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EVALUATING SORGHUM GENOTYPES FOR MULTIPLE INSECT RESISTANCE*

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Abstract—Most germplasm lines and improved sorghum genotypes identified as resistant to shoot fly (*Atherigona soccata* Rond.), stem borer (*Chilo partellus* Swin.), midge (*Contarinia sorghicola* Coq.) and head bugs (*Calocoris angustatus* Leth.) are resistant to only one of these insects which usually will infest the same crop during the same season. At ICRISAT Center, India, a technique was developed in which entries were subjected to an array of combinations of pest infestations for identifying and separating genotypes with resistance to one or more insects.

Using this technique, 220 resistance sources and breeding lines were evaluated for multiple insect resistance. Less than 10% of shoot fly resistance sources had acceptable resistance (< 3 on a scale of 1–9) to shoot fly, but over 50% showed good resistance (scores of 1–3) to stem borer. IS 18551 and IS 2195 were the best entries with resistance to both shoot fly and stem borer. However, the majority (80–90%) of shoot fly and stem borer resistant sources were highly susceptible to midge with scores > 8. Similarly, all midge resistant sources were highly susceptible to shoot fly but less so to stem borer where seven midge lines had scores < 5. IS 22464 was the best midge line with a score of 3 for stem borer resistance. Advanced breeding lines showed a wider range of resistance to shoot fly, stem borer and midge with a higher frequency for resistance to stem borer. PS 28060-3 and PM 14388-1 were the most promising breeding lines.

Key Words: Sorghum, insect pests, shoot fly, *Atherigona soccata*, stem borer, *Chilo partellus*, midge, *Contarinia sorghicola*, resistance sources, breeding lines, multiple insect resistance

Résumé—La plupart des lignées des ressources génétiques et des génotypes de sorgho améliorés qui sont identifiés comme résistants à la mouche des pousses (*Atherigona soccata* Rond.), au borer ponctué du sorgho (*Chilo partellus* Swin.) à la cécidomyie (*Contarinia sorghicola* Coq.) et à la punaise des panicules (*Calocoris angustatus* Leth.) ne le sont qu'à un seul de ces insectes qui infestent généralement la même culture pendant la même campagne. Une technique, mise au point au Centre ICRISAT en Inde, permet de soumettre les entrées à une grande série de combinaisons d'infestations par les insectes en vue d'identifier et de séparer les génotypes ayant une résistance à un ou plusieurs insectes.

Grâce à cette technique, 220 sources de résistance et lignées de séléction ont été évaluées pour la résistance multiple aux insectes. Moins de 10% des sources de résistance à la mouche des pousses avaient une résistance acceptable (< 3 sur une échelle de notation de 1 à 9) à la mouche des pousses. Mais, plus de 50% de celles-ci ont manifesté une bonne résistance (1 à 3) au borer ponctué. Les sorghos IS 18551 et IS 2195 étaient les meilleures entrées avec une résistance aussi bien à la mouches des pousses qu'au borer. Par ailleurs, la majorité (80 à 90%) des sources de résistances à la mouche des pousses et au borer étaient extrêmement sensibles à la cécidomyie

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(> 8). De même, toutes les sources de résistance à la cécidomyie étaient très sensibles à la mouche des pousses mais l'étaient moins au borer. Sept lignées résistantes à la cécidomyie avaient des notes de < 5. IS 22464 était la meilleure lignée résistante à la cécidomyie avec une note de 3 pour la résistance au borer. Des lignées de sélection avancées ont montré une plus grande diversité de résistance à la mouche des pousses, au borer et à la cécidomyie, avec une fréquence plus élevée de résistance au borer. Les lignées de sélection PS 28060-3 et PM 14388-1 se sont avérées les plus prometteuses.

Mots Cléfs: Sorgho, insectes ravageurs, mouche des pousses, *Atherigona soccata*, borer ponctué, *Chilo partellus*, la cécidomyie *Contarinia sorghicola*, sources de résistance, lignées de selection, résistance multiple aux insectes

INTRODUCTION

Over 150 insect species have been listed as pests or potential pests of sorghum (Jotwani and Young, 1972; Seshu Reddy and Davies, 1979a). However, only a few of these are pests of economic importance and the major species are the sorghum shoot fly (*Atherigona soccata* Rondani), the spotted stem borer (*Chilo partellus* Swinhoe), the sorghum midge (*Contarinia sorghicola* Coquillett) and the head bug (*Calocoris angustatus* Lethiery). These pests infest sorghum at different stages of crop development and in most sorghum growing areas, two or more species may be present at damaging levels on the same crop during a particular crop season. Resistance in plants to insects is one of the most efficient means of insect pest control (Luginbill, 1969). At the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), host-plant resistance is a major component in the development of control strategies against insect pests that attack sorghum in the semi-arid regions of Africa and Asia.

Efficient and repeatable techniques have been developed at ICRISAT and elsewhere for field screening for resistance to each of the four major pests (Blum, 1967; Soto, 1972; Jotwani et al., 1978; Seshu Reddy and Davies, 1979b; Taneja and Leuschner, 1985a and b; Sharma, 1985; Sharma et al., 1988a and b). By using these techniques, several lines have been identified as resistant to one or the other of these pests (Jotwani et al., 1978; Sharma and Davies, 1981; Singh et al., 1983; Prem Kishore and Sharma, 1984; Taneja and Leuschner, 1985a and b; Kundu, 1985; Prem Kishore et al., 1985; Singh and Rana, 1986; Agrawal et al., 1987). However, since more than one pest species is known to occur during crop growth, resistance to one insect species is inadequate in most situations in farmers' fields.

Under natural conditions, these insects will attack sorghum at distinctly different periods of crop growth: shoot fly in the first 3 weeks after crop emergence, stem borer beginning only 2 weeks after crop emergence, head bugs beginning at panicle exsertion and midge at flowering. This makes it possible to evaluate the same crop for its performance under multiple insect infestation. It however, necessitates the development of a technique that will permit the separation of genotypes for their levels of resistance to each pest, without masking the effect of individual pest infestation during the evaluation process. This paper reports the development of a technique for evaluating sorghum for multiple insect resistance and reports the results of the evaluation of known single insect resistant lines under multiple insect infestations. In view of the limited progress on head bugs, our studies were limited to shoot fly, stem borer and midge.

MATERIALS AND METHODS

All field trials were conducted on the research farm of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) located at Patancheru near Hyderabad, India. Trials were planted in 4 m row plots with a plant spacing of 0.75 x 10 cm in three replications in a randomized complete block design. A basal dose of ammonium phosphate at the rate of 150 kg/ha was applied at sowing. Thinning was done at 10 days after crop emergence (DAE) and all other recommended agronomic practices were carried out where necessary.

Material to be evaluated for multiple insect resistance consisted of a collection of 220 entries which was made up of 170 germplasm sources identified for resistance to single pests at ICRISAT Center (shoot fly 60, stem borer 73 and midge 37), 42 improved breeding lines for insect resistance and eight commercial high yielding cultivars.

Optimum and uniform infestation by each pest was ensured either by the manipulation or augmentation of natural pest populations using already existing techniques. For shoot fly, this involved the improved inter-lard/fish meal technique developed by Starks in 1970 (Sharma et al., 1983). Stem borer infestation was done artificially with first instar larvae by using the "Bazooka" applicator (Mihm et al., 1978; Wiseman et al., 1980; Taneja and Leuschner, 1985a). Larvae were obtained from the ICRISAT stem borer laboratory and infestation was carried out at 15–20 DAE depending on time of year. Midge infestation was achieved by planting infestor rows, split plantings, spreading of infested sorghum panicles containing diapausing midge flies and use of sprinkler irrigation (Sharma et al., 1988a).

In order to achieve all possible combinations of pest attack, seven treatments (T1 to T7) were used involving single, double and triple combinations of infestations by shoot fly (SF), stem borer (SB) and sorghum midge (SM) (Table 1). T2 (SB only), T3 (SM only) and T6 (SB + SM) were achieved by treating seedlings at 7DAE with cypermethrin (225 g a.i./ha) and removing plants with dead hearts at thinning to control shoot fly infestation. Natural infestations of stem borer are negligible at ICRISAT Center. When a treatment involved a combination of two or three pests (T4, T5, T6 and T7), a partitioning of overall pest damage was achieved by initially tagging shoot fly and/or stem borer damaged plants with coloured labels. Uninfested plants were either then infested with or monitored for the subsequent insect infestation.

Table 1. Combinations of pest infestations used in evaluating sorghum genotypes for multiple insect resistance

Treatments	Pest combinations		
	Shoot fly (SF)	Stem borer (SB)	Midge (SM)
T1	✓	-	-
T2	-	✓	-
T3	-	-	✓
T4	✓	✓	-
T5	✓	-	✓
T6	-	✓	✓
T7	✓	✓	✓

Evaluation of entries was based on existing parameters that are used in screening for resistance to insect pests. For shoot fly, egg count and dead hearts were recorded respectively at 14 and 21 DAE (Taneja and Leuschner, 1985b); stem borer leaf feeding damage and dead heart respectively at 7 and 14 days after infestation (Taneja and Leuschner, 1985a) and midge damage (chaffy florets) at physiological crop maturity (Sharma et al., 1988a).

These trials were conducted over four crop seasons between 1987 and 1989 in a randomized complete block design with three replications. Data were pooled and subjected to an analysis of variance. Recorded field data in total numbers and percentages were converted into a 1–9 scale for classification of resistance where 1 = highly resistant and 9 = highly susceptible.

RESULTS AND DISCUSSION

Resistance levels on a 1–9 scale were classified into four groups: (a) resistant (1–3) (where 1 = highly resistant, 2 and 3 = acceptably resistant); (b) moderately resistant (4 and 5); (c) susceptible (6 and 7) and (d) highly susceptible (8 and 9). From treatments T1, T2 and T3, it was possible to reconfirm the levels of resistance of identified sources. After the first season of testing in 1987, 55 entires were found to be highly susceptible to all pests. These were therefore deleted from further evaluations. Our results indicated that while the majority of earlier identified stem borer (92.2%) and midge (79.2%) resistant sources were confirmed as resistant, less than 50% of these actually fell within acceptable levels of resistance (Table 2). Similarly less than 10% of the shoot fly sources actually possessed acceptable levels of resistance and 50% were found to be susceptible to this pest.

Most shoot fly lines (50%) which had earlier been classified as resistant to this pest possessed acceptable levels of resistance to stem borer and were in fact more resistant to stem borer than to shoot fly (Table 2). The best of these were IS 18551, IS 2195 and IS 3962 (Table 3). Most stem borer lines had good levels of resistance to shoot fly, but the majority (80–90%) of shoot fly and stem borer resistant sources were however, highly susceptible to midge (Table 3). On the other hand, all midge lines were highly susceptible to shoot fly, but less so to stem borer where seven midge lines (29.2%) were found to possess resistance to these pests. IS 22464 was the best midge line with a rating of 3.3 for stem borer resistance (Table 3).

Breeding lines showed a higher frequency of resistance to stem borer than to other pests (Table 2). There was also a higher number of breeding lines with resistance to both midge and stem borer

Table 2. Distribution of identified insect resistant sorghum genotypes under multiple insect infestations (Mean of four seasons). ICRISAT Center, 1987–1989

Resistance source	To insect species	Degree of resistance/susceptibility: Per cent distribution of genotypes R˙ (1-3)ᵉ	MR (4–5)	MS (6-7)	S (8–9)
Shoot fly (54)*	SF**	9.2	40.7	50.1	0
	SB	50.0	44.4	3.7	1.9
	SM	0	0	9.3	90.7
Stem borer (51)	SF	0	13.7	82.4	3.9
	SB	45.1	47.1	5.9	1.9
	SM	0	0	17.6	82.4
Midge (24)	SF	0	0	79.2	20.8
	SB	4.2	25.0	70.8	0
	SM	41.7	37.5	12.5	8.3
Breeding lines (28)	SF	0	10.7	85.7	3.6
	SB	3.6	50.0	39.3	7.1
	SM	3.6	10.7	46.4	39.3
Checks (8)	SF	0	0	75.0	25.0
	SB	0	12.5	75.0	12.5
	SM	0	0	12.5	87.5

*Figures in brackets indicate total number of entries.
**SF = shoot fly, SB = stem borer, SM = sorghum midge.
˙R = resistant, MR = moderately resistant, MS = moderately susceptible, S = highly susceptible.
ᵉScale of 1–9, where 1 = highly resistant and 9 = highly susceptible.

Table 3. Comparison of some insect resistant sorghum genotypes under multiple insect infestations (Mean of four seasons). ICRISAT Center, 1987–1989

Entries	Source˙	Resistance rating*: Shoot fly	Stem borer	Sorghum midge
IS 2122	SF	5.3	2.3	7.5
IS 2146	SF	5.2	2.3	8.5
IS 2195	SF	5.3	2.3	8.5
IS 18551	SF	3.0	3.7	8.0
IS 2269	SF	5.3	3.3	7.0
IS 3962	SF	5.0	2.5	8.0
IS 5613	SF	5.2	2.5	7.0
IS 5585	SB	5.0	2.5	7.5
IS 2205	SB	5.0	3.5	8.0
IS 18573	SB	5.2	1.8	8.0
IS 3461	SM	6.5	4.8	3.0
IS 7005	SM	6.5	5.2	3.5
IS 18695	SM	6.8	4.7	3.0
IS 19476	SM	7.0	4.2	3.5
IS 19512	SM	6.2	4.7	4.0
IS 22464	SM	7.7	3.3	4.3
PS 19230	Br	5.3	3.7	7.0
PS 28060-3	Br	4.3	4.3	4.5
PS 30715-2	Br	5.5	3.0	8.5
PS 13668-1	Br	6.8	3.9	4.0
PM 14388-1	Br	7.1	4.5	3.0
ICSV 197	Br	6.7	9.0	2.0
ICSV 1	C	7.0	8.9	7.5
CSH 1	C	8.3	6.5	8.0
CSH 5	C	6.8	6.0	9.0
SPV 475	C	7.7	5.3	8.0
Mean (170 entries)		5.9	4.1	6.1
S.E. ±		1.1	1.6	0.9
CV %		18.8	39.1	16.1

*On a scale of 1–9 where 1 = highly resistant and 9 = highly susceptible.
˙SF = shoot fly, SB = stem borer, SM = sorghum midge, Br = breeding line and C = control.

than for other combinations and it was also within this group that entries were identified with moderate levels of resistance to all three pests. PS 28060-3 was the most promising breeding line for multiple insect resistance (Table 3). However, the best midge resistant breeding line ICSV 197 was very susceptible to shoot fly and stem borer.

In general, resistant sources tended to combine resistance to stem borer with other pest species i.e. SF + SB and SB + SM; consequently, there was a higher frequency for stem borer resistances as a second component than for any other insect in all groups. Combined resistance to shoot pests (shoot fly and stem borer) was more frequent and this may be explained by the commonality of resistance factors for these two pests (Taneja and Leuschner 1985a, b).

The results of this study show that some entries that were previously classified as resistant possess only moderate to low levels of resistance. This is particularly true for shoot fly resistance sources. In previous screening for resistance to insect pests at ICRISAT Center, a 1–5 rating scale was used. This scale has a limitation in that it presents a narrow range within which entries can be classified. Thus for example, in a 1–5 scale, a rating of 3 is classified as moderately resistant, whereas if this was expanded into a 1–9 scale, it would be equivalent to 6, but be classified as moderately susceptible. This may explain the apparent contradiction in the rating of some earlier selected resistant genotypes. It should, however, be noted that the majority of the lines evaluated still fell within resistant categories (SF — 49.9%; SB — 92.2%; and SM — 79.2%).

CONCLUSIONS

The occurrence of two or more species of sorghum insect pests at damaging levels is common in both Africa and India. In northern Nigeria, the stem borer, *Busseola fusca* Fuller, midge and head bugs are recognized as severe pests (Harris, 1962, 1985; Ajayi, 1989); in Mali both midge and head bugs are the major insect pests, while in Burkina Faso, stem borers and midge have been reported as important pests of sorghum and shoot fly as a problem in late sown crop (Nwanze, 1988). In northern and parts of Central India, shoot fly and stem borer (*C. partellus*) can be devastating and the practice of cultivating mostly forage sorghums is partly attributed to the severity of midge attack. In the states of Karnataka and Maharashtra, while midge is the predominant species, severe shoot fly damage is not infrequent (Gahukar and Jotwani, 1980). What this implies is the need for pest maps which will indicate both the distribution of important pest species and their status in different agroecological zones. The results of this study present evidence of the possibility of screening for multiple insect resistance in sorghum. They also show that several genotypes, while possessing acceptable levels of resistance to one pest, also possess moderate levels of resistance to another pest. In particular, breeding lines with resistance to stem borer are those that are also resistant to midge. This indicates definite progress in the sorghum breeding programme at ICRISAT Center.

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