 on feeding and oviposition by the head bugs (DR = damage rating, eggs = eggs/10 grains, and FP = number of feeding punctures).

grain damage in different genotypes under natural infestation. CSM 388 was less preferred by the bugs than E 35-1 in olfactometer tests (Fig. 3). Differences in cultivar preference were reduced when the bugs

Table 8. Correlation coefficients between head bug numbers, grain damage, and panicle and glume characteristics

Glume/ panicle character	Head bug numbers		Damage rating	
	Natural conditions	Headcage conditions	Natural conditions	Headcage conditions
Panicle compactness	0.45	0.72*	0.60*	0.55
Days to glume opening	-0.55	-0.72*	-0.82**	-0.73**
Glume length G1	-0.38	-0.42	-0.60*	-0.42
Glume length G2	-0.52	-0.35	-0.60*	-0.41
Glume hairiness	0.09	0.07	0.19	0.44
Glume covering	-0.83**	-0.56	-0.67*	-0.52

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

were not allowed a contact with the host plant (Fig. 4). Therefore, both contact and odour stimuli seem to determine host plant selection and acceptance by *E. immaculatus*.

Effect of removing glume G1 on feeding and oviposition in guineuse sorghums. During the 1986

season, removal of glume G1 in S 29 (a less susceptible *guineuse* cultivar) did not affect the number of eggs laid, but the number of feeding punctures and grain damage increased substantially (Fig. 5).

Association of panicle and glume characteristics with resistance to head bugs. Head bug resistant genotypes (IS 14332, CSM 388, 83F6-87) took longer period for glume opening, had longer glumes (>5 mm), and >50% of the grain surface was covered by the glumes (Table 2). Malisor 84-7, though less susceptible to bugs than E 35-1, had medium sized glumes. However, it has a very hard corneous grain. Genotypes with shorter glumes were generally more susceptible to bugs. 83F6-111 and 83F6-16 had medium sized glumes and suffered moderate levels of bug damage. These genotypes required about 2 weeks for glume opening. Genotypes with loose to semi-compact panicles were less susceptible to bugs (Table 2). Kamboinse local, S 29, CSM 388 and Sakoika, which were less susceptible to the head bugs, had longer glumes than the susceptible checks SPV 35 and S 34 (Tables 5 and 7). Panicle compactness was positively associated with head bug numbers (Table 8). Days to glume opening, glume length, and glume covering of the grain were negatively associated with head bug numbers and grain damage.

DISCUSSION

Mirid head bugs are one of the most important factors limiting sorghum production in the semi-arid tropics (Sharma and Lopez, 1990a; Steck et al., 1989; McFarlane, 1989). Head bug damage also spoils the grain quality and renders it unfit for human consumption (Sharma and Lopez, 1989; Sharma et al., 1992). *E. immaculatus* lays eggs inside the grain, which results in decomposition of the grain at the site of oviposition. Bug damaged grain also shows greater severity of mould incidence (Sharma et al., 1992). Thus, it is very important to identify sources of resistance to this insect and identify the factors associated with resistance in order to transfer resistance into improved high yielding cultivars.

Screening for resistance can be carried out by using infester row and headcage techniques (Sharma and Lopez, 1992a; Sharma et al., 1992). Identified sources of resistance should be tested across seasons and/or locations to identify genotypes with stable resistance (Sharma and Lopez, 1991). The present studies indicate that *guineuse* land races with a greater covering of the grain by the glumes and having hard corneous grain are resistant to the head bugs.

Cultivar differences in susceptibility to *E. immaculatus* were evident both under natural and headcage conditions. *Guineuse* land races with long glumes (traditionally cultivated in the guinean zone) (CSM 388, Sakoika, and IS 14332), were less damaged

by head bugs than S 34 and E 35-1. Many germplasm accessions of *guinense* origin have earlier been identified to be resistant to another mirid bug, *Calocoris angustatus* Leth. (Sharma and Lopez, 1992b). Malisor 84-7 derived from *guinense* sorghums, is of medium height, has a hard corneous grain, and is relatively resistant to head bug damage. It can be grown in head bug endemic areas, and used in breeding for resistance to head bugs.

Feeding and oviposition by the head bugs decreased 1000 grain weight, increased the percentage of light grain, decreased grain hardness, and rendered the grain unfit for food. Even low levels of head bug damage could render the grain unfit for human consumption. Similar effects of head bug damage on sorghum grain have been reported for *C. angustatus* (Sharma and Lopez, 1989). Since genotypes with a hard corneous grain are a prerequisite for food in West Africa (Da et al., 1982), breeding for resistance to head bugs should be one of the most important components for sorghum improvement.

Cultivar non preference by the adults at the milk stage is one of the mechanisms of resistance to head bugs. At this stage, the adults select their host plant for feeding and oviposition. Genotypic differences in relative preference by the bugs were observed both under field and laboratory conditions. However, both odour and contact stimuli were important in host selection since differences between genotypes were reduced when the bugs were not allowed contact with the host plant. Cultivar nonpreference has also been observed to influence host plant selection by *C. angustatus* (Sharma and Lopez, 1990b).

Genotypes with compact panicles provide a safe niche for the development and multiplication of bugs (Sharma, 1985), although genotypes with compact panicles may not necessarily be susceptible, e.g. Malisor 84-7 has a compact panicle, but was less susceptible to the bugs. On the other hand, genotypes with loose panicles may also be highly susceptible, e.g. 83 F6-42, 83 F6-148 and A 13120. Some of these interactions are highly influenced by the glume and grain characteristics of different genotypes (Sharma, 1985). Days to glume opening appeared to be associated with genotypic resistance to head bugs. This is because of the fact that head bug feeding and oviposition were confined to the grain surface not covered by the glumes. Cultivars with more than 20 days to glume opening (e.g., IS 14332 and CSM 388) were resistant to the bugs. In cultivars with a longer period required for glume opening, the grain becomes relatively harder for feeding and oviposition when it becomes visible outside the glumes. 83 F6-87 and 83 F6-111 took about 2 weeks to glume opening and suffered moderate levels of grain damage. Malisor

84-7 does not have the above characteristics, but it is less susceptible because of faster grain hardening and has a highly corneous grain on which feeding and oviposition may be difficult.

Several lines identified to be resistant to *E. immaculatus* (CSM 388, Malisor 84-7, Sakoika, S 29 and Kamboinse Local) can be used in a resistance breeding programme to develop head bug resistant high yielding cultivars. Greater covering of the grain by the glumes, days to glume opening, grain hardness and quicker grain maturity, can be used as marker traits to select for resistance to head bugs.

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