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Sorghum head-bugs and grain molds in West and Central Africa: I. Host plant resistance and bug–mold interactions on sorghum grains

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Abstract

A regional sorghum head-bug and grain mold resistance trial was conducted in 1996 and 1997 at 15 and 13 research stations located in 10 West and Central African countries, respectively. Two cultivars namely IS 14384 and CGM 39/17-2-2 exhibited consistently high levels of resistance both to head-bugs and grain molds over years and localities. *Eurystylus oldi* was the dominant head-bug species at all localities except in Benin, Chad and Guinea. Sorghum grain mycoflora varied little between sites with genera *Phoma* and *Fusarium* dominating, followed by *Curvularia*. Efficiency of the insecticidal treatment on head-bug incidence partially confirmed the critical role played by head-bugs in aggravating mold infection.

Keywords: Sorghum; Head-bugs; Grain molds

1. Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is the most important food crop in the savanna areas of West and Central Africa (WCA), notably in Nigeria, Burkina Faso, Mali and Niger. Average annual production during the 1992–1994 period were 6.10, 1.25, 0.73 and 0.42 million tons, respectively (FAO and ICRISAT, 1996).

Since the early 1980s, panicle-feeding bugs, particularly of the family "Miridae", have become key-pests of this cereal in all these countries (Doumbia and Bonzi, 1985; MacFarlane, 1989; Steck et al., 1989; Ratnadass and Ajayi, 1995). The list of heteropteran bugs other than mirids attacking sorghum is provided in Ratnadass and Ajayi (1995). The head-bug mirid complex is dominated by *Eurystylus oldi* Poppius. This species is now also being reported among major sorghum pests in Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Mali, Niger, Nigeria, Senegal and Togo (Ajayi and Ratnadass, 1998).

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Feeding and oviposition of these head-bugs on maturing sorghum grains result in severe quantitative and qualitative losses, particularly on improved compact-headed types of the caudatum race (Ratnadass et al., 1994a). Thus, these pests have become a major threat to increased sorghum production through adoption of improved cultivars, which, although better yielding, are more susceptible to head-bug damage than West African local loose-panicled guinea landraces (Ratnadass et al., 1994a, 1998).

It is important to recognize here the slight but significant differences in the biology and behavior of *E. oldi* and *Calocoris angustatus* Lethiery, the predominant mirid sorghum head pest in India (Henzell et al., 1997). The former causes damage by feeding and laying eggs in the developing caryopsis (Ratnadass et al., 1994b), while the latter causes damage by feeding on the grain, eggs being laid in the spikelets at anthesis. This difference leads to differences in sources and mechanisms of resistance to the two pests.

In some parts of West Africa, grain molds are rare in farmer's fields; however, in Nigeria, the disease occurs on farmer's fields because of the development of non-photoperiod sensitive sorghums of relative shorter duration than traditional photoperiod sensitive cultivars (King, 1973). Many of these cultivars have been widely adopted (Atala et al., 1998). Most local sorghum varieties in normal years develop the grain toward the end of the rainy season when high humidity is rare. However, grain molds effects are major problems with introduced compact-headed genotypes which mature during the relatively high rainfall period (Denis and Girard, 1980; Williams and Rao, 1981; Thomas, 1992).

Under these conditions, harvested grain yields are often reduced. More significantly, grain quality is adversely affected. The physical effects of molds on the grain may include discolored pericarp, softened and chalky endosperm, decreased grain size and density, sprouting, presence of mycotoxins, and altered composition of phenolic compounds (Dada, 1979; Salifu, 1981; Williams and Rao, 1981).

Grain mold is caused by non-specialized fungi (generally weak parasites or saprophytes) of several genera that are widely distributed in nature (Forbes et al., 1992; Marley and Ajayi, 1999; Bandyopadhyay et al., 2000). These include *Fusarium moniliforme* Sheld., *Curvularia lunata* (Wakker), *Phoma sorghina* (Sacc.), *Alternaria* and *Cladosporium* species.

While grain mold fungal infection may occur through seed-, soil- and air-borne inoculum followed by entry of the causal fungi under suitable conditions of high humidity (Bandyopadhyay et al., 1991), infection can be aided by biotic factors especially insects. Damage to sorghum grain by *C. angustatus* has been shown to be significantly correlated with grain mold severity (Sharma et al., 2000). Early studies in the sub-region showed that even on traditional cultivars ripening when the humidity was still high, grain could be attacked by fungi which invaded the seed directly through punctures made by sucking insects (Harris, 1962). Further indications were provided by Steck et al. (1989) and Sharma et al. (1992) who reported that bug-damaged grains showed greater severity of mold incidence.

The first clear evidence of this relationship in the West and Central Africa sub-region was provided by Ratnadass et al. (1995b). Experiments carried out by IER at Sotuba, Mali, in 1990 and 1991 clearly demonstrated the strong relationship between head-bugs and grain molds. This was confirmed in experiments conducted by IAR at Samaru, Nigeria, in 1995 and 1996 (Marley and Malgwi, 1999).

Some sources of resistance to either head-bugs or grain molds have been identified and used in breeding programs, and some of the factors associated with resistance elucidated (Sharma et al., 1994; Ratnadass et al., 1995a; Bandyopadhyay et al., 1988; Singh et al., 1995; Prasada Rao et al., 1995; Audilakshmi et al., 1999; Marley, 2001; Abdullahi and Marley, 2002).

A Regional Sorghum Head-Bug and Grain Mold Resistance Variety Trial was conducted in 1996 and 1997 under the auspices of the West and Central African Sorghum Research Network, in 15 and 13 research stations respectively across 10 countries participating in the network. The objectives of this study were to:

(i) update information on species/genera composition of sorghum panicle pest and disease complexes in the region;
(ii) to identify sorghum genotypes with reasonably high and stable resistance to either head-bugs or grain molds or both;
(iii) to elucidate the role of head-bugs in grain infection by molds.

2. Materials and methods

2.1. Trial design

The Regional Sorghum Head-Bug and Grain Mold Trial was conducted in 1996 and 1997 in 15 and 13 stations, respectively (Table 1).

The trial was planted on one date, in a split-plot design with three replications [main plots = insecticide treatment (T: insecticide-treated; NT: untreated); subplots = varieties], and conducted under natural infestation by head-bugs and infection by grain molds.

The twenty-one (21) varieties tested are provided in Table 2.

Table 1
Sowing date and local cultivars sown on the 16 stations where the WCASRN Regional Sorghum Head-Bug and Grain Mold Trial was conducted in 1996 and 1997

Country	Station	Longitude	Latitude	Sowing date		Local cultivar
				1996	1997	
Benin	Ina	02°44′E	09°58′N	01/07	22/07	Blanc de Karimana
Burkina Faso	Fada-Kouaré	0°10′E	12°05′N	27/07	—	Nongossomba
	Farako-bâ	04°20′W	11°06′N	—	16/07	Gnofing
Cameroon	Maroua	14°30′E	10°30′N	05/07	10/07	Damougari
CAR	Soumbé	17°36′E	06°29′N	22/07	—	Koï
	Poumbaïdi	16°25′E	07°05′N	—	21/07	IKI 164
Chad	Bébédjia	16°34′E	08°41′N	05/06	11/06	GOOP
Côte d'Ivoire	Ferkessédougou	05°12′W	09°36′N	29/07	05/08	NWS 63 D
Ghana	Nyankpala	0°58′W	09°25′N	11/07	11/07	Kapaala
Guinea	Bordo	09°18′W	10°23′N	19/07	09/07	Lombogbe
Mali	Cinzana	03°56′W	13°18′N	18/07	25/07	CSM 219^{E}
	Longorola	05°41′W	11°21′N	06/07	11/07	Locale Sikasso
	Samanko	08°07′W	12°32′N	10/07	09/07	CSM 388
Niger	Bengou	03°30′E	11°59′N	25/07	—	Local B.K.C.
Nigeria	Bagauda	08°30′E	11°40′N	08/07	07/07	Gaya early
	Samaru	07°38′E	11°11′N	26/07	17/07	NR 71182

Table 2
Sorghum varieties tested in the WCASRN Regional Sorghum Head-Bug and Grain Mold Trial in 1996 and 1997

Head-bug resistant varieties	Grain mold resistant varieties	Controls
1. ICSV 905	9. IS 30469C-1526-4	19. S 34 (head-bug and grain mold susceptible)
2. M 943208-1	10. IS 30469C-1518T-5	20. Naga White (regional standard check)
3. Malisor 84-7	11. IS 14384	21. Local check (cf. Table 1)
4. 87W810	12. IS 21658	
5. 91W113-2-1	13. CEM-328/1-1-1-2	
6. 82 Sel 1-Grain dur	14. CEM-328/3-3-1-1	
7. R 6078	15. CCGM-1/19-1-1	
8. 87-SB-F4-54-2	16. CGM-39/17-2-2	
	17. ICSV 1079	
	18. CEM-326/11-5-1-1	

Dates of sowing (DOS) and local cultivars at the different stations are given in Table 1. Individual plots generally consisted of two rows of 5 m each, with an inter-row spacing of 0.75 m. These dimensions were, however, slightly modified in some cases, depending on locally suggested recommendations.

Main plots were separated from each other by two rows of the fast growing, head-bug susceptible variety ICSV 197, which provided wind break/infestor rows, planted 2–3 weeks before test entries. Locally recommended cultural practices were followed, notably for fertilizer applications. Except for the panicle treatments that are part of the protocol, no insecticide was applied after the heading stage of the sorghum crop.

These insecticide sprays of cypermethrin EC (0.02%) or deltamethrin (0.014%) were applied at 900 l/ha depending on availability, at weekly intervals starting from complete anthesis, using hand trigger operated sprayers. Cypermethrin was used at Bagauda, Cinzana, Samaru, Maroua, Bordo, and Poumbaindi, while deltamethrin was used at Samanko, Longorola, Bebedjia and Ina. At Nyankpala, ULV lambda-cyalothrin was applied (24 g ha^{-1}).

2.2. Data collection

Cooperators were trained in data collection during a training workshop held in Mali during the 1996 cropping season (Ratnadass et al., 2001). Before harvest, five panicles randomly chosen on the second row were visually scored for head-bug damage, using a 1–9 rating scale where 1 = all grains fully developed, of which less than 10% show a few head-bug feeding punctures and 9 = more than 75% grains remaining undeveloped and barely visible outside the glumes (Ratnadass et al., 2002).

In addition, from the first row of each plot, another five randomly selected panicles were harvested 2 weeks

Table 3
Field data sets that could be included in the combined analysis of variance

Station	HB score			TGMR			% Germination			No. days 50% flowering			Midge score			Grain yield		
	96	97	96–97	96	97	96–97	96	97	96–97	96	97	96–97	96	97	96–97	96	97	96–97
Ina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
Farako-bâ	—	1	—	—	1	—	—	1	—	—	1	—	—	1	—	—	1	—
Maroua	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0
Soumbé	1	—	—	1	—	—	1	—	—	1	—	—	1	—	—	1	—	—
Poumbaïdi	—	1	—	—	1	—	—	1	—	—	1	—	—	1	—	—	1	—
Ferkessédougou	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nyankpala	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bordo	1	1	1	1	1	1	0	1	1	0	1	1	0	1	0	0	1	1
Cinzana	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Longorola	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Samanko	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bagauda	0	1	0	0	1	1	1	1	0	1	1	0	1	1	1	1	1	1
Samaru	1	1	1	1	1	1	0	1	1	0	1	0	0	1	0	0	1	0
Total	9	12	9	9	12	9	9	12	9	9	12	8	9	12	8	9	12	7

1996: all cultivars, including local, except ICSV 905, and also except R 6078, IS 21658 and Naga White for the last two parameters.
1997: all cultivars except local.
1996–1997: 14 cultivars, namely the 17 of 1996 plus IS 21658 and Naga White, and except local, M 943208-1, 91W113-2-1 and 82-Sel1-Grain dur, IS 30469C-1518T-5.
'1' indicates a data set included and '0' indicates a data set not available or omitted because of too many missing data.

after physiological maturity (black layer formation), threshed separately and threshed grains evaluated for mold, using the following 1–9 rating scale, based on the grain surface area colonized by fungi (1 = no mold, and 9 = more than 75% grain surface area molded). This method is referred to as TGMR (Threshed Grain Mold Rating: Bandyopadhyay and Mughogho, 1988). Germination tests in Petri dishes were carried out on 100 grains from each of the above harvests.

In 1996 at each locality threshed seeds from all varieties of each treatment were analyzed qualitatively for grain mold damage. At each locality, 42 samples (21 samples from insecticide-treated plots and 21 from non-treated plots), i.e. materials from all replicates of each treatment for each variety were bulked and 50 g taken as a sample. From each sample, the number of fungal colonies was determined by plating 200 grains randomly chosen in humid chambers. The resulting colonies of fungi were counted and recorded. Furthermore, 100 grains were plated on potato dextrose agar (PDA) amended with streptomycin (PDAS) to determine the spectrum of fungi colonizing grains internally and to determine the effects of head-bugs on fungal type (Marley and Malgwi, 1999).

2.3. Statistical analysis

Individual and combined analyses of variance were performed respectively on data from individual stations each year, and across stations for each year and over both years, using STATITCF software (ITCF, 1991). A factorial analysis of variance was done, with locality, year, treatment and cultivar as the main factors. Germination rates were analyzed after arcsine transformation. Sets of field observations that could be included in these combined analyses are given in Table 3. F statistics and Newman–Keuls tests were considered significant at $P < 0.01$ in the case of combined analyses, because of the large number of observations and the resulting ability to detect differences, and at $P < 0.05$ in the case of individual analyses.

3. Results

3.1. Entomofauna and mycoflora composition

Eurystylus oldi was reported as the dominant species in most localities. However, at Ina (Benin) in 1996, *E. oldi* was present, but *Dysdercus voelkeri* Schmidt (Heteroptera: Pyrrhocoridae) was dominant. At Bordo (Guinea) where *E. oldi*'s incidence was negligible, *D. voelkeri* and *Spilostethus* sp. (Heteroptera: Lygaeidae) were dominant, followed by *Creontiades pallidus* Rambur (Heteroptera: Miridae) and *Mirperus jaculus* (Thunberg) (Heteroptera: Alydidae). At Bebedjia (Chad) and Soumbé (CAR), *E. oldi*'s incidence was reported as minor, as compared to that of *Megacoelum apicale* Reuter (Heteroptera: Miridae), *M. jaculus*, *D. voelkeri* and *Spilostethus* sp. in the latter locality.

The analysis of data from observations on the grain mycoflora showed that at 12 stations, *Fusarium* and

Table 4
Complex of fungi observed on 19 entries of the WCASRN Regional Head-Bug and Grain Mold Trial (1996 rainy season)[a]

Fungus genus		*Fusarium*		*Phoma*			*Curvularia*		
Cultivars	T	NT	Mean	T	NT	Mean	T	NT	Mean
M 943208-1	20 (21)[b]	32 (33)	26 (27 abc[c])	30 (31)	35 (35)	32 (33 a)	15 (16)	15 (17)	15 (17 ab)
Malisor 84-7	26 (28)	32 (34)	29 (31 abc)	36 (35)	40 (38)	38 (36 a)	9 (12)	10 (14)	10 (13 ab)
87 W 810	29 (31)	31 (30)	30 (31 abc)	30 (30)	40 (39)	35 (35 a)	11 (14)	18 (20)	14 (17 ab)
91 W 113-2-1	25 (27)	30 (32)	27 (30 abc)	35 (34)	34 (35)	35 (35 a)	14 (18)	19 (22)	16 (20 ab)
82-Sel 1-Grain dur	26 (28)	29 (31)	27 (30 abc)	32 (33)	37 (36)	34 (35 a)	23 (24)	13 (17)	18 (21 ab)
R 6078	30 (32)	36 (36)	33 (34 a)	24 (26)	36 (36)	30 (31 a)	7 (11)	8 (12)	8 (11 b)
87-SB-F4-54-2	29 (29)	36 (37)	32 (33 ab)	27 (30)	33 (32)	30 (31 a)	16 (19)	16 (19)	16 (19 ab)
IS 30469C-1526-4	27(29)	39 (37)	33 (33 ab)	33 (32)	36 (37)	35 (34 a)	15 (17)	8 (11)	12 (14 ab)
IS 30469C-1518T-5	33 (34)	33 (32)	33 (33 ab)	24 (27)	34 (34)	29 (30 a)	15 (17)	16 (20)	16 (19 ab)
IS 14384	15 (18)	22 (25)	18 (22 c)	34 (35)	33 (34)	33 (35 a)	11 (13)	9 (12)	10 (13 ab)
IS 21658	25 (28)	32 (32)	28 (30 abc)	38 (36)	28 (30)	33 (33 a)	15 (18)	12 (15)	14 (17 ab)
CEM 328/1-1-1-2	32 (33)	28 (28)	30 (31 abc)	29 (29)	32 (32)	30 (30 a)	16 (19)	22 (25)	19 (22 a)
CEM 328/3-3-1-1	32 (33)	30 (30)	31 (32 ab)	32 (32)	39 (37)	35 (34 a)	10 (13)	14 (17)	12 (15 ab)
CGM 1/19-1-1	32 (33)	31 (32)	31 (33 ab)	24 (26)	32 (32)	28 (29 a)	13 (16)	16 (19)	15 (17 ab)
CCGM 39/17-2-2	19 (22)	27 (29)	23 (25 abc)	36 (36)	34 (34)	35 (35 a)	15 (16)	11 (15)	13 (15 ab)
ICSV 1079	31(32)	36 (36)	33 (34 a)	29 (31)	30 (31)	29 (31 a)	15 (16)	16 (18)	15 (16 ab)
CEM 326/11-5-1-1	24 (26)	26 (27)	25 (27 abc)	37 (35)	34 (33)	36 (34 a)	17 (21)	16 (20)	17 (20 ab)
S 34	30 (31)	24 (27)	27 (29 abc)	25 (25)	36 (36)	31 (30 a)	15 (17)	18 (20)	17 (18 ab)
Naga White	21 (23)	23 (23)	22 (23 bc)	29 (29)	42 (40)	35 (35 a)	17 (19)	19 (21)	18 (20 ab)
Mean	26 (28 a)	30 (31 a)	28 (30)	31(31 a)	35 (35 a)	33 (33)	14 (17 a)	15 (18a)	14 (17)
F-test[c]									
F1 (treatments)			(ns)			(ns)			(ns)
F2 (cultivars)			(***)			(ns)			(**)
F1 × F2			(ns)			(ns)			(ns)
F3 (locality) × F1			(***)			(***)			(***)
F3 × F2			(***)			(***)			(ns)
F3 × F1 × F2			(**)			(***)			(ns)

[a] Split-plot designs with 3 reps: T = insecticide-treated; NT = untreated. Combined analysis of the mycoflora data from 8 stations: Samanko, Longorola and Cinzana (Mali); Bagauda and Samaru (Nigeria); Bordo (Guinea); Maroua (Cameroon); Soumbé (CAR).
[b] Values after arcsine transformation are given in parentheses.
[c] Signification at the *F*-test: **, *** = significant respectively at the 1% and 0.1% levels; ns = not significant at the 5% level. Means within lines or columns followed by the same letter are not statistically different at the 5% level by the Newman–Keuls method.

Phoma genera were dominant (each infesting about 30% of the grains), followed by *Curvularia* (18%), while the incidence of *Penicillium* was negligible. The combined analysis of data from eight stations (Table 4) showed that:

- insecticide application did not significantly affect the presence of any of the three fungal genera;
- there were highly significant differences between the varieties, except for *Phoma*, and interactions between treatments, varieties and sites were highly significant, except for *Curvularia*;
- IS 14384 and Nagawhite were less infected by *Fusarium*, whereas R 6078 and IS 14384 were less infected by *Curvularia*.

3.2. Agronomic/biological parameters

For the combined analysis of 1996 and 1997 data, the effect of cultivar was significant for all parameters, while that of treatment was significant only for head-bug damage score (Table 5). The effect of year was significant for none of the parameters. The effect of locality was significant for head-bug and grain mold damage scores.

For head-bug and grain mold damage scores, there were significant interactions between cultivar and locality, and between locality and year. For germination rate, the same interactions were significant, as well as the interaction between cultivar and year.

Only the three-way cultivar-by-locality-by-year, and the treatment-by-locality-by-year interactions were significant for head-bug and grain mold damage scores, and germination rate.

Taking the 1996 and 1997 data sets separately, the effect of cultivar was significant for all parameters, while that of treatment was significant only for head-bug score. The three-way interaction was significant only for germination rate in 1996. In 1996, for this parameter, there were also significant interactions between

Table 5
Mean squares (MS) and their significance[a], from combined analysis of variance of head-bug visual score, grain mold visual score and germination rate

Source of variation	DF	HB score MS	TGMR MS	% Germination[b] MS
Total	503	3.64	1.65	383.11
F3 (locality)	8	24.35 (*)	74.82 (*)	10785.19 (ns)
F4 (year)	1	1.14 (ns)	3.86 (ns)	526.33 (ns)
F1 (treatment)	1	230.80 (*)	140.95 (ns)	13589.81 (ns)
F2 (cultivar)	13	4.31 (*)	23.83 (*)	774.68 (*)
F3 × F4	8	3.24 (*)	8.70 (*)	3289.98 (*)
F3 × F1	8	8.26 (ns)	17.58 (ns)	1069.77 (ns)
F3 × F2	104	0.97 (*)	2.22 (*)	180.36 (*)
F4 × F1	1	0.98 (ns)	0.02 (ns)	3.56 (ns)
F4 × F2	13	0.53 (ns)	0.89 (ns)	162.81 (*)
F1 × F2	13	1.21 (ns)	1.52 (ns)	84.88 (ns)
F3 × F4 × F1	8	1.87 (*)	5.73 (*)	807.63 (*)
F3 × F4 × F2	104	0.42 (*)	1.20 (*)	105.97 (*)
F3 × F1 × F2	104	0.35 (ns)	0.70 (ns)	35.53 (ns)
F4 × F1 × F2	13	0.23 (ns)	0.50 (ns)	56.48 (ns)
F3 × F4 × F1 × F2	104	0.30 (ns)	0.54 (ns)	33.32 (ns)

[a] Signification at the *F*-test: * = significant at the 1% levels; ns = not significant at the 1% level.
[b] Data analyzed after arcsine transformation.

treatment and locality and between cultivar and locality. There were significant interactions between treatment and cultivar, between treatment and locality, and between cultivar and locality for head-bug and grain mold damage scores.

In 1997 (individual year's data set not provided), there were significant interactions between treatment and locality and between cultivar and locality for head-bug damage score, grain mold visual score and germination rate. The effect of insecticide treatment on head-bug damage score was significant at respectively 9 and 5 stations out of 11 in 1996 (Table 6) and 1997 (Table 7). Genotypic effect was significant at most localities (namely all localities except Ghana in both years, and Guinea in 1996 and Cameroon in 1997). Significant interactions between cultivar and locality translated slight variations in the rankings of cultivars from one locality to another, except for IS 14384 and CCGM 39/17-2-2, which consistently exhibited very low head-bug damage (Table 8).

Tables 9 and 10 show that for grain mold visual score, there was a significant genotypic effect at most localities (namely all localities except Ghana in both years, and Cameroon and Nigeria in 1997). Significant interactions between cultivar and locality translated slight variations in the rankings from one locality to another. However, at all localities, S 34, 82-Sel-1-Grain dur and 87-SB-F4-54-2 were consistently the most susceptible cultivars, while IS 14384, CCGM 39/17-2-2 and CCGM 1/19-1-1 were the most resistant, all the other cultivars being intermediate. R 6078, and to a lesser extent 82-Sel-1-Grain dur and 87-SB-F4-54-2 in 1997, had a high score in all stations, located to the south. The effect of insecticide treatment on grain mold damage score was significant at respectively 5 and 4 stations out of 11 in 1996 and 1997.

The effect of insecticide treatment on germination rate was significant at six stations out of 11 in 1996 (Table 11) compared to only three out of 10 in 1997 (Table 12). Genotypic effect was significant both years at all localities except Nyankpala and Samaru. The best cultivar was CEM 326/11-5-1-1, followed by ICSV 1079 and CCGM 1/19-1-1.

4. Discussion

Although the head-bug damage levels were generally rather low during the 2 years of experiment, two cultivars exhibited consistently high levels of resistance over years and localities, both to head-bugs and grain molds, namely IS 14384 and CGM 39/17-2-2. Conversely, S 34 was particularly susceptible to both biotic stresses.

IS 14384 was reported as grain mold resistant by Bandyopadhyay et al. (1988). This guinea cultivar from Zimbabwe, although red-grained, has no testa and its tannin content is low. Its grain is also hard (Jambunathan et al., 1992).

CGM 39/17-2-2 is a progeny derived from a cross between the guinea cultivar no. 87-31 in the Senegalese collection and a guinea landrace from Senegal (no. 62-15 in the Senegalese collection, and no. 1058 in the Gervex CIRAD collection) (Chantereau and Luce, pers. comm., 1999).

Table 6
Head-bug damage rating observed on the 21 entries of the WCASRN Regional Sorghum Head-Bug and Grain Mold Trial in 11 localities in 1996

Station cultivar	Ina (Benin)	Maroua (Cameroon)	Soumbé (CAR)	Bébédjia (Chad)	Ferkessé-dougou (CI)	Nyankpala (Ghana)	Bordo (Guinea)	Cinzana (Mali)	Longorola (Mali)	Samanko (Mali)	Samaru (Nigeria)
ICSV 905	2.5 ab BCD	2.8 ab BC	1.5 de CD	4.7 abcde A	5.2 abc A	1.8 a CD	—	1.5 c CD	3.0 a BC	-	1.3 efg D
M 943208-1	3.3 ab BC	3.3 ab BC	3.0 b BCD	5.8 ab A	4.4 abcd AB	1.7 a DE	—	1.3 c E	2.3 abc CDE	3.0 b BCD	1.5 defg DE
Malisor 84-7	2.8 ab CD	1.3 b DE	2.5 bc CD	6.0 ab A	4.4 abcd B	1.7 a CDE	1.0 a E	1.5 c DE	2.0 abc CDE	2.0 bc CDE	1.5 defg DE
87 W 810	3.0 ab BC	3.5 ab ABC	2.2 cd CD	4.3 bcdef AB	4.7 abcd A	1.7 a CD	1.0 a D	1.5 c CD	2.7 ab CD	2.3 bc CD	2.0 cdefg CD
91 W 113-2-1	2.8 ab CD	3.5 ab BC	1.7 cde D	5.2 abcd A	4.7 abcd AB	1.7 a D	1.7 a D	1.8 bc D	—	3.0 b CD	1.5 defg D
82-Sel 1-Grain dur	3.0 ab CD	1.5 b DE	1.0 e E	6.3 a A	4.0 abcde BC	2.0 a DE	1.0 a E	2.2 abc DE	1.0 d E	1.5 c DE	2.0 cdefg DE
R 6078	3.0 ab C	2.3 b CD	1.5 de CD	6.0 ab A	5.2 ab AB	1.8 a CD	-	1.3 c D	1.8 bcd CD	—	1.3 efg D
87-SB-F4-54-2	3.0 ab BC	2.7 ab BCD	1.0 e D	5.8 ab A	3.5 cde B	1.8 a CD	1.2 a D	1.3 c D	1.8 bcd CD	2.7 b BCD	2.5 bcde BCD
IS 30469C-1526-4	3.0 ab BC	3.7 ab B	2.0 cde C	—	5.5 a A	1.7 a C	1.5 a C	3.5 a B	2.5 abc BC	3.0 b BC	3.3 ab BC
IS 30469C-1518T-5	3.7 a AB	3.7 ab AB	1.2 e C	—	4.5 abcd A	2.2 a BC	1.7 a C	—	2.5 abc BC	2.7 b BC	1.7 defg C
IS 14384	2.0 b A	1.2 b A	1.2 e A	1.3 i A	1.4 f A	1.3 a A	1.5 a A	1.0 c A	1.5 cd A	2.0 bc A	1.2 fg A
IS 21658	2.2 ab ABC	3.3 ab AB	1.3 de C	2.5 ghi ABC	3.6 bcde A	2.0 a BC	1.3 a C	2.7 abc ABC	1.7 bcd BC	2.2 bc ABC	2.0 cdefg BC
CEM 328/1-1-1-2	2.5 ab ABC	2.7ab AB	1.8 cde BC	2.2 hi ABC	3.4 de A	1.8 a BC	1.0 a C	2.7 abc AB	2.5 abc ABC	2.7 b AB	3.0 abc AB
CEM 328/3-3-1-1	2.7 ab CD	5.3 a A	1.0 e E	3.8 cdefgh ABC	4.7 abcd AB	2.0 a DE	1.8 a DE	2.2 abc DE	2.5 abc CDE	3.0 b CD	2.3 bcde DE
CCGM 1/19-1-1	2.2 ab BC	1.3 b C	3.2 b AB	3.5 defgh AB	3.8 abcde A	2.0 a BC	1.5 a C	3.7 a A	2.7 ab ABC	2.5 b ABC	1.2 fg C
CCGM 39/17-2-2	2.0 b AB	1.3 b AB	1.0 e B	2.8 fgh A	2.4 ef AB	1.7 a AB	1.3 a AB	1.7 bc AB	1.8 bcd AB	2.0 bc AB	1.0 g B
ICSV 1079	3.2 ab BCD	3.7 ab BC	2.5 bc CD	5.3 abc A	4.7 abcd AB	1.8 a D	1.7 a D	3.5 a BC	2.5 abc CD	2.8 b CD	2.8 abc CD
CEM 326/11-5-1-1	2.8ab ABC	3.2 ab AB	1.3 de C	4.2 bcdefgh A	2.7 ef ABC	1.7 a BC	1.0 a C	3.2 ab AB	2.5 abc BC	2.7 b ABC	2.2 cdefg BC
S 34	3.3 ab BCD	2.8 ab BCD	2.0 cde D	5.8 ab A	4.3 abcd AB	1.8 a D	2.5 a CD	3.2 ab BCD	2.2 abc CD	3.8 a BC	3.8 a BC
Naga White	2.7 ab ABC	1.3 b D	1.5 de CD	3.5 defgh AB	3.9 abcde A	1.7 a CD	1.0 a D	1.2 c D	2.7 ab ABC	2.7 b ABC	3.8 a A
Local	1.8 b CD	1.0 b D	4.3 a A	3.3 efgh AB	2.6 ef BC	1.5 a CD	1.0 a D	1.8 bc CD	—	2.0 bcBCD	2.7 bcd BC

Means within columns followed by the same low case letters are not significantly different, Newman–Keuls test, $P = 0.05$.
Means within rows followed by the same upper case letters are not significantly different, Newman–Keuls test, $P = 0.05$.

Table 7
Head-bug damage rating observed on the 21 entries of the WCASRN Regional Sorghum Head-Bug and Grain Mold Trial in 12 localities in 1997

Station cultivar	Ina	Farako-bâ	Maroua	Poumbaïdi	Bébédjia	Ferkessédougou	Nyankpala	Bordo	Cinzana	Longorola	Samanko	Bagauda
ICSV 905	1.0 c D	5.3 a A	2.5 a CD	1.4 bcde CDE	1.0 c D	4.1 b AB	1.3 a D	1.0 c D	1.2 h D	2.3 b CD	2.9 ab BC	1.5 cdef CDE
M 943208-1	2.2 abc BCD	4.8 ab A	1.7 a CD	1.5 bcde CD	3.7 abc AB	4.5 b A	1.7 a CD	1.5 bc CD	1.2 h D	2.7 ab BC	2.1 abc CD	1.5 cdef CDE
Malisor 84-7	3.0 a AB	2.7 cdef B	1.7 a BC	1.7 abcde BC	—	4.5 b A	2.0 a BC	1.5 bc C	1.7 fgh BC	2.4 ab B	2.1 abc BC	1.2 ef C
87 W 810	2.2 abc B	4.0 bc A	1.7 a B	1.5 bcde B	—	4.3 b A	1.7 a B	1.8 bc B	1.3 gh B	2.4 ab B	2.8 ab AB	1.3 def B
91 W 113-2-1	1.7 bc C	3.5 bcde AB	2.3 a BC	2.0 abc B	3.3 abc AB	4.0 b A	1.8 a BC	1.8 bc BC	2.0 efgh BC	—	3.2 a AB	1.3 def C
82-Sel 1-Grain dur	2.2 abc AB	3.5 bcde A	1.5 a B	1.5 bcde B	1.8 c B	2.9 b AB	2.0 a AB	2.0 bc AB	2.3 cdefgh AB	2.7 ab AB	1.9 bc B	2.2 bcde AB
R 6078	2.2 abc BC	2.8 cde B	1.0 a C	2.2 a BC	—	5.9 a A	1.8 a BC	1.8 bc BC	1.5 gh BC	3.1 ab B	2.5 abc BC	1.5 cdef BC
87-SB-F4-54-2	1.8 abc BC	3.5 bcde AB	1.3 a C	1.6 bcde BC	—	3.8 b A	2.0 a B	1.0 c C	1.3 gh C	3.0 ab AB	1.8 bc BC	2.0 bcdef C
IS 30469C-1526-4	2.0 abc BC	3.5 bcde AB	1.2 a C	1.6 abcde C	4.5 abc A	3.3 b AB	2.2 a B	1.5 bc C	3.5 abc AB	3.2 ab AB	1.6 c C	2.3 abcd BC
IS 30469C-1518T-5	2.7 ab AB	2.7 cdef AB	3.2 a AB	1.8 abcd B	—	4.1 b A	2.0 a B	1.5 bc B	4.0 a A	2.4 ab B	2.8 ab AB	1.5 cdef B
IS 14384	1.0 c B	1.0 g B	1.3 a B	1.0 e B	2.5 bc AB	3.3 b A	1.7 a B	1.2 bc B	1.0 h B	2.5 ab AB	2.1 abc AB	1.5 cdef B
IS 21658	2.2 abc AB	2.2 defg AB	2.3 a AB	1.4 bcde B	—	3.5 b A	1.8 a B	1.5 bc B	2.3 cdefgh AB	2.4 ab AB	2.2 abc AB	2.2 bcde AB
CEM 328/1-1-1-2	2.0 abc BC	2.5 cdef BC	2.3 a BC	1.7 abcde C	5.7 ab A	3.5 b B	1.8 a C	2.0 bc BC	2.7 bcdefg BC	2.5 ab BC	2.4 abc BC	2.2 bcde BC
CEM 328/3-3-1-1	2.2 abc BC	2.5 cdef BC	2.7 a BC	1.5 bcde C	6.7 a A	3.5 b B	1.5 a C	2.3 b BC	2.2 defgh BC	2.5 ab BC	2.6 abc BC	2.8 ab BC
CCGM 1/19-1-1	1.0 c C	3.5 bcde AB	1.0 a C	1.2 de C	3.3 abc AB	4.4 b A	2.2 a BC	2.2 bc BC	3.8 ab AB	3.3 a AB	2.8 ab B	1.5 cdef BC
CCGM 39/17-2-2	1.0 c B	2.7 cdef AB	1.2 a B	1.0 e B	—	3.2 b A	1.5 a B	1.2 bc B	1.5 gh B	2.1 b AB	2.2 abc AB	1.0 f B
ICSV 1079	1.7 bc B	2.3 cdefg B	2.5 a B	1.7 abcde B	—	4.2 b A	2.0 a B	1.3 bc B	2.8 abcdef AB	3.1 ab AB	2.5 abc B	1.8 cdef B
CEM 326/11-5-1-1	1.8 abc AB	2.7 cdef AB	2.0 a AB	1.3 cde B	—	3.2 b A	1.7 a AB	1.0 c B	3.2 abcde A	2.3 ab AB	2.1 abc AB	2.3 abcd AB
S 34	2.5 ab B	3.8 bcd AB	3.0 a AB	2.1 ab B	—	4.1 b A	1.5 a B	3.0 a AB	3.3 abcd AB	—	3.1 a AB	3.2 a AB
Naga White	1.5 bc B	1.2 fg B	2.0 a B	1.7 abcde B	4.0 abc A	3.3 b AB	1.8 a B	1.0 c B	1.0 h B	2.8 ab AB	2.4 abc B	2.5 abc AB
Local	1.0 c B	2.0 efg B	1.2 a B	1.2 de B	2.8 bc AB	3.7 b A	1.8 a B	1.0 c B	1.5 gh B	2.8 ab AB	1.9 bc B	1.8 bcdef B

Means within columns followed by the same low case letters are not significantly different, Newman–Keuls test, $P = 0.05$.
Means within rows followed by the same upper case letters are not significantly different, Newman–Keuls test, $P = 0.05$.

Table 8
Effect of insecticidal treatment on head-bug visual scores on 14 cultivars of the WCASRN Regional Sorghum Head-Bug and Grain Mold Trial in 1996 and 1997

Treatment cultivars	Mean insecticide-treated 1996-1997	Mean control 1996–1997	Mean
Malisor 84-7	1.6	2.8	2.1 abc
87 W 810	1.6	3.0	2.3 ab
87-SB-F4-54-2	1.6	2.6	2.1 bcd
IS 30469C-1526-4	1.8	3.4	2.6 ab
IS 14384	1.3	2.0	1.6 d
IS 21658	1.6	3.1	2.3 ab
CEM 328/1-1-1-2	1.6	3.1	2.3 ab
CEM 328/3-3-1-1	1.7	3.7	2.7 ab
CCGM 1/19-1-1	1.7	3.1	2.4 ab
CCGM 39/17-2-2	1.2	2.2	1.7 cd
ICSV 1079	1.9	3.4	2.6 ab
CEM 326/11-5-1-1	1.6	3.0	2.3 ab
S 34	1.8	3.7	2.7 a
Naga White	1.6	2.5	2.0 bcd
Combined	1.6 b	2.9 a	3.3

Means within right column and bottom row followed by the same letters are not significantly different, Newman–Keuls test, $P = 0.01$.

Although Singh et al. (1995) reported white-grained sorghum cultivars IS 30469C-1526-4 and IS 30469C-1518T-5 as reasonably resistant to grain mold in India, this was not confirmed in this study, which however supported other observations in Mali (Bandyopadhyay and Sissoko, unpublished data).

CEM 326/11-5-1-1, also known as CIRAD 406 or ICSV 2001, is a pure line variety developed by a pedigree selection from a cross between IS 9225 (a Ugandan guinea landrace with high grain quality and anthracnose resistance), and F2-20 (an improved Senegalese caudatum line) (Chantereau et al., 1997). CEM 328/1-1-1-2 and CEM 328/3-3-1-1 are two progenies of a cross between F2-20 and I-24 (a high yielding caudatum cultivar from Senegal) (Chantereau and Luce, pers. comm., 1999).

In terms of germination, the best cultivar was CEM 326/11-5-1-1, followed by ICSV 1079 and CCGM 1/19-1-1, a progeny derived from a cross between a sterile caudatum panicle taken from a ms3 composite, and a guinea landrace from Southern Africa (no. 50-8 in the Senegalese collection, and no. 3 in the Gervex CIRAD collection (Chantereau and Luce, pers. comm., 1999).

We also showed efficient insecticidal treatment on head-bug damage. The effect was also significant on grain mold incidence in five and four localities respectively out of 11 in 1996 and 1997, thus partially confirming the critical role played by head-bugs as factors aggravating mold infection. In this respect, these results complement those obtained by IER at Sotuba in 1990 and 1991, where plastic bag protection could have affected exposure to grain mold inoculum, which was not the case with insecticide protection.

Work at Samaru, Nigeria, in the 1995 and 1996 wet seasons by Marley and Malgwi (1999) has also shown the influence of head-bugs on grain molds. Results showed clearly that bug damage increased grain mold infection and the number of fungal colonies associated with the grain. However, in some cases, grain mold incidence was high even with low head-bug damage, following insecticidal protection, or on head-bug resistant cultivars such as 87-SB-F4-54-2, Malisor 84-7 and 87W810.

One should note that although sorghum grain mycoflora varied little from one site to another (with genera *Phoma* and *Fusarium* dominating, followed by *Curvularia*) there were large variations in the specific composition of the head-bug entomofauna across sites. Notably, *E. oldi* was not the dominant species on all stations. This resulted in a mixed reaction of some cultivars recognized as head-bug resistant such as Malisor 84-7. This is susceptible to heteropteran bugs such as *Dysdercus* or *Spilostethus* (Ratnadass, unpublished data) which were the dominant species on some stations.

In this respect, our results are not necessarily conflicting with those of earlier studies since there was no report so far on the incidence of *E. oldi* from Guinea (Ajayi and Ratnadass, 1998; Ajayi et al., 2001). On the other hand, reports from Benin concerned only Goubafari and Guéné research stations, while those from Chad concerned only eight farmers' fields (Ajayi et al., 2001). Conversely, this pest is reported here for the first time from Ghana, since it was not observed in the only earlier detailed survey, conducted at Nyankpala in the mid-1970s (Agyen-Sampong, 1978). Similarly, although the insect was known from the Central African Republic (Stonedahl, 1995), this is also the first report of its occurrence as a sorghum pest in this country.

Lastly, factors associated with genotypic resistance to both stresses, particularly on IS 14384 and CCGM 39/17-2-2, should be further investigated.

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Table 9
Grain mold rating observed on the 21 entries of the WCASRN Regional Sorghum Head-Bug and Grain Mold Trial in 11 localities in 1996

Station cultivar	Ina	Maroua	Soumbé	Bébédjia	Ferkessédougou	Nyankpala	Bordo	Cinzana	Longorola	Samanko	Samaru
ICSV 905	3,0 abcde BC	1,3 de D	4,3 cd AB	5,5 b A	4,8 abcd A	2.3 a ABCD	—	3,0 de BC	3.0 ef BC	—	1,3 d D
M 943208-1	4,5 ab AB	4,5 b AB	3,5 def BC	4,7 bcd AB	4,7 abcd AB	5.2 a A	—	2,3 defg CD	3.3 def BC	2.2 abcde CD	4,0 abcd AB
Malisor 84-7	3,5 abcd ABC	3,0 bcde BC	2,7 efgh CD	1,8 cd CD	4,3 abcd AB	4.2 a AB	3,2 abc BC	5,0 b A	3.3 def BC	2.3 abcde CD	2,2 cd CD
87 W 810	4,0 ab ABC	4,5 b AB	3,3 defg BC	3,7 bcd AB	5,0 abc A	4.3 a AB	2,5 bc CD	3,3 cd BC	3.0 ef BC	1.5 cde D	3,0 bcd BCD
91 W 113-2-1	4,5 ab B	2,8 bcde CDE	3,0 efg CD	8,0 a A	4,2 abcd BC	5.0 a B	1,8 bc DE	3,2 cde CD		1.8 bcde DE	2,2 cd DE
82-Sel 1-Grain dur	4,5 ab BC	7,0 a A	5,0 bc B	1,5 d E	4,8 abcd B	5.0 a B	—	4,8 b B	5.5 bc AB	3.2 a CD	4,3 abcd BC
R 6078	4,7 ab AB	2,5 bcde BC	2,0 ghi C	2,2 cd BC	5,2 abc A	4.3 a AB	2,0 bc C	4,0 c AB	4.2 de AB	—	4,5 abcd AB
87-SB-F4-54-2	4,3 ab BC	2,5 bcde D	5,8 ab AB	3,3 bcd CD	4,3 abcd BC	6.2 a A	5,3 a AB	5,8 a AB	6.0 b A	3.0 ab CD	6,0 ab A
IS 30469C-1526-4	4,8 ab AB	3,3 bcd BC	2,8 efg C	2,8 bcd C	6,0 a A	4.2 a B	2,3 bc C	2,3 defg C	3.3 def BC	2.0 abcde C	2,7 cd C
IS 30469C-1518T-5	5,2 a A	3,5 bc BC	2,8 efg C	2,3 bcd C	4,8 abcd A	4.5 a AB	2,0 bc C	—	3.2 ef BC	2.3 abcd C	3,8 abcd BC
IS 14384	1,5 e D	1,2 de D	1,3 i D	4,3 bcd AB	3,2 d BC	5.0 a A	1,2 c D	1,7 fgh CD	1.2 g D		1,7 d CD
IS 21658	3,0 abcde B	1,8 cde C	2,2 fghi BC	3,7 bcd AB	5,2 abc A	3.3 a B	1,3 bc C	1,5 fgh C	3.2 ef B	2.3 abcd BC	3,8 abcd AB
CEM 328/1-1-1-2	4,5 ab AB	2,0 cde CD	3,8 de AB	3,3 bcd BC	5,0 abc A	5.3 a A	2,3 bc CD	2,0 efgh CD	2.5 f CD	1.5 cde D	3,2 bcd BC
CEM 328/3-3-1-1	4,7 ab AB	3,3 bcd BC	5,2 abc A	4,8 bc AB	5,5 abc A	4.5 a AB	3,2 abc BC	2,0 efgh CD	3.0 ef CD	1.7 cde D	2,8 bcd CD
CCGM 1/19-1-1	2,0 cde CD	1,2 de D	1,5 hi CD	2,8 bcd BC	3,8 cd AB	4.2 a AB	1,0 c D	1,2 gh D	2.0 fg CD	1.0 e D	4,7 abcd A
CCGM 39/17-2-2	1,3 e C	1,0 e C	1,5 hi C	4,2 bcd A	3,8 cd A	3.5 a AB	1,7 bc C	1,0 h C	2.3 fBC	1.0 e C	2,0 cd BC
ICSV 1079	4,2 ab B	2,7 bcde BC	3,0 efg BC	2,3 bcd C	5,8 ab A	4.2 a B	1,5 bc CD	2,2efgh C	2.7 ef BC	1.3 de D	4,3 abcd AB
CEM 326/11-5-1-1	3,8 abc BC	2,5 bcde CD	3,5 def BC	3,5 bcd BC	4,0 bcd BC	5.7 a A	3,0 abc C	2,7 def CD	2.7 ef CD	1.2 de D	2,2 cd D
S 34	5,2 a BC	3,2 bcd DE	6,2 a AB	7,5 a A	5,2 abc BC	4.5 a CD	4,3 ab CD	6,2 a AB	7.5 a A	2.0 abcde E	5,3 abc BC
Naga White	1,7 de DE	3,2 bcd CD	3,3 defg CD	5,0 bc AB	4,2 abcd BC	6.0 a A	2,5 bc DE	1,3 gh E	4.7 cd AB	2.7 abc CD	5,2 abc AB
Local	2,8 bcde BC	1,3 de CD	2,5 efghi BC	2,2 cd CD	3,2 d BC	6.5 a A	1,0 c D	1,0 h D	—	1.8 bcde CD	6,5 a A

Means within columns followed by the same low case letters are not significantly different, Newman–Keuls test, $P = 0.05$.
Means within rows followed by the same upper case letters are not significantly different, Newman–Keuls test, $P = 0.05$.

Table 10
Grain mold rating observed on the 21 entries of the WCASRN Regional Sorghum Head-Bug and Grain Mold Trial in 13 localities in 1997

Station cultivar	Ina	Farako-bâ	Maroua	Poumbaïdi	Bébédjia	Ferkessédougou	Nyankpala	Bordo	Cinzana	Longorola	Samanko	Bagauda	Samaru
ICSV 905	2,0 bcd D	1,7 bc D	1,0 a D	6,7 ab A	4,3 bc BC	5,2 bc B	6,7 a A	3,5 abc C	3,5 c C	3.2 c C	1.2 fg D	2.0 a D	3,8 a C
M 943208-1	2,2 bcd EF	1,8 abc F	2,2 a EF	5,0 abc BC	3,3 bc DE	5,7 abc AB	6,7 a A	2,5 bc EF	1,2 d G	3.7 bc D	2.2 cde EF	2.3 a EF	4,2 a CD
Malisor 84-7	2,8 bcd DE	2,0 abc E	2,2 a E	4,8 abc BC	—	5,8 abc AB	6,3 a A	3,8 abc CD	3,7 c CD	4.0 bc C	2.5 cd EF	2.5 a EF	2,8 a DE
87 W 810	1,5 cd F	1,7 bc F	1,3 a F	7,3 ab A	—	5,8 abc B	5,3 a BC	2,2 bc FG	4,2 bc CD	3.8 ab CDE	2.1 cde F	2.0 a F	4,7 a BCD
91 W 113-2-1	1,7 cd D	1,5 bc D	1,8 a D	5,0 abc AB	4,5 bc BC	5,2 bc AB	6,0 a A	4,2 abc BC	1,7 d D	6.0 ab A	1.7 cdefg D	1.8 a D	3,5 a C
82-Sel 1-Grain dur	2,8 bcd CD	2,0 abc D	1,7 a D	7,7 ab A	3,2 bc CD	6,3 ab AB	6,0 a B	2,5 bc CD	4,0 bc C	6.0 ab B	3.2 b CD	3.2 a CD	3,7 a C
R 6078	5,7 a AB	2,2 abc DE	1,0 a E	6,7 ab A	5,7 ab AB	6,8 ab A	6,7 a A	5,3 ab AB	3,5 c CD	2.5 c DE	1.9 cdef E	2.2 a DE	4,8 a BC
87-SB-F4-54-2	2,7 bcd DE	2,7 ab DE	1,5 a E	—	—	6,5 ab AB	6,5 a AB	3,0 bc DE	5,2 a BC	7.2 a A	3.6 ab CD	2.3 a DE	4,5 a BC
IS 30469C-1526-4	3,0 bcd EFG	2,7 ab EFG	1,7 a G	7,7 ab A	5,2 ab CD	5,8 abc BC	6,7 a ABC	3,7 abc DEF	1,8 d G	7.7 a A	3.6 ab EF	2.3 a FG	4,0 a DE
IS 30469C-1518T-5	1,8 bcd E	2,0 abc DE	2,7 a DE	5,0 abc ABC	—	5,8 abc AB	6,3 a A	3,5 abc CD	1,8 d EF	2.8 c DE	2.6 c DE	1.8 a E	3,3 a CD
IS 14384	1,0 d E	1,0 c E	1,5 a DE	3,3 bc ABC	2,0 c CDE	4,3 c AB	2,8 b BCD	1,5 c DE	1,3 d E	3.0 c BC	1.5 efg DE	2.3 a CDE	4,7 a A
IS 21658	3,7 bc B	2,0 abc BC	2,0 a BC	1,7 c C	-	5,7 abc A	5,5 a A	3,5 abc B	1,3 d CD	3.8 bc B	2.1 cde BC	2.5 a BC	2,8 a BC
CEM 328/1-1-1-2	1,8 bcd C	1,5 bc C	1,5 a C	5,8 ab A	5,6 ab A	6,2 ab A	5,2 a A	2,8 bc B	1,3 d C	3.3 c B	2.0 cdef BC	2.0 a BC	3,5 a B
CEM 328/3-3-1-1	2,0 bcd EF	1,8 abc EF	1,7 a EF	6,2 ab AB	7,3 a A	5,2 bc BC	6,2 a AB	3,3 abc DE	1,5 d F	3.2 c DE	1.8 cdefg EF	2.3 a EF	3,8 a CD
CCGM 1/19-1-1	1,5 cd C	3,0 a AB	1,0 a C	4,3 abc A	3,5 bc ABC	4,2 c A	2,7 b BC	2,0 c C	1,2 d C	2.2 c BC	1.9 cdef C	3.8 a AB	4,5 a A
CCGM 39/17-2-2	1,5 cd DE	1,2 c DE	1,2 a DE	4,3 abc AB	—	5,2 bc A	3,2 b BC	2,2 bc CD	1,3 d DE	2.0 c CD	1.7 defg CD	3.0 a BCD	3,7 a ABC
ICSV 1079	2,5 bcd DE	1,8 abc E	2,7 a CDE	3,5 abc CD	—	5,8 abc A	5,5 a AB	3,2 abc CD	1,8 d E	2.5 c DE	2.3 cde DE	3.0 a CD	4,2 a BC
CEM 326/11-5-1-1	1,5 cd B	1,3 c B	1,7 a B	5,0 abc A	—	5,5 abc A	5,5 a A	2,2 bc B	1,5 d B	2.8 c B	1.9 cdef B	1.3 a B	5,5 a A
S 34	4,0 b DE	2,7 ab EF	3,0 EF	7,8 a A	—	7,0 a AB	6,7 a AB	6,0 a BC	4,7 ab CD	8.0 a A	2.5 cd EF	1.5 a F	4,2 a DE
Naga White	1,3 d F	2,7 ab EF	1,7 a F	7,5 ab A	3,2 bc DEF	5,8 abc BC	6,3 a AB	2,2 bc EF	1,3 d FG	4.2 bc DE	4.1 a DE	2.0 a F	4,5 a CD
Local	1,5 cd DE	2,0 abc DE	1,0 a E	7,3 ab A	3,0 bc BC	3,2 d BC	7,0 a A	1,0 c E	1,0 d E	1.5 c DE	1.1 g E	2.7 a CD	4,5 a B

Means within columns followed by the same low case letters are not significantly different, Newman–Keuls test, $P = 0.05$.
Means within rows followed by the same upper case letters are not significantly different, Newman–Keuls test, $P = 0.05$.

Table 11
Germination rates observed on the 21 entries of the WCASRN Regional Sorghum Head-Bug and Grain Mold Trial in 11 localities in 1996

Station cultivar	Ina	Maroua	Soumbé	Bébédjia	Ferkessédougou	Nyankpala	Bordo	Cinzana	Longorola	Samanko	Samaru
ICSV 905	15 (23 j D)	82 (66 cdefg AB)	57 (49 ab BC)	39 (38 fgh CD)	89 (73 ab AB)	26 (26 a D)	—	88 (72 a AB)	59 (51 d BC)	—	95 (86 a A)
M 943208-1	39 (39 g D)	91 (72 abcde AB)	51 (46 ab BCD)	46 (43 efgh CD)	85 (70 abc AB)	40 (34 a D)	-	87 (69 a AB)	72 (61 abcd BC)	72 (61 efghi BC)	95 (86 a A)
Malisor 84-7	42 (40 fg C)	96 (80 abc A)	42 (40 ab C)	65 (57 bc BC)	82 (67 abcd AB)	62 (54 a BC)	46 (41 bcd C)	76 (62 ab AB)	74 (60 bcd AB)	73 (61 efghi AB)	92 (78 a A)
87 W 810	70 (57 a BC)	76 (63 efg B)	61 (52 ab BC)	45 (42 fgh C)	75 (61 cd BC)	38 (36 a C)	51 (46 abcd C)	89 (71 a AB)	73 (59 bcd BC)	66 (59 fghi BC)	97 (84 a A)
91 W 113-2-1	50 (45 cd BC)	86 (68 abcdef A)	74 (58 a ABC)	51 (45 defg BC)	81 (66 abcd AB)	41 (39 a C)	51 (46 abc BC)	83 (66 a AB)	—	73 (61 efghi AB)	85 (72 ab A)
82-Sel 1-Grain dur	42 (40 efg C)	92 (74 abcde A)	55 (48 ab BC)	79 (68 a AB)	76 (63 bcd ABC)	42 (40 a C)	—	62 (52 bc BC)	46 (42 e C)	66 (56 ghi ABC)	84 (75 a A)
R 6078	7 (15 k E)	91 (74 abcde A)	45 (42 ab CD)	56 (49 cdef BC)	61 (52 e BC)	18 (22 a DE)	26 (28 d DE)	86 (69 a AB)	36 (36 ef CD)	—	78 (67 ab AB)
87-SB-F4-54-2	33 (35 h D)	96 (82 abc A)	49 (45 ab CD)	54 (47 cdef CD)	86 (71 abc AB)	36 (36 a D)	55 (48 abc CD)	61 (52 bc BCD)	60 (51 d BCD)	74 (61 efghi BC)	95 (85a A)
IS 30469C-1526-4	52 (46 b BC)	64 (53 g B)	36 (36 abc BCD)	—	70 (58 de AB)	24 (28 a D)	40 (38 cd C)	82 (67 a AB)	76 (61 abcd AB)	62 (54 hi B)	87 (75 a A)
IS 30469C-1518T-5	70 (57 a AB)	84 (67 bcdefg A)	32 (34 bc CD)	—	69 (58 de AB)	24 (27 a D)	54 (47 abc BC)	—	70 (59 cd AB)	75 (58 fghi AB)	82 (70 ab A)
IS 14384	38 (38 g CD)	96 (81 abc A)	39 (39 ab CD)	55 (48 cdef C)	91 (74 a AB)	13 (20 a D)	59 (52 abc BC)	80 (64 a AB)	89 (71 ab AB)	95 (78 abc AB)	37 (39 c CD)
IS 21658	46 (43 de B)	86 (69 abcdef A)	15 (21 c C)	72 (59 b AB)	83 (66 abcd AB)	33 (34 a BC)	64 (54 abc AB)	84 (67 a A)	83 (66 abc AB)	79 (65 defgh AB)	55 (48 bc B)
CEM 328/1-1-1-2	71 (58 a B)	81 (65 cdefg B)	68 (56 ab B)	66 (56 bcd B)	81 (66 abcd AB)	20 (20 a C)	69 (58 abc B)	86 (69 a AB)	76 (62 abcd B)	88 (72 abcde AB)	97 (86 a A)
CEM 328/3-3-1-1	20 (27 i C)	68 (57 fg B)	69 (56 ab B)	42 (40 fgh BC)	77 (62 bcd AB)	17 (20 a C)	54 (46 abc BC)	84 (66 a AB)	83 (66 abc AB)	75 (64 defghi AB)	94 (81 a A)
CCGM 1/19-1-1	45 (42 ef B)	96 (80 abc A)	59 (51 ab B)	33 (34 h B)	93 (77 a A)	33 (32 a B)	75 (62 ab AB)	92 (74 a A)	86 (68 abc AB)	94 (80 ab A)	90 (77 a A)
CCGM 39/17-2-2	18 (25 i C)	95 (79 abcd A)	59 (51 ab BC)	62 (53 bcde B)	82 (74 a A)	31 (32 a C)	74 (60 abc AB)	88 (70 a AB)	84 (67 abc)	96 (78 abc A)	85 (71 ab AB)
ICSV 1079	69 (56 a B)	97 (82 abc A)	71 (58 ab B)	71 (59 b B)	85 (68 abcd AB)	44 (41 a B)	78 (64 a AB)	92 (74 a AB)	86 (69 abc AB)	89 (75 abcd AB)	93 (81 a A)
CEM 326/11-5-1-1	70 (57 a B)	99 (84 a A)	73 (59 a B)	81 (68 a AB)	93 (77 a AB)	29 (27 a C)	72 (59 abc B)	89 (72 a AB)	91 (73 a AB)	86 (69 bcdef AB)	95 (83 a A)
S 34	20 (27 i C)	78 (64 defg AB)	62 (52 ab AB)	21 (27 i C)	88 (72 ab A)	28 (29 a C)	54 (47 abc BC)	49 (45 c BC)	28 (31 f BC)	59 (51 i B)	84 (70 ab AB)
Naga White	57 (49 b BC)	98 (83 ab A)	63 (53 ab BC)	36 (36 gh C)	91 (74 a AB)	64 (55 a BC)	62 (53 abc BC)	94 (76 a A)	(57 cd AB)	83 (74 abcd AB)	85 (76 a A)
Local	46 (43 de B)	87 (69 abcdef AB)	56 (48 ab B)	54 (48 cdef B)	91 (73 ab A)	38 (35 a B)	40 (39 cd B)	92 (75 a A)	—	97 (82 a A)	77 (64 ab AB)

Data analyzed after arcsine transformation (transformed values are in parentheses).
Means within columns followed by the same low case letters are not significantly different, Newman–Keuls test, $P = 0.05$.
Means within rows followed by the same upper case letters are not significantly different, Newman–Keuls test, $P = 0.05$.

Table 12
Germination rates observed on the 21 entries of the WCASRN Regional Sorghum Head-Bug and Grain Mold Trial in 10 localities in 1997

Station cultivar	Ina	Farako-bâ	Poumbaïdi	Bébédjia	Ferkessédougou	Nyankpala	Bordo	Cinzana	Bagauda	Samaru
ICSV 905	33 (33 bcd CD)	82 (65 bc B)	25 (28 abc D)	—	79 (64 a B)	61 (52 a BC)	27 (31 cdef D)	44 (41 abc CD)	96 (83 a AB)	99 (87 a A)
M 943208-1	32 (33 bcd D)	84 (67 abc B)	27 (30 abc D)	76 (62 a BC)	64 (54 ab C)	59 (50 a CD)	37 (37 bcde CD)	48 (44 a CD)	98 (83 a A)	99 (88 a A)
Malisor 84-7	31 (34 bcd C)	90 (72 abc AB)	32 (34 abc C)	—	76 (64 a B)	54 (48 a BC)	28 (31 cdef C)	41 (40 abc C)	91 (73 ab AB)	96 (85 a A)
87 W 810	29 (31 cd C)	86 (69 abc AB)	39 (37 abc BC)	—	67 (56 a B)	45 (42 a BC)	41 (39 bcde BC)	45 (42 ab BC)	99 (84 a A)	93 (81 a A)
91 W 113-2-1	19 (25 d C)	88 (70 abc AB)	33 (32 abc C)	44 (41 ab BC)	63 (55 ab B)	52 (47 a BC)	14 (21 def C)	45 (42 ab BC)	97 (81 a A)	97 (86 a) A
82-Sel 1-Grain dur	27 (30 cd C)	86 (68 abc AB)	37 (37 abc C)	53 (47 ab BC)	58 (50 ab BC)	50 (45 a BC)	43 (41 bcd C)	41 (40 abc)	98 (82 a A)	99 (87 a A)
R 6078	26 (30 cd CD)	76 (61 c BC)	21 (26 bc CD)	—	43 (38 b C)	52 (46 a C)	13 (19 ef D)	32 (34 c) C	86 (71 ab AB)	99 (88 a A)
87-SB-F4-54-2	36 (37 bcd B)	89 (71 abc A)	44 (41 abc B)	—	54 (47 ab B)	41 (39 a B)	39 (38 bcde B)	33 (35 bc B)	99 (83 a A)	97 (86 a A)
IS 30469C-1526-4	35 (36 bcd BC)	88 (70 abc) AB	50 (45 abc BC)	61 (52 ab B)	61 (52 ab B)	59 (51 a BC)	29 (32 cdef C)	44 (41 abc BC)	97 (82a A)	100 (90 a A)
IS 30469C-1518T-5	40 (38 bcd CD)	84 (67 abc AB)	55 (48 abc BC)		58 (50 ab BC)	39 (37 a CD)	22 (27 cdef D)	38 (38 abc CD)	82 (67 b AB)	99 (87 a A)
IS 14384	70 (58 a B)	95 (78 a AB)	29 (30 abc)	63 (52 ab BC)	73 (62 a B)	70 (59 a BC)	64 (53 b BC)	47 (43 a C)	61 (51 c BC)	100 (90 a A)
IS 21658	21 (27 d D)	87 (68 abc B)	35 (33 abc C)	—	66 (55 ab B)	67 (56 a B)	34 (34 bcdef C)	40 (39 abc BC)	61 (52 c BC)	100 (90 a A)
CEM 328/1-1-1-2	36 (36 bcd C)	92 (73 ab AB)	47 (40 abc BC)	28 (30 b C)	69 (57 a B)	60 (52 a BC)	32 (34 bcdef C)	34 (35 bc C)	99 (85 a A)	99 (88 a A)
CEM 328/3-3-1-1	34 (35 bcd C)	88 (70 abc AB)	52 (46 abc C)	—	67 (58 a BC)	53 (48 a C)	41 (39 bcde C)	36 (37 abc C)	96 (78 a AB)	100 (90 a A)
CCGM 1/19-1-1	52 (46 b C)	88 (70 abc AB)	66 (55 a BC)	45 (41 ab C)	66 (56 ab BC)	64 (55 a BC)	38 (44 bc C)	37 (38 abc C)	95 (80 a AB)	100 (90 a A)
CCGM 39/17-2-2	34 (35 bcd C)	87 (69 abc B)	40 (39 abc C)	—	61 (52 ab BC)	70 (59 a BC)	42 (40 bcd C)	47 (43 a C)	95 (80 a AB)	99 (90 a A)
ICSV 1079	46 (42 bc C)	90 (72 abc AB)	46 (43 abc C)	—	67 (56 a BC)	56 (50 a BC)	35 (35 bcdef C)	41 (40 abc C)	95 (80 a AB)	100 (90 a A)
CEM 326/11-5-1-1	44 (41 bc C)	95 (77 a AB)	64 (53 ab C)	—	73 (60 a BC)	69 (58 a BC)	46 (42 bc C)	45 (42 ab C)	99 (85 a A)	100 (90 a A)
S 34	19 (25 d D)	79 (63 bc B)	43 (40 abc CD)	—	62 (52 ab BC)	50 (45 a C)	9 (16 f D)	42 (40 abc CD)	97 (80 a AB)	99 (90 a A)
Naga White	38 (38 bcd CD)	82 (65 bc B)	22 (28 bc D)	71 (59 a BC)	75 (61 a B)	50 (45 a CD)	42 (40 bcd CD)	42 (41 abc CD)	99 (85 a A)	97 (90 a A)
Local	41 (39 bcd CD)	84 (67 abc AB)	15 (20 c D)	72 (59 a AB)	76 (64 a AB)	69 (58 a AB)	87 (69 a AB)	48 (44 a B)	98 (81 a A)	99 (84 a A)

Data analyzed after arcsine transformation (transformed values are in parentheses).
Means within columns followed by the same low case letters are not significantly different, Newman–Keuls test, $P = 0.05$.
Means within rows followed by the same upper case letters are not significantly different, Newman–Keuls test, $P = 0.05$.

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