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Host plant resistance in sorghum to *Eurystylus oldi* in West Africa

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Abstract — The panicle-feeding bug *Eurystylus oldi* Poppius (Heteroptera : Miridae) has recently become a key pest of sorghum in West and Central Africa, particularly in Mali, and on improved compact-panicled types. To reduce losses incurred at the small farm level, detailed studies were carried out in 1989-1996 by Icrisat-Cirad, on several aspects of host plant resistance. These studies made it possible to identify sources of resistance, and particularly to confirm high and stable resistance in compact-panicled sorghum cultivar Malisor 84-7. Results of studies suggested that the major factor associated with head bug resistance in Malisor 84-7 was a quicker endosperm hardening pattern in this cultivar. Studies on the genetics of this resistance showed that it is highly heritable and mainly under additive gene action. Using pedigree breeding selection, it has been possible to transfer head bug resistance from crosses between Malisor 84-7 and high yielding cultivars, and several promising progenies combining reasonable head bug resistance and acceptable agronomic traits were obtained. Further screening is underway, with the aim of identifying new sources of resistance, possibly involving other factors. On the other hand, efforts are now underway, aiming at mapping resistance genes, using molecular markers.

Résumé — Résistance variétale du sorgho à *Eurystylus oldi* en Afrique de l'Ouest. Les punaises des panicules, particulièrement *Eurystylus oldi* Poppius (Heteroptera : Miridae), sont récemment devenues les principaux ravageurs du sorgho en Afrique de l'Ouest, notamment au Mali, et sur les variétés améliorées à panicule compacte. Afin de réduire les pertes subies par les petits producteurs, des études ont été conduites de 1989 à 1996 par le Programme conjoint sur le sorgho Icrisat-Cirad (Mali) sur plusieurs aspects de la résistance variétale de la plante hôte à son ravageur. Les recherches ont permis l'identification de sources de résistance, et notamment la confirmation du haut niveau et de la stabilité de la résistance rencontrée chez Malisor 84-7, une variété à panicule compacte. Les résultats de l'étude suggèrent que le principal facteur associé à la résistance aux punaises chez Malisor 84-7, est le durcissement rapide de l'albumen de cette variété, par rapport aux variétés sensibles. L'étude de la génétique de cette résistance a montré qu'elle était fortement héritable et principalement sous l'action de gènes additifs. Par sélection généalogique, il a été possible de transférer la résistance aux punaises de Malisor 84-7, en la croisant avec des variétés productives. Plusieurs descendances prometteuses, combinant un niveau raisonnable de résistance aux punaises et un bon niveau de rendement, ont ainsi été obtenues. Le criblage se poursuit, en vue d'identifier de nouvelles sources de résistance qui feraient appel à d'autres facteurs. Des études impliquant des marqueurs moléculaires sont également en cours, avec pour objectif la cartographie des gènes de résistance, dans l'optique de programmes de sélection assistée par marqueurs.

The mirid panicle-feeding bugs, particularly *Eurystylus oldi* Poppius have recently become key-pests of sorghum in West Africa. Feeding and oviposition of these head bugs on maturing sorghum grains result in severe quantitative and qualitative losses, particularly on improved compact-headed types.

These pests are therefore a major threat to the increase of sorghum production through the extension of improved cultivars, which, although better yielding, are more susceptible to head bug damage than local loose-panicled guinea landraces. Sorghum improvement programs in the region should therefore focus on host plant resistance to these panicle feeding bugs.

The use of resistant cultivars is often the most efficient means of controlling crop pests, particularly in the case of small-scale farmers, whose access to inputs is limited. In addition, this technique does not have harmful effects on man (namely producers and consumers) or the environment, including pests natural enemies. In this respect, it is fully compatible with other crop protection techniques, and should be the cornerstone of any integrated pest management program.

Earlier work in the West Africa region is limited. However, considerable efforts by Icrisat and Nars, notably Ier in Mali, have resulted in the development of reliable artificial infestation techniques to screen sorghum lines for resistance to *E. oldi* and the identification of a few sources of resistance, and of some of the factors associated with head bug resistance in sorghum.

The studies presented were carried out from 1989-1996 by Icrisat-Cirad, with the following specific objectives:

– identification of sources of resistance to sorghum head bugs in the compact-panicled background;

– elucidation of a factor imparting resistance to head bugs;

– determination of the genetic nature of this resistance;

– selection of sorghum cultivars combining good level of head bug resistance with acceptable agronomic traits.

Screening and breeding compact-panicled sorghum varieties for head bug resistance

During 1989 and 1990 rainy seasons, we evaluated 12 sorghum cultivars, at Samanko and Cinzana (Mali), and Farako-Ba (Burkina Faso), in two Dos and under both natural and artificial head bug infestation (Ratnadass *et al.*, 1994).

Besides head bug infestation, population buildup, and damage scores, other parameters, namely 1 000-kernel weight, percent "floaters" in a sodium nitrate solution of specific density 1.205, vitrosity, and germination rate, were measured for protected and infested panicles for all 12 entries. In addition, grains from protected and infested panicles of selected entries were analyzed for dehulling recovery rate.

Results showed the high level and stability of head bug resistance in the Ier cultivars Malisor 84-7 and Csm 388, for all parameters measured under both natural and artificial infestation, and the dramatic effect of head bug attack on susceptible cultivars such as S 34.

For instance, Malisor 84-7 and Csm 388 were by far the least infested cultivars, with maximum values for the infestation level of respectively 51 and 62 head bugs per five panicles on the 10 trials where this parameter was measured, compared with > 400 on all the other entries. Under natural infestation, maximum head bug visual scores observed on the 12 trials where this parameter was taken, were ≤ 4.0 in these two entries, compared with > 7.0 in Framida and S 34. These results were partly confirmed under artificial infestation, although differences between cultivars narrowed down under cage conditions.

In both years, 1 000-kernel weight was reduced by about 50% in S 34, following artificial infestation by head bugs, whereas it was not significantly affected in Malisor 84-7 and Csm 388. Dehulling recovery rate was reduced by about 30% in S 34 and Gadiaba (a Durra cultivar), compared with only 5% in Malisor 84-7 and Csm 388. Similarly, in S 34, germination rate was reduced by half, and proportion of low density grains increased threefold, whereas differences between protected and infested panicles were not significant in Malisor 84-7, for these parameters. Loss of vitrosity was three times greater in S 34 than in Malisor 84-7 (Ratnadass *et al.*, 1994).

We then conducted Advanced Head Bug Trials during the 1991 rainy season at Samanko and Farako-Ba, and the 1992 rainy season at Samanko. We evaluated nine and 12 compact-headed sorghum cultivars, respectively, along with a local guinea cultivar as control (Csm 388 at Samanko, and Gnofing at Farako-Ba), in two Dos in 1991, and one in 1992 (Ratnadass *et al.*, 1995).

Among the cultivars evaluated in both years were notably the best two entries of the 1990 Preliminary Head Bug Screening Trial (87W810 and 89W891, advanced progenies from a cross between high yielding Icsv 1002 and Malisor 84-7). The same observations were made as in the 1989 and 1990 Advanced Head Bug Screening Trials, on head bug infestation and damage under natural and artificial infestation.

In 1991, infestation was maximum at Samanko on the first Dos, and at Farako-Ba on the second Dos. We recorded 37 and 30 head bugs per 5 panicles respectively in both locations on Malisor 84-7, compared with 301 and 331 on Icsv 197 (second susceptible check). Under natural infestation, Malisor 84-7 had a visual damage score of 3.8 at Samanko, and 3.3 at Farako-Ba, compared with 6.7 on S 34 in both locations. These differences were partially confirmed under cage conditions. At Samanko, we recorded on first and second Dos resp. 57 and 69 bugs per panicle on Malisor 84-7, compared with > 100 on both Dos in Csm 388, Icsv 197, and 89W891. Under artificial infestation, Malisor 84-7 had a damage score of 3.7 and 3.8, compared with 4.0 and 2.8 in Csm 388, and 7.2 and 6.5 in S 34.

In 1992 at Samanko, we recorded 28 head bugs per 5 panicles on Csm 388 and 67 on Malisor 84-7, compared with 340 on S 34 and 355 on Hadien-Kori (a Heggeri sorghum from the river Senegal region). Under natural infestation, Csm 388 had a mean damage score of 2.5 and Malisor 84-7 had 3.2, compared with 5.7 for both S 34 and Icsv 197. Under cage conditions, we recorded 75 bugs per panicle on Csm 388 and 95 on Malisor 84-7, compared with 510 on Hadien-Kori, and 484 on 89W891. Damage rating under artificial infestation was 3.7 for Csm 388 and 4.8 for Malisor 84-7, compared with 4.5 for 87W810 and 7.7 for Icsv 197.

The proportion of light grains (percent floaters) in the first Dos and the germination rate in the second Dos differed significantly (P = 0.05) in Malisor 84-7 between protected and artificially infested panicles. In contrast, Icsv 197 and S 34 showed markedly reduced quality for all parameters. Malisor 84-7, 87 W810 and Csm 388 showed almost no reduction in dehulling recovery rate, while S 34 showed a marked reduction of 55%. Malisor 84-7 showed no change in tô quality, whereas Csm 388 showed a noticeable decrease in acceptability of tô color.

In 1992, 1 000-kernel weight was not affected by exposure to natural head bug infestation in Malisor 84-7, Isiap Dorado and Csm 388, whereas it was reduced by over 30% in 89W891. Under artificial infestation, cultivars Isiap Dorado, Malisor 84-7, Csm 388 and 87W810 showed < 20% reduction in 1 000-kernel weight, compared to 48% in S 34, and 59% in Hadien-Kori. In the latter, quantitative loss was further aggravated by a reduction of 94% in dehulling recovery rate. The germination rate was similar for all the protected panicles, with a mean of 94%, while there were large differences for the artificially infested panicles. The local control Csm 388 had a germination rate of 85%, while the only other varieties with a germination rate above 55% were Malisor 84-7 and 87W810.

Although 1991 results confirmed high level and stability of head bug resistance reported earlier for Malisor 84-7, this cultivar did not perform as well in 1992, particularly under artificial infestation. However, it remains our best source of head bug resistance among the compact-headed types. Isiap Dorado, although little infested and damaged by head bugs under natural conditions, had a high damage score despite a medium level of infestation under cage conditions, and therefore showed a super-susceptible response. On the other hand, Hadien-Kori was highly susceptible. Although this cultivar genetically accounts for 12.5% of the Malian base population of sorghum, from which the Malisor series is derived, it is obviously not responsible for the resistance found in Malisor 84-7.

In contrast, 87W810 had low scores despite medium infestation levels, and showed a reasonable tolerance to head bug attacks. In addition, its yield in 1992 was higher (1.44 t/ha) than those of Malisor 84-7 (1.23 t/ha) and Csm 388 (1.25 t/ha). These results suggest that it is possible to transfer a reasonable level of head bug resistance into good agronomic background, using pedigree breeding selection (Ratnadass *et al.*, 1995).

Mechanism of head bug resistance in sorghum

As glume characteristics (notably length of period to glume opening) do not seem to be the factors imparting head bug resistance to Malisor 84-7, it was suggested that the mechanism involved in this genotype might be a faster grain hardening pattern. Earlier attempts to document this evidence were not quite conclusive. We therefore conducted studies in 1991 and 1992 at Samanko, Mali, and Montpellier, France, to further examine physical and chemical characteristics of maturing grains (Fliedel *et al.*, 1993 ; Ratnadass *et al.*, 1995).

These included the evolution of hardness of the pericarp and endosperm (by penetration tests using an Instron Universal food testing machine, on which a minutia was adapted), and contents in free phenolic compounds and tannins, determined respectively by a Floin-Ciocalteu method (using gallic acid as a standard), and an acidic vanillin method (using a catechin standard). Three sorghum cultivars, resistant Malisor 84-7, susceptible S 34, and Irat 202, moderately resistant, were used in this study.

In 1991 at Samanko, S 34 had a damage score of 7.9 under natural infestation, compared with 5.4 in Irat 202, and 3.8 in Malisor 84-7 (averages of two Dos); under cage conditions, damage score were respectively 6.3, 5.1, and 3.9. In 1992, scores under natural infestation were respectively 7.9 for S 34, 5.5 for Irat 202, and 3.5 for Malisor 84-7, whereas under cage conditions, they were respectively 6.5, 5.8, and 3.4. In 1993, scores under natural infestation were respectively 6.0 for S 34, 3.6 for Irat 202, and 3.4 for Malisor 84-7, whereas under cage conditions, they were respectively 7.7, 5.8, and 4.4.

The results of these studies suggested that grain hardening was due to the endosperm rather than the pericarp. Head bug resistance in Malisor 84-7 seemed to be related to endosperm hardening rather than to free phenolic compounds or tannin contents which were much higher in Irat 202, due to the presence of a subcoat in the grains of this cultivar (Fliedel *et al.*, 1993 ; Ratnadass *et al.*, 1995).

Genetics of sorghum resistance to *E. oldi*

As a first step in our attempts to elucidate the mode of inheritance of the resistance to head bugs found in Malisor 84-7, we evaluated at Samanko in 1992 and 1993, three sorghum cultivars, Malisor 84-7 (head bug resistant), S 34 and Icsv 197 (both susceptible), and the F_1s of their crosses, in Randomized complete block designs (Rcbds) with three replications.

Results showed that in both years, head bug population buildup and damage were less on the resistant parent than on both susceptible parents, and all F_1s. On the other hand, F_1s' reaction to head bugs did not differ significantly among crosses, whatever the maternal parent. This suggested that resistance was rather recessive in nature and that there was no maternal effect (Ratnadass *et al.*, 1995, Icrisat, 1994).

More complete studies were conducted in 1995 and 1996, using four parents (namely the same as in the 1992-1993 studies, plus 87W810 as a second resistant parent). In addition to all F_1s of their crosses, F_2s and back crosses (Bcs) were also evaluated. These were evaluated in one Dos under natural head bug infestation in 1995, and in two Dos in 1996, under natural head bug infestation, and artificial infestation of the non-segregating generations (Sharma and Ratnadass 1996, Coulibaly, 1996).

In both years and under both types of infestation, F_1s and F_2s were not statistically different from their reciprocal, confirming that no maternal effect is involved in head bug resistance. Generation mean analysis on 1996 natural infestation data showed that an important fraction of head bug resistance in Malisor 84-7 was heritable through its different crosses. Diallel analyses were carried out, using the "Diallel" program (Burow and Coors, 1994); they gave General combining ability (Gca) variance values significantly higher than Specific combining ability (Sca) variance values, in terms of damage scores under both types of infestation ; this was also the case for head bug population buildup under artificial infestation (table I). These results show that head bug resistance in Malisor 84-7 is mainly under additive gene action (table II). This suggests that pedigree breeding selection is an appropriate strategy to develop sorghum cultivars combining head bug resistance with other desirable characteristics (Coulibaly, 1996).

Discussion

The availability of a reliable screening technique, notably under uniform pest pressure and no-choice conditions, made it possible to identify sources of resistance to head bugs, and particularly to confirm high and stable resistance in compact-panicled sorghum cultivar Malisor 84-7.

The major factor associated with this resistance seems to be a quicker endosperm hardening pattern in this cultivar, resulting in a shorter period during which head bugs can feed and lay their eggs in the maturing grains.

Studies on the genetics of this resistance showed that it did not involve maternal effect, that it was highly heritable, and mainly under additive gene action. These studies could be completed by mapping resistance genes, using molecular markers. Such studies are now underway at Cirad and Texas A & M University.

Table I. General Combining Ability (Gca) effects on head bug visual scores under natural and artificial infestation, and head bug population buildup under artificial infestation observed at Samanko in 1996.

Parents	Head bug visual score		No head bugs per panicle (artificial infestation)
	natural inf°	artificial inf°	
Malisor 84-7	- 0.84 **	- 0.58 **	- 4.31 **
87W810	- 0.42 **	- 0.85 **	- 1.50 **
S 34	0.82 **	0.90 **	1.40 **
Icsv 197	0.45 **	0.53 **	4.41 **
Se	± 0.170	± 0.149	± 0.456

Table II. Effects of additivity and dominance variances and heritability values on head bug visual score under natural and artificial infestation, and head bug population buildup under artificial infestation observed at Samanko in 1996.

Parents	Head bug visual score		No head bugs per panicle (artificial infestation)
	natural inf°	artificial inf°	
Additivity	1.16	1.44	25.30
Dominance	- 0.05	- 0.05	2.38
H^2 (ns)	0.73	0.82	0.81
H^2 (bs)	0.70	0.79	0.89

H^2 (ns): narrow-sense heritability.
H^2 (bs): broad-sense heritability.

Using pedigree breeding selection, it has been possible to transfer head bug resistance from crosses between Malisor 84-7 and high yielding cultivars and several advanced progenies which combine reasonable head bug tolerance and acceptable agronomic traits were obtained, of which 87W810 is the most promising.

This was confirmed by further evaluation of advanced progenies of another cross involving Malisor 84-7 (namely with Icsv 1014) (Thiéro, 1996). One of these progenies, namely 91W113-2-1, is currently being tested, along with 87W810, Malisor 84-7 and other resistant varieties identified by Ier, in a multilocational trial coordinated by Wcasrn, on 15 stations distributed in 11 countries of the region.

Also, as evidence was found of a diversity of genotypic reactions to head bug attacks, further screening is underway, with the aim of identifying new sources of resistance, possibly involving other factors, such as glume characters, contents in certain chemicals, etc., in view of broadening the genetic basis of head bug resistance.

On the other hand, on-going on-farm studies in the Kolokani region (north of Bamako), should provide information on the level of resistance actually required in improved varieties for their cultivation in large stands at the farm level.

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