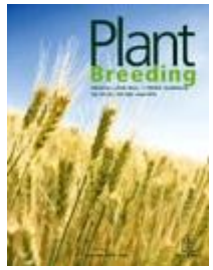

Interactions of spotted stem borer Chilo partellus with wild relatives of sorghum

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Article first published online: 10 APR 2012

DOI: http://dx.doi.org/10.1111/j.1439-0523.2012.01966.x

Genetic Resources and Crop Evolution

Wild relatives as a source of genes for resistance to spotted stem borer, *Chilo partellus* in sorghum, *Sorghum bicolor*

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Abstract The levels of resistance in the sorghum germplasm to spotted stem borer, *Chilo partellus* are quite low, and therefore, we evaluated wild relatives of sorghum to identify accessions with different mechanisms of resistance to this pest. *Heterosorghum* (*Sorghum laxiflorum*), *Parasorghum* (*S. australiense*, *S. purpureosericeum*, *S. versicolor*, *S. matarankense*, *S. timorense*, *S. brevicallosum*, and *S.*

nitidum), and *Stiposorghum* (*S. angustum*, *S. ecarinatum, S. extans, S. intrans, S. interjectum*, and *S. stipoideum*) showed very high levels of resistance to damage by the spotted stem borer larvae. *Chaetosorghum* (*S. macrospermum*) and the four wild races of *S. bicolor* subsp. *verticilliflorum* were susceptible to stem borer damage, as was *S. halepense*. Under no-choice conditions, egg-laying was observed on all the accessions, although there were significant differences among the species/accessions tested. Two accessions of *S. laxiflorum* (*Heterosorghum*) were preferred for oviposition, while the accessions belonging to *Stiposorghum* and *Parasorghum* (*S. purpureosericeum, S. versicolor,* and *S. timorense*) were significantly less preferred for oviposition than the resistant check, IS 2205. Accessions belonging to *Stiposorghum* showed slight leaf feeding, and there was no deadheart formation. Despite some damage in *Parasorghum*, very few deadhearts were formed, and two larvae were recovered, which died after sometime. In *Heterosorghum*, up to 82% deadhearts were recorded, but only six larvae were recovered. Accessions belonging to section *Sorghum* showed maximum deadhearts and larval recovery. High levels of resistance to *C. partellus* in wild relatives of sorghum in terms of antixenosis and antibiosis, which at times were closer to immunity, can be used to increase the levels and diversify the bases of resistance to this pest in sorghum.

Keywords: Sorghum, wild relatives, spotted stem borer, chilo partellus, plant resistance, resistance mechanisms

Introduction

Sorghum, *Sorghum bicolor* (L.) Moench, is an important cereal crop in the semi-arid tropics in Asia and Africa, but the yields on farmers' fields are generally low (500 - 800 kg ha^{-1}) due partly to insect damage. Nearly 150 insect species have been reported as pests of sorghum (Sharma 1993), of which spotted stem borer, *Chilo partellus* (Swin.) is a major pest in Asia and eastern and southern Africa. Annual losses due to stem borer damage have been estimated at US$366 million (ICRISAT 1992). The spotted stem borer, *C. partellus* attacks the sorghum plants two weeks after seedling emergence, and the insect continues to feed on the sorghum plant till crop harvest. The first symptom of attack is the presence of shot-holes caused by the early instar larval feeding, and the infested plants show a ragged appearance. The older larvae leave the plant whorl and bore into the stem at the base, damage the growing point, which results in deadheart formation. In older plants, the larvae feed inside the stem, causing stem tunneling. Later infestations also result in peduncle breakage, and production of completely- or partially-chaffy panicles. A number of sorghum genotypes with resistance to spotted stem borer, *C. partellus* have been identified (Sharma 193; Taneja and Leuschner 1885; Sharma et al. 2003). Improved genotypes such as ICSV 705, SPV 135, CSV 8R, SPV 104, SPV 238, and SPV 842 with moderate levels of resistance to stem borer have been developed (Sharma 1993; Singh and Rana 1989). Nevertheless, development of sorghum cultivars with high and stable resistance to the spotted stem borer remains a major constraint in sorghum improvement. Wild relatives of crops have frequently been used as sources of resistance to insect pests, and genes from wild relatives have played a key role in developing crop cultivars with durable resistance to insect pests.

Sorghum is a highly variable genus, and has 24 species distributed in five sections: *Sorghum*, *Chaetosorghum*, *Heterosorghum*, *Parasorghum* and *Stiposorghum*. The most comprehensively studied section, *Sorghum*, includes the cultivated grain and fodder sorghums (*Sorghum bicolor* subsp. *bicolor*), closely related wild annual sorghums (*S. bicolor* subsp. *verticilliflorum*) from Africa, weedy perennial sorghums (*S. halepense*) from southern Europe and Asia, and a perennial wild species (*S. propinquum*) from South and South-east Asia (Doggett 1988). The other four sections comprise of wild species distributed in Africa, Australia, and Asia. Wild relatives of sorghum have not been explored as sources of resistance to insect pests, particularly, *C. partellus*. Earlier studies have identified wild relatives of sorghum with high levels of resistance to sorghum shoot fly, *Atherigona soccata* (Rondani) (Mote 1984), sorghum midge, *Stenodiplosis sorghicola* (Coq.) (Sharma and Franzmann 2001), and greenbug, *Schizaphis graminum* (Rondani) (Duncan et al. 1991). In the present studies, we evaluated a diverse array of accessions belonging to wild relatives of sorghum for resistance to spotted stem borer, *C. partellus*, and also studied the underlying resistance mechanisms.

Materials and Methods

Screening for resistance to spotted stem borer, *C. partellus* was carried out at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India. Fifty-five accessions of wild relatives of sorghums belonging to 17 species were screened for resistance to stem borer, *C. partellus* damage under artificial infestation in the field. A set of 27 accessions from the primary, secondary, and tertiary genepools was evaluated for antixenosis and antibiosis components of resistance under greenhouse conditions. *Sorghum bicolor* cultivars, IS 2205 and ICSV 1, were used as resistant and susceptible checks, respectively, along with two improved cultivars (ICSV 700 and ICSV 708) with moderate levels of resistance to this pest.

Evaluation of wild relatives of sorghum for resistance to spotted stem borer, *Chilo partellus* under field conditions

Fifty-five accessions of wild relatives of sorghum along with resistant and susceptible checks were sown in three replications in a randomized complete block design (RCBD) in the field. Recommended agronomic practices were followed for raising the crop. Each genotype was planted in a 2 m long 2-row plot, with an inter-row spacing of 75 cm. The sorghum seedlings were thinned to a spacing of 10 cm between the plants at 15 days after seedling emergence. The test material was evaluated for resistance to *C. partellus* using artificial infestation (Sharma et al. 1992). Nearly 500 black-head-stage egg masses, along with 85 g of poppy seeds (*Papaver* sp.) were kept overnight in a plastic jar with a tightly fitted lid. In the morning, the first-instar larvae that emerged from the eggs were mixed with the carrier (poppy seeds) and transferred into the plastic bottle of the Bazooka applicator. The plants were infested with neonate larvae of *C. partellus* at 20 days after seedling emergence. The nozzle of the Bazooka applicator was placed close to the central leaf whorl, and each plant was infested with 5 to 7 larvae. The plants were infested in the morning between 08.00 to 11.00 h to avoid larval mortality due to high temperature. The Bazooka applicator was rotated after every 10 strokes to ensure uniformity in larval distribution. One week after infestation, data were recorded on intensity of leaf feeding on a 1 to 9 visual damage rating scale (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged). Plants showing deadhearts symptoms were recorded 20 days after artificial infestation (Sharma et al. 1992).

Antixenosis for oviposition to spotted stem borer, *Chilo partellus* in wild relatives of sorghum

Non-preference for oviposition was studied under multi-choice and no-choice conditions. In multi-choice tests, the moths were given a choice between 10 to 12 accessions (including the susceptible, ICSV 1 and resistant, IS 2205 checks) for oviposition. The test entries were raised in pots (30 cm diameter, and 30 cm high) in the greenhouse, and thinned 10 days after emergence. The potting mixture consisted of black soil (Vertisols), sand, and farm yard manure (2: 1: 1). There were 5 seedlings in each pot. Pots with 18 day-old plants were placed inside a wooden cage (80 x 70 x 60 cm) at random along with the resistant and susceptible checks. The wooden framed cages were covered with a wire-mesh screen on three sides, and a glass door in the front. Fifty pairs of newly emerged adults were released inside each cage. The insects were cultured on artificial diet in the insect-rearing laboratory (Sharma et al. 1992). Moths were provided with water in a cotton swab. After releasing the moths in the cage, they were allowed to oviposit on the plants for three nights. To avoid predation by ants, Tanglefoot^{R} was smeared on all the four legs of the cages. The experiment was carried out in three sets having 10, 11, and 12 accessions. Accessions in each experiment were replicated thrice, and the position of each accession was changed everyday to avoid any position effect. Antixenosis for oviposition under no-choice conditions was studied by keeping only one accession in the test arena. The plants were grown in pots in the greenhouse as described earlier. There were five plants in each pot. The oviposition cages were arranged on a table in the greenhouse in a completely randomized design. Ten pairs of newly emerged adults were released inside each oviposition cage. Moths were allowed to oviposit on the test entries for three nights. In both the multi- and no-choice experiments, observations were recorded on the number of egg masses and number of eggs laid on each plant.

Antibiosis to *Chilo partellus* in wild relatives of sorghum under no-choice conditions

Expression of antibiosis to *C. partellus* in wild relatives of sorghum was studied in the greenhouse in terms of survival and development of neonate larvae. The experiment was laid out in a completely randomized design with 23 accessions, and each accession was replicated thrice. The plants were raised in trays (30 x 45 x 20 cm) in the greenhouse at 23 ± 5ºC and 65 ± 5% RH. Ten days after seedling emergence, 20 plants were retained in each tray. Urea (@ 10 g per tray) was applied after thinning. The plants were infested artificially with 10 first-instar larvae per plant using a camel hairbrush at 20 days after seedling emergence. Observations were recorded on deadheart formation, larval survival, and adult emergence.

Statistical analysis

Data were subjected to analysis of variance using GENSTAT release 7.1 (Payne et al. 2006). Data on egg and larval numbers, and percentage deadhearts were transformed to Log (x + 1) and Angular values, respectively, and subjected to analysis of variance. The results of the transformed and non-transformed data were similar, and therefore, results from non-transformed data are presented in this paper. The significance of differences between the genotypes was measured by *F*-test, while the treatment means were compared using the least significant difference (LSD) at $P \leq 0.05$.

Results

Reaction of wild relatives of sorghum for resistance to spotted stem borer, *Chilo partellus*

There were significant differences among the wild relatives of sorghum for susceptibility to spotted stem borer, *C. partellus* (Table 1). Leaf damage scores (LDS) varied between 1 to 6.8 over the two years as compared to 6.8 in the susceptible check, ICSV 1, and 4.8 in the resistant check, IS 2205. Deadheart formation due to stem borer ranged from 0 to 100% during the 1998, and 0 to 97.3% during the 1999 cropping season. The susceptible check, ICSV 1 had 95.9% damaged plants and 93.6% plants with deadhearts, while the resistant check, IS 2205 showed 79% plants with leaf damage and 40.8% plants with deadhearts. *Chaetosorghum* (*S. macrospermum*) showed a mean LDS of 3.7, 72.9% plants with leaf damage, and 59.1% plants with deadhearts. Accessions belonging to section *Sorghum* showed a LDS of 3.3 to 6.8, and 44.8 to 98.1% plants with deadhearts, while accessions belonging to *Heterosorghum*, *Parasorghum*, and *Stiposorghum* showed very low LDS (<1.0) and there was no deadheart formation, except in one accession of *Heterosorghum* (TRC 243486), which had 2% plants with deadhearts.

Antixenosis for oviposition to spotted stem borer, *Chilo partellus* in wild relatives of sorghum

There were significant differences in egg laying by the *C. partellus* females on different accessions under multi- and no-choice tests in the greenhouse (Table 2). In *Stiposorghum*, there was no oviposition on *S. extans*, while *S. interjectum, S. ecarinatum, S. intrans,* and *S. stipoideum* had significantly less egg masses and eggs compared to the resistant, IS 2205 and the susceptible, ICSV 1 checks. *Stiposorghums* had 0.2 to 1.6 egg masses per plant compared to 2.8 egg masses on the resistant check, IS 2205. In *Parasorghum*, there was no oviposition on *S. versicolor* (IS 14262 and IS 14275), and *S. purpureosericeum* (IS 18944). Accessions belonging to *S. timorense*, *S. nitidum*, *S. brevicallosum*, *S. purpureosericeum* (RN 285, IS 18947, IS 18943, and IS 18945), and *S. australiense* (IS 18956) had significantly less number of egg masses per plant as compared to the susceptible check, ICSV 1. *Sorghum timorense* and *S. purpureosericeum* (RN 285, IS 18945, and IS 18947) had significantly less number of eggs per plant compared to the resistant check, IS 2205. The two accessions of *S. laxiflorum* (*Heterosorghum*) were highly preferred for oviposition, both in terms of egg masses and number of eggs per plant. In section *Sorghum*, the four wild races of *verticilliflorum* exhibited moderate preference for oviposition.

Accessions belonging to *Parasorghum* and *Stiposorghum* that exhibited antixenosis for oviposition under multi-choice conditions were subjected to oviposition preference tests under no-choice conditions. Significant differences in number of egg masses (0.07 to 4.27), number of eggs per egg mass (2.76 to 71.57), and number of eggs per plant (0.53 to 287.73) were observed among the accessions tested (Table 3). *Stiposorghum* accessions belonging to *S. ecarinatum*, *S. intrans*, and *S. interjectum* had significantly lower number of eggs per plant (37.13 to 86.00) relative to both, the susceptible and resistant checks.

Sorghum extans, which showed no oviposition in multi-choice tests, had 0.33 egg masses per plant, 5.87 eggs per plant, and 11.56 eggs per egg mass, while the resistant check, IS 2205 had 3.4 egg masses, 49.63 eggs per egg mass, and 163.67 eggs per plant.. In *Parasorghum*, two accessions of *S. versicolor*, (IS 14262 and IS 14275, which had no oviposition under multi-choice conditions, had 0.07 and 0.13 egg masses per plant, 3.67 and 32.0 eggs per egg mass, and 0.73 and 6.40 eggs per plant, respectively. However, egg laying on these accessions was much lower than that on the resistant check, IS 2205. Some of the accessions belonging to *S. purpureosericeum* (RN 285, IS 18943, and IS 18947) also exhibited non-reference for oviposition (14.20 to 51.47 eggs per plant) as compared to the resistant check, IS 2205. Four accessions (IS 18944, IS 18945, TRC-243498, and IS 18956) of *S. purpureosericeum*, which showed no oviposition in multi-choice tests, were preferred for oviposition under no-choice conditions, while the reverse was true in case of IS 23177 (*S. versicolor*). There were more egg masses and eggs on the upper surface, except on *S. timorense* (*Parasorghum)* and *S. interjectum* (*Stiposorghum*).

Antibiosis to *Chilo partellus* in wild relatives of sorghum under no-choice conditions

Accessions belonging to *Stiposorghum* and one accession of *Parasorghum* (IS 18944) did not show any deadheart formation (Table 4). There was considerable variation among *Parasorghum* accessions for leaf damage. *Sorghum australiense* (IS 18956), *S. matarankense*, *S. purpureosericeum* (IS 18943 and IS 18944), *S. timorense* and *S. versicolor* showed very low levels of leaf damage (LDS 1.0), while the accessions belonging to *S. nitidum* and *S. purpureosericeum* (RN 285 and IS 18947) suffered moderate leaf damage (LDS 2.7 to 6.0). However, all these accessions had very few deadhearts (0 to 14.8%). *Heterosorghum* accessions TRC 243492 suffered 15.3% deadhearts, while IS 18958 had 82.5% deadhearts. Accessions belonging to section *Sorghum* were highly susceptible and showed maximum deadheart formation. *Sorghum halepense* (IS 14212) and *S. bicolor* race *virgatum* of subsp. *verticilliflorum* (IS 18808) were highly susceptible (LDS 6.0, and 98.2 to 98.4% deadhearts), and were on par with the cultivated susceptible cultivar, ICSV 1. The cultivated resistant check showed high leaf damage (LDS 6.0), but suffered low deadheart formation (43.4%).

When plants with deadhearts were split open to check for the presence of larvae 15 days after infestation, no larvae were observed in 11 accessions of *Parasorghum*, except in IS 18945 (*S. purpureosericeum*) and IS 18956 (*S. australiense*) (Table 4). In *S. laxiflorum* (*Heterosorghum*), no larvae were observed in the deadhearts in TRC 243492, but six larvae were recorded from 20 deadhearts in IS 18958, all of which died in 28 to 30 days. There was no larval survival beyond 30 days and consequently, no adult emerged on *Stiposorghum*, *Parasorghum*, and *Heterosorghum*. In section *Sorghum*, 65 and 55% larvae were recovered from *S. halepense* and race *virgatum*, respectively, in comparison to 40 and 95% larval recovery from the resistant, IS 2205 and susceptible, ICSV 1 checks, respectively. Larval period varied from 37 to 43 days on race *virgatum* and 37 to 45 days on *S. halepense* compared to 30 to 36 days on the susceptible check, ICSV 1. Pupation ranged from 66% on *S. halepense* to 100% on race *virgatum*, and the susceptible check, ICSV 1. Pupal period varied from 8 to 12 days on *S. halepense*, 9 to 13 days on race *virgatum*, and 7 to 8 days on ICSV 1. Adult emergence was 27 and 37.5% on race *virgatum* and *S. halepense*, respectively, as compared to 63.2% adult emergence on the susceptible check, ICSV 1.

Discussion

Fifteen species of wild relatives of sorghum showed high levels of resistance to the spotted stem borer, *C. partellus* under artificial infestation in the field. Species belonging to *Heterosorghum*, *Parasorghum*, and *Stiposorghum* showed little damage by the spotted stem borer larvae, except for one accession of *Heterosorghum*, which had 2% plants with deadhearts. In contrast, section *Chaetosorghum* was highly susceptible to stem borer damage. Within section *Sorghum*, the four wild races of *S. bicolor* subsp. *verticilliflorum* were highly susceptible to stem borer damage, as was *S. halepense*. These wild races/species have been reported to be common hosts of stem borers under natural conditions (Reddy, 1985). There were no differences in oviposition under multi-choice conditions within the section *Sorghum* and the wild races of subsp. *verticilliflorum*, and *S. halepense*. The differences in oviposition between the resistant, IS 2205 and susceptible check, ICSV 1 were statistically non-significant. The two accessions of *S. laxiflorum* belonging to *Heterosorghum* were preferred for oviposition, while accessions of

Stiposorghum, in general, were not preferred for oviposition. There were marked differences in oviposition among *Parasorghum* accessions. *Sorghum australiense, S. matarankense*, and *S. nitidum* were as much or more preferred for oviposition than the resistant check, IS 2205, while *S. purpureosericeum*, *S. versicolor*, and *S. timorense* were significantly less preferred than IS 2205. Under no-choice conditions, egg-laying was observed on all the accessions. However, significant variation was observed in terms of the numbers of eggs.

Differences in oviposition on different species/accessions might be due to non-suitability of the given host for oviposition. Stem borer moths readily laid eggs on inert material in cages (Roome et al. 1977). Nevertheless, if plant leaves are presented, they are a preferred site for oviposition (Chapman and Woodhead 1985). Physical and chemical characteristics of the plant/leaf surface probably influence egg-laying by *C. partellus* females. Most of the accessions of *Parasorghum*, *Stiposorghum*, *Heterosorghum*, and *Chaetosorghum* have a medium- to high-density cover of hairs on the abaxial and the adaxial surfaces of the leaves (Chadha and Roome 1980), and they might influence the oviposition by the stem borer moths. Oviposition preference may also be mediated by chemical stimuli, which either attract or repel the *C. partellus* females. Significant differences in oviposition on resistant and susceptible genotypes of the cultivated sorghums have been reported earlier (Rana and Murty 1971; Singh and Rana 1984; Lal and Pant 1980; Taneja and Woodhead 1989; van den Berg and Westhuizen 1997). Oviposition by *C. partellus* on maize and sorghum varies greatly in terms of leaf number and leaf blade surface, as well as the position where oviposition takes place (Bates et al. 1990). Differential distribution of egg masses on the upper and lower leaf surfaces may be due to differences in trichome density/hairiness (Kumar and Saxena 1895). In maize, smooth areas of the lower surface of leaves along the midrib are preferred by *C. partellus* for oviposition (Durbey and Sarup 1982; Dabrowski and Nyangiri 1983). The present studies indicated that antixenosis for oviposition is an important component of resistance to stem borer in wild relatives of sorghum. The tendency of early-instars to disperse from the leaves (Lal and Pant 1980) may partially account for absence of damage in wild relatives of sorghum, despite heavy oviposition. However, absence of deadhearts in some accessions under no-choice conditions may be due to failure of neonate larvae to reach the feeding site or inability to feed in the plant whorl. Physico-chemical characteristics of the leaf may also disorient the larvae.

Absence of deadhearts and low larval recovery in *Parasorghum* and *Stiposorghum* may be attributed to larval mortality either due to antibiotic effect of chemicals in the plant tissues or their inability to feed on the leaves/shoots due to anatomical features of the plant. Maximum larval survival and adult emergence were noted in the susceptible check, ICSV 1, but low larval survival was recorded on the resistant check, IS 2205. Prolongation of larval period and low adult emergence were important components of resistance in accessions belonging to *S. halepense* and the accessions belonging to race *virgatum*. While the wild races/species within section *Sorghum* were highly preferred for oviposition, it is possible that they contain some antibiotic compounds that are inimical to larval growth and development. Further biochemical studies are needed to identify the compounds that may be responsible for such antibiotic effects. The present studies suggested that some of the accessions of wild relatives of sorghum though preferred for oviposition, had high levels of antibiosis, suggesting that suitability of plants for feeding of the neonate larvae is not a major factor determining the choice of oviposition site by the *C. partellus* females (Ampofo and Nyangiri 1986). High levels of resistance, which at times were close to immunity, exist in wild relatives of sorghums, and some of these accessions can be used to increase the levels and diversify the bases of resistance to *C. partellus* in sorghum.

Acknowledgements

The authors thank the staff of entomology and genebank for their help in these studies.

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Table 1 Field evaluation of wild relatives of sorghum for resistance to spotted stem borer, *Chilo partellus* (ICRISAT, Patancheru, India)*

Section /species	Accession	Plants damaged (%)	Leaf damage score[1]	Plants with deadhearts (%)
Chaetosorghum				
S. macrospermum	TRC-241162	72.9	3.7	59.1
Heterosorghum				
S. laxiflorum	TRC-243486	7.0	1.0	2.0
	TRC-243492	6.5	1.0	0.0
	IS 18958	0.0	1.0	0.0
Parasorghum				
S. australiense	IS 18954	0.0	1.0	0.0
	IS 18955	0.0	1.0	0.0
	IS 18956	2.0	1.0	0.0
S. brevicallosum	TRC-243491	0.0	1.0	0.0
	IS 18957	0.7	1.0	0.0
S. matarankense	TRC-243576	0.0	1.0	0.0
	RN341	0.0	1.0	0.0
S. nitidum	TRC-243514	0.9	1.0	0.0
S. purpureosericeum	RN285	7.4	1.0	0.0
	IS 18943	0.0	1.0	0.0

	IS 18947	7.9	1.0	0.0
	IS 18951	2.4	1.0	0.0
	IS 18944	8.4	1.0	0.0
	IS 18945	10.9	1.0	0.0
S. timorense	TRC-243437	6.8	1.0	0.0
	TRC-243498	6.5	1.0	0.0
S. versicolor	IS 18926	0.0	1.0	0.0
	IS 23177	0.0	1.0	0.0
	IS 14262	0.0	1.0	0.0
	IS 14275	3.0	1.0	0.0
	IS 18940	0.9	1.0	0.9
	IS 18941	0.0	1.0	0.0
Stiposorghum				
S. angustum	TRC-243598	0.0	1.0	0.0
S. angustum	TRC-243499	0.0	1.0	0.0
S. ecarinatum	TRC-243574	0.0	1.0	0.0
S. extans	TRC-243601	0.0	1.0	0.0
S. interjectum	TRC-243461	0.0	1.0	0.0
S. intrans	TRC-243571	0.0	1.0	0.0
S. intrans	TRC-243602	0.0	1.0	0.0
S. stipoideum	TRC-243399	0.0	1.0	0.0
Sorghum				
race aethiopicum	IS 27584	86.7	6.3	95.3
	IS 18819	87.7	4.8	83.8
	IS 14564	90.6	5.3	90.2
race aundinaceum	IS 18883	72.1	3.7	82.2
	IS 18826	96.2	5.3	84.6
	IS 18830	87.4	3.3	87.4
race verticilliflorum	IS 18865	94.2	4.0	87.2
	IS 14278	85.0	4.5	71.0
	IS 20995	96.5	5.2	88.8
	IS 14717	96.1	3.8	82.5
race virgatum	IS 18803	98.1	5.8	98.1
	IS 18808	94.5	6.8	85.1
	IS 18813	100.0	5.5	94.8
	IS 18817	98.3	6.2	92.2
S. halepense	IS 18891	90.5	4.5	78.4
	IS 33712	100.0	3.3	71.0
	IS 14299	79.2	3.7	71.4
	IS 14212	92.0	5.0	55.6
	IS 18845	86.4	3.5	64.8
	IS 18849	94.4	4.8	67.2
Cultivated checks				
IRC	ICSV 700	82.2	6.2	44.8
IRC	ICSV 708	83.2	5.3	48.8
RC	IS 2205	79.0	4.8	40.8
SC	ICSV 743	99.3	6.8	76.8
SC	ICSV 1	95.9	6.8	93.6
LSD (P 0.05)		16.65**	1.51**	22.99**

* Data are means of two seasons. ** F-test significant at P 0.01. [1]Leaf damage score (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged).

Table 2 Oviposition by spotted stem borer, *Chilo partellus* females on wild relatives of sorghum under multi-choice conditions in the greenhouse (ICRISAT, Patancheru, India).

Section /species	Accession	Egg masses plant^{-1}	Eggs plant^{-1}	Eggs egg mass^{-1}
Heterosorghum				
S. laxiflorum	TRC-243492	3.27	132.87	39.85
	IS 18958	2.93	158.93	52.91
Parasorghum				
S. australiense	IS 18955	3.13	123.47	38.57
S. matarankense	TRC-243576	2.40	106.33	45.95
S. purpureosericeum	RN 285	0.27	7.60	19.00
	IS 18947	0.40	7.73	19.33
S. versicolor	IS 23177	1.13	48.47	37.92
Sorghum				
S.bicolor subsp.*verticilliflorum*				
race *virgatum*	IS 18808	2.87	152.00	49.92
S. bicolor (RC)	IS 2205	1.67	95.00	59.27
S. bicolor (SC)	ICSV-1	2.20	122.20	53.27
LSD (5%)		**NS**	NS	27.77*
Parasorghum				
S. versicolor	IS 14262	0	0	0
	IS 14275	0	0	0
S. purpureosericeum	IS 18944	0	0	0
	IS 18943	0.53	24.4	30.5
	IS 18945	0.07	1.53	7.67
S. australiense	IS 18956	0.53	18.2	21.39
Stiposorghum				
S. angustum	TRC-243499	1.87	62.13	37
S. interjectum	TRC-243461	0.27	10.2	12.75
Sorghum				
S. halepense	IS 14212	3.27	113.53	39.61
S. bicolor (RC)	IS 2205	2.8	91.13	40.79
S. bicolor (SC)	ICSV 1	5.47	249.33	46.29
LSD (5%)		**1.56****	**56.441****	**30.937***
Parasorghum				
S. brevicallosum	IS 18957	3.07	215.40	66.40
S. nitidum	TRC-243514	2.20	104.60	41.95
S. timorense	TRC-243498	0.40	14.93	38.67
Stiposorghum				
S. extans	TRC-243601	0.00	0.00	0.00
S. ecarinatum	TRC-243574	0.20	7.47	24.00
S. stipoideum	TRC-243399	1.60	36.60	22.23
S. intrans	TRC-243571	0.80	62.13	46.29
Sorghum				
S.bicolor subsp.*verticilliflorum*				
race *aethiopicum*	IS 14564	2.40	204.40	93.40
race *arundinaceum*	IS 18826	3.67	192.53	51.80
race *verticilliflorum*	IS 18865	4.13	317.60	71.68

S. bicolor (RC)	IS 2205	1.73	86.53	51.69
S. bicolor (SC)	ICSV 1	4.6	196	42.34
LSD (5%)		1.971**	188.86*	38.56**

*, ** F-test significant at P 0.05, and 0.01, respectively.

Table 3 Evaluation of wild relatives of sorghums for oviposition non-preference by spotted stem borer, *Chilo partellus* females under no-choice conditions (ICRISAT, Patancheru, India)

Section/species	Accession	No. of egg masses plant^{-1}	No. of eggs per egg mass	No. of eggs plant^{-1}
Parasorghum				
S. australiense	IS 18956	4.27	22.52	94.87
S. purpureosericeum	IS 18947	0.27	35.50	14.20
	IS 18943	0.53	18.50	10.93
	RN285	0.93	54.03	51.47
	IS 18945	2.47	44.31	120.47
	IS 18944	2.60	47.00	120.47
S. timorense	TRC-243498	2.53	57.70	141.93
S. versicolor	IS 23177	0.07	2.67	0.53
	IS 14262	0.07	3.67	0.73
	IS 14275	0.13	32.00	6.40
Stiposorghum				
S. ecarinatum	TRC-243574	0.67	53.39	37.13
S. intrans	TRC-243571	2.07	41.06	86.00
S. extans	TRC-243601	0.33	11.56	5.87
S. interjectum	TRC-243461	0.67	64.78	42.20
Sorghum				
S. bicolor (SC)	ICSV 1	4.07	71.57	287.73
S. bicolor (RC)	IS 2205	3.40	49.63	163.67
LSD (5%)		0.835**	31.41**	58.47**

** F-test significant at $P \leq 0.01$.

Table 4 Adult emergence after artificial infestation with 1st instar larvae under no-choice conditions in the greenhouse (ICRISAT, Patancheru, India)

Section/species	Accession	Plants damaged (%)	Deadhearts (%)	Leaf damage rating*	No. of larvae recovered (%)
Heterosorghum					
S. laxiflorum	TRC-243492	29.0	15.3	1.3	0
	IS 18958	100.0	82.5	1.7	6
Parasorghum					
S. australiense	IS 18955	22.9	10.5	1.0	0
	IS 18956	73.1	11.1	1.0	1
S. matarankense	TRC-243576	33.3	5.2	1.0	0
S. nitidum	TRC-243514	93.7	0.0	2.7	0
S.purpureosericeum	RN 285	100.0	11.1	6.0	0
	IS 18943	37.5	0.0	1.0	0
	IS 18944	0.0	0.0	1.0	0
	IS 18945	28.6	12.7	1.3	1
	IS 18947	60.7	8.2	4.3	0
S. timorense	TRC-243498	22.1	0.0	1.0	0
S. versicolor	IS 23177	41.5	0.0	1.0	0
	IS 14262	7.7	0.0	1.0	0
	IS 14275	71.0	14.8	1.0	0
Stiposorghum					
S. angustum	TRC-243499	0.0	0.0	<1	0
S. ecarinatum	TRC-243574	0.0	0.0	<1	0
S. extans	TRC-243601	0.0	0.0	<1	0
S. intrans	TRC-243571	0.0	0.0	<1	0
S. interjectum	TRC-243461	0.0	0.0	<1	0
S. stipoideum	TRC-243399	0.0	0.0	<1	0
Sorghum					
S. bicolor subsp. *verticilliflorum*					
race *virgatum*	IS 18808	98.2	98.2	6.0	55 %
S. halepense	IS 14212	98.4	98.4	6.0	65%
S. bicolor (SC)	ICSV-1	98.4	98.4	7.0	90%
S. bicolor (RC)	IS 2205	96.8	43.4	6.0	40%
LSD (5%)		5.9**	4.4**	0.4**	

SC = Susceptible check. RC = Resistant check. *Leaf damage rating (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged). ** F-test significant at P<0.01.