Selection of Sorghum Line CIRAD 441 Combining Productivity and Resistance to Midge and Head Bugs

A Ratnadass[1,2]*, J Chantereau[1,3], B Cissé[1], M Ag Hamada[1], G Fliedel[4], J Grabulos[4] and **C Luce[1,3]**
(1. ICRISAT-CIRAD, BP 320 Bamako, Mali; 2. Present address: URP SCRiD, University of Antananarivo-FOFIFA-CIRAD, BP 230, Antsirabe, Madagascar; 3. CIRAD, UPR Agrobiodiversity in Savannah Environments, TA 70/01, 34398 Montpellier Cedex 5, France; 4. CIRAD, UPR Tropical Food Quality, TA 70/16, 34398 Montpellier Cedex 5, France)
*Corresponding author: ratnadass@cirad.mg

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is the most important food crop in the savannah areas of West and Central Africa (WCA), notably in Burkina Faso and Mali, where production in 2005 was 1.40 million tons and 0.66 million tons, respectively (FAO 2006). Feeding and oviposition of mirid bugs (head bugs), particularly *Eurystylus oldi* Odhiambo, 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 effort to increase sorghum production through the extension of improved cultivars. Although these genotypes are better-yielding, they are more susceptible to head bug damage than the local loose-panicled guinea landraces. On the other hand, sorghum midge [*Stenodiplosis sorghicola* (Coquillett)] is the most important pest of the crop in the southern, central and eastern regions of Burkina Faso (Ratnadass and Ajayi 1995).

Results from inheritance studies have suggested independent genetic systems for head bug and midge resistance in sorghum (Ratnadass et al. 2002). Short and tight glumes and rapid ovary development make oviposition difficult and adversely affect midge larval development and thereby contribute to midge resistance. However, these characteristics expose the maturing grain to damage by head bug and contribute to susceptibility to this particular pest. On the other hand, factors such as long glumes covering the developing grains virtually up to the maturity stage (which is the main head bug resistance factor in guinea cultivars) and quicker endosperm hardening contribute to head bug resistance. Through plant breeding, factors conferring resistance to sorghum midge, and those conferring resistance to head bugs can be used to develop lines that combine short and tight glumes, rapid ovary development and quick endosperm hardening.

Materials and Methods

Malisor 84-7, a head bug-resistant genotype with quick endosperm hardening, derived from a random-mating Malian population (Shetty et al. 1991), and ICSV 197, a midge-resistant progeny derived from a cross between IS 3443 and DJ 6514 (Agrawal et al. 1987), were crossed during the 1992 rainy season. This cross (named CCAL 1) was made at the ICRISAT-CIRAD research station of Samanko, Mali (12°32′N; 08°07′W). Pedigree selection in the F_2, F_3, F_4 and F_5 generations was done under natural head bug infestation at Samanko during the cropping seasons from 1993 to 1996. The F_2 plot consisted of 2000 plants, while the F_3 to F_5 plots consisted of 100 plants. CIRAD 441 was selected as a line with dual resistance to midge and head bugs during the 1996 rainy season bearing the selection no. CCAL 1/13-1-1-1, along with nine other F_6 lines from the same cross.

This F_6 generation was evaluated under natural head bug infestation in Mali during the rainy season of 1997, both at Samanko and at the Institut d'economie rurale (IER) research station of Longorola (11°21′N; 05°41′W) in Mali. The F_7 generation was evaluated under natural midge infestation and artificial head bug infestation during the late rainy season of 1998 at Samanko, along with four head bug-resistant progenies from a cross between Malisor 84-7 and ICSV 1079, and the three parents. In both years, trials were conducted in a randomized complete block design (RCBD) with three replications, with plots consisting of four rows of 5 m length. In 1998, at the heading stage, five plants randomly chosen from the two central rows were covered with a paper selfing bag. At early anthesis, three of these bags, chosen at random, were removed and replaced with head-cages, and the panicles were confined with 40 *E. oldi* adults from late anthesis until 20 days later, following the technique described by Sharma et al. (1992). At grain maturity, all panicles, namely both the ones exposed to artificial infestation (in 1998), and those exposed to natural infestation (both in 1997 and 1998), were visually scored for head bug damage using a 1–9 rating scale (Ratnadass et al. 2002). Midge damage was evaluated by visually rating five plants per plot using a 1–9 scale (Sharma et al. 1992).

During the 1999 rainy season, CIRAD 441 was tested under high natural midge and head bug pressure at Samanko. It was included in a preliminary yield test conducted under natural head bug infestation in an RCBD design in three replications, and plots consisting of four rows of 6 m length. Grain yield was the only parameter recorded.

Table 1. Evaluation of CIRAD 441 (generations F_6 to F_8 of the line CCAL 1/13-1-1-1) for head bug and midge resistance and grain yield in panicle pest screening nurseries at Samanko and Longorola, Mali, 1997–1999.

Cultivar	Head bug damage score[1]			Midge damage score[2]	Grain yield (t ha^{-1})
	Samanko 1997 (natural infestation)	Longorola 1997 (natural infestation)	Samanko 1998 (artificial infestation)	Samanko 1998 (natural infestation)	Samanko 1999 (natural infestation)
CIRAD 441	3.3a[3]	3.3a	4.7ab	1.0a	1.6a
Malisor 84-7	3.1a	3.0a	4.0a	2.0a	0.7b
ICSV 197	5.2a	3.5a	8.0c	1.0a	1.4a
Mean	4.0 (17)[4]	3.9 (17)	5.6 (17)	2.6 (17)	1.1 (7)

1. Head-bug damage scored on a 1–9 scale, where 1 = all grains fully developed, of which < 10% showing a few head bug punctures, no eggs, no browning/shrivelling; and 9 = >75% of the grains remaining undeveloped and barely visible outside the glumes.
2. Midge damage scored on a 1–9 scale, where 1 = no mold and 9 = >75% of grain surface area molded.
3. Means followed by the same letter in each column are not significantly different at $P = 0.05$ with the Newman-Keuls test.
4. Number of cultivars involved in mean calculation are given in parentheses.

Further analyses of grain quality were carried out on 14 cultivars, namely eight progenies of Malisor 84-7, their parents (Malisor 84-7, ICSV 1002, ICSV 1079 and ICSV 197), and two controls (S 34 and IRAT 202), grown at Montpellier, France, during the summer of 2000. The vitrosity index was determined on a 1–5 scale (Maxson et al. 1971). The abrasive hardness index (AHI) method was used for grain hardness evaluation (Reichert et al. 1982).

Results and Discussion

CIRAD 441 showed high levels of stable resistance to midge and head bugs (Table 1). It is a photoperiod-insensitive, medium-maturing cultivar (73–77 days to 50% flowering) with height ranging from 1.9 m to 2.2 m. At Samanko in 1998, CIRAD 441 was resistant to both head bugs and midge. In 1999, it produced 1.5 t ha^{-1} and yielded more than all the other test cultivars. CIRAD 441 was as hard and vitreous as its head bug-resistant parent, Malisor 84-7 (Table 2).

In 2000 and 2001, CIRAD 441 was evaluated in on-farm tests in the eastern and central-western regions of Burkina Faso, an area where many farmers have abandoned cultivation of white sorghum due to high midge pressure. It confirmed there is dual resistance to sorghum midge and head bugs, along with an average yield gain of 140% over farmers' local varieties used as controls. In addition, its grain quality for human consumption and stem quality as cattle fodder were rated very high by farmers (Dakouo et al. 2005). This variety is therefore very promising for cultivation in all midge and head bug endemic areas. It can also be used as a donor to combine resistance to both pests, grain quality and other traits. Its seeds are available at the CIRAD genebank.

Table 2. Grain quality parameters observed on CIRAD 441 (CCAL 1/13-1-1-1) and its parents (Montpellier, France, 2000).

Cultivar	Grain vitrosity[1]	Grain hardness (AHI)[2]
CIRAD 441	2.2a[3]	25.8a
Malisor 84-7	2.2a	23.9ab
ICSV 197	2.7a	19.6b
Mean (14 cultivars)	2.7	24.2

1. Grain vitrosity index scored on a 1–5 scale, where 1 = grain hard and highly corneous, and 5 = grain soft and floury.
2. AHI (abrasive hardness index) defined as the time (in s) required for the abrasion of 1% by weight of the kernel; the harder the grains, the higher the AHI.
3. Means followed by the same letter in each column are not significantly different at $P = 0.05$ with the Newman-Keuls test.

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