Evaluation of Whorl Damage by Fall Armyworm (Lepidoptera: Noctuidae) on Field- and Greenhouse-Grown Sweet Sorghum Plants[1]

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Abstract The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), is an economically important pest of sorghum, *Sorghum bicolor* (L.) Moench. However, resistance to fall armyworm in sweet sorghum has not been extensively studied. A collection of primarily sweet sorghum accessions were evaluated in the field for natural fall armyworm infestation. Fall armyworm damage ratings ranged from 1.88 $\pm$ 0.35 to 4.75 $\pm$ 0.37, suggesting that a range of response to fall armyworm feeding exists in this collection. Based on the results of field data from two planting dates, accessions with the highest and lowest fall armyworm damage ratings were selected for greenhouse evaluations. At 7 d after infestation, the sorghum accessions, excluding BTx623 and Plant Introduction (PI) 147573, had significantly higher fall armyworm damage than resistant control MP708. Furthermore, at 7 d after the infestation, genotype PI 147573 was the most resistant; whereas, genotypes 13, 22, 'GT-IR8′, and 'GT-IR6′ were the most susceptible to fall armyworm feeding. For the damage ratings at 14 d after the infestation, sorghum Entry 13 had significantly higher fall armyworm damage than GT-IR7 and PI 17548. At 14 d after infestation, all nine sorghum accessions were as resistant as the MP708 resistant control and had significantly less damage than the susceptible control AB24E. These data suggest that the sorghum lines at 14 d have induced resistance in the growing whorl.

Key Words *Sorghum bicolor*, *Spodoptera frugiperda*, maize, infestation

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), occurs throughout the United States and is an economically important pest of sorghum, *Sorghum bicolor* (L.) Moench (Ashley et al. 1989). Fall armyworm infestations in the whorl stage (from five leaves to boot stage) can reduce grain yields of susceptible sorghum lines by 55–80% (Andrews 1988). Furthermore, fall armyworm injury in sorghum can reduce plant height, delay plant maturity, and increase the number of tillers and panicles per plant (McMillian and Starks 1967, Starks and Burton 1979). Fall armyworms overwinter in southern Texas and Florida and migrate within the United States from the Mexican to the Canadian border (Nagoshi et al. 2012). In sorghum, the young larvae (instars 1–3) feed on expanded leaves, and older larvae (instars 4–6) move to the whorl to feed (Luginbill 1928). When the plant is in the reproductive stage, larvae will feed on the leaves and seeds

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(Buntin 1986). Released grain sorghum germplasm lines GT-IR6, GT-IR7, and GT-IR8 have been selected for resistance to fall armyworm and the sorghum midge, *Stenodiplosis* (*Contarinia*) *sorghicola* (Coquillett) (Diptera: Cecidomyiidae) (Widstrom 1998). The grain sorghum genotype CIMMYT 1821 has been characterized as having whorl feeding resistance to fall armyworm in the United States (Wiseman and Gourley 1982, Wiseman and Lovell 1988). However, resistance to fall armyworm in sweet sorghum has not been as extensively studied. The objectives of this study were to identify genotypes of sweet sorghum with fall armyworm resistance or susceptibility from a naturally infested sweet sorghum nursery collection and to confirm the fall armyworm resistance or susceptibility using artificially infested greenhouse-grown plants.

Materials and Methods

Plant materials for the field nursery. A primarily sweet sorghum nursery collection consisting of 117 accessions (Table 1) were grown in Tifton, Georgia, during 2009 with two planting dates of 13 May and 14 July. The collection consisted of 65 inbred lines from the USDA-ARS Plant Genetic Resources Conservation Unit, Griffin, Georgia, 26 inbreds and hybrids from the University of Florida, 15 inbred lines and hybrids from the USDA-ARS in Tifton, and 11 commercial inbred lines.

Fall armyworm damage ratings in the sweet sorghum field nursery. Feeding damage caused by natural fall armyworm infestation in the field was rated on 4 August (83 d after planting) and 18 September 2009 (66 d after planting). A visual rating scale was used, as described by Ni et al. (2008), of 1–9 where 1 = no damage and 4 = completely lost the whorl tissue, and 9 = completely defoliated. The rating presented in Table 1 was based on the average fall armyworm damage rating on all plants examined.

Experimental design and data analysis for the field nursery. For the field screening, each of the two plantings utilized a randomized complete block design. Each plot was a two-row plot (6 $\times$ 2 m), and each entry had two replications (Anderson et al. 2011). The field data were analyzed as a split-plot design with the two plantings as the main plot and the accession entries as the subplot. The data were analyzed by PROC MIXED using the accession entries as the fixed effect, and the other factors (i.e., planting, replication, row, and means) were separated using the Fisher's Protected LSD test ($\alpha = 0.05$) (SAS Institute 2003).

Plant materials for the greenhouse experiment. Based on the field data collected in 2009, six entries that displayed the highest (Entries 13, 22, and 63) and lowest (Entries 2, 54, and 82) natural fall armyworm damage were selected for a greenhouse experiment with two trials in 2013, which were planted on 25 July 2013 and 23 September 2013, respectively. Three resistant lines, GT-IR6, GT-IR7, and GT-IR8, were released in 1997 as combined sources of resistance to leaf feeding by fall armyworm and to the sorghum midge, and greater selection for resistance to insects occurred in the GT-IR7 than in the GT-IR6 population (Widstrom 1998). Most of the previous studies of fall armyworm resistance in sorghum have been conducted under field conditions (Diawara et al. 1990, 1992) or grown in the field and then dried and ground for use in artificial diet bioassays (Wiseman and Duncan 1989). Therefore, two maize lines, 'AB24E' and 'MP708′, which have been

Table 1. Fall armyworm damage ratings of the 116 accessions* observed from the two plantings in 2009.

Entry	Name	Other Name/Pedigree	*n*	Damage Rating
78	PI 196584		8	4.75 ± 0.37 a
3	ATx 625		5	4.6 ± 0.51 ab
4	BTx 625		8	4.56 ± 0.8 ab
63*	PI 147573	MN 600	8	4.5 ± 0.33 ab
93	PI 562716	Honey No. 2	8	4.5 ± 0.42 ab
66	PI 152909	Mahananga	8	4.38 ± 0.50 abc
96	PI 586443	MN 818	8	4.38 ± 0.26 abc
18		(A11 × (AY18 × TAM 2566)-23-1-1-B	8	4.25 ± 0.37 a–d
39		Brandes (Gorbet)	8	4.25 ± 0.45 a–d
84	PI 257600		8	4.25 ± 0.25 a–d
22*		(A Wheat. × AF28)-6-2-2-2-B	8	4.13 ± 0.23 a–e
7		Brandes (Hanna)	8	4 ± 0.19 a–f
13*	87-5542-49	bmr	8	4 ± 0.68 a–f
14	A 98 (Tift98 bmr A1)		8	4 ± 0.6 a–f
19		(A Wheat. × AF28)-1-1-1-B	8	4 ± 0.27 a–f
28			8	4 ± 0.53 a–f
85	PI 257602		7	4 ± 0.31 a–f
112	PI 651493	Ramada	8	4 ± 0.38 a–f
5			8	3.88 ± 0.55 a–g
32		(A11 × (AY18 × TAM 2566)-25-2-2-B	8	3.88 ± 0.52 a–g
34		(AY55 × AF28)-42-1-1-1-3	8	3.88 ± 0.30 a–g
46	Bundle King BMR		8	3.88 ± 0.55 a–g
47	Sweeter ’N Honey II BMR		8	3.88 ± 0.40 a–g
111	PI 643017	MN 2672	8	3.88 ± 0.30 a–g
16	BK6		8	3.75 ± 0.49 b–h
17	BK7		8	3.75 ± 0.37 b–h

Table 1. Continued.

Entry	Name	Other Name/Pedigree	*n*	Damage Rating
31		(A11 × (AY18 × TAM 2566)-25-1-3	8	3.75 ± 0.37 b–h
33		(A11 × (AY18 × TAM 2566)-13-2-1-1-1-1	8	3.75 ± 0.25 b–h
65	PI 152771		8	3.75 ± 0.62 b–h
69	PI 155336	Muyo, MN 1569	8	3.75 ± 0.49 b–h
95	PI 583832	TOP 76-6	8	3.75 ± 0.53 b–h
30		(AY55 × AF28)-42-3-3-B	8	3.63 ± 0.32 b–i
36	04 BK 8-1		8	3.63 ± 0.26 b–i
110	PI 643013	MN 2576	8	3.63 ± 0.38 b–i
114	PI 651497	Theis	8	3.63 ± 0.38 b–i
8	84–5660 AF 28	84–5660 AF 28	8	3.5 ± 0.45 c–j
23		(A11 × (AY18 × TAM 2566)-12-2-1-B	8	3.5 ± 0.33 c–j
35		(ATx630 × McCurdy Bird off)	6	3.5 ± 0.43 c–j
38	PI 651414	Mer 76-3	8	3.5 ± 0.65 c–j
45	X47345		8	3.5 ± 0.42 c–j
83	PI 257599	No. 5 Gambela	8	3.5 ± 0.33 c–j
89	PI 511355	Smith	8	3.5 ± 0.33 c–j
113	PI 651495	Dale	8	3.5 ± 0.19 c–j
21		(A Wheat. × AF28)-6-1-1-1-B	7	3.43 ± 0.37 c–j
9	Tift MR9115		8	3.38 ± 0.32 d–l
26		(AY55 × AF28)-42-1-1-1-B	8	3.38 ± 0.50 d–l
49	Topper		8	3.38 ± 0.32 d–l
86	PI 260210		8	3.38 ± 0.32 d–l
103	PI 641821	Honey Drip	8	3.38 ± 0.50 d–l
42	B2816C		7	3.29 ± 0.64 d–m
51	Pace Setter		7	3.29 ± 0.47 d–m
56	PI 52606	MN 2680	7	3.29 ± 0.42 d–m

Table 1. Continued.

Entry	Name	Other Name/Pedigree	*n*	Damage Rating
12			8	3.25 ± 0.53 e–m
48	Dale		8	3.25 ± 0.37 e–m
57	PI 144134		8	3.25 ± 0.41 e–m
58	PI 144331	Isidomba, MN 400	8	3.25 ± 0.31 e–m
67	PI 152914		8	3.25 ± 0.37 e–m
71	PI 170787		8	3.25 ± 0.31 e–m
74	PI 180008	Juar	8	3.25 ± 0.45 e–m
94	PI 566819	Della	8	3.25 ± 0.25 e–m
108	PI 641893	Dwarf Ashburn	8	3.25 ± 0.41 e–m
25	03 BK 7B		7	3.14 ± 0.26 f–n
37		(AY55 × AF28)-46-2-1-1-1	7	3.14 ± 0.67 f–n
1	ATx 623		8	3.13 ± 0.4 f–n
6			8	3.13 ± 0.35 f–n
20		(A11 × (AY18 × TAM 2566)-11-1-1-2-B	8	3.13 ± 0.30 f–n
27		(AY55 × AF28)-49-1-1-B	8	3.13 ± 0.44 f–n
41	A2816C		8	3.13 ± 0.67 f–n
44	Pacesetter BMR		8	3.13 ± 0.35 f–n
52	Bundle King		8	3.13 ± 0.30 f–n
55	PI 48191	Saccaline, MN 276, MN 26	8	3.13 ± 0.35 f–n
61	PI 145632		8	3.13 ± 0.58 f–n
68	PI 154800		8	3.13 ± 0.13 f–n
72	PI 177156		8	3.13 ± 0.13 f–n
15	Tift98 bmr B1		8	3 ± 0.53 g–o
43	Pacesetter		6	3 ± 0.63 g–o
53	Keller		8	3 ± 0.38 g–o
70	PI 156890		8	3 ± 0.27 g–o
73	PI 177554		8	3 ± 0 g–o

Table 1. Continued.

Entry	Name	Other Name/Pedigree	*n*	Damage Rating
87	PI 302120	MN 4155	4	3 ± 0 g–o
88	PI 302131	MN 4179	8	3 ± 0.19 g–o
98	PI 641806	Ames Amber	8	3 ± 0.27 g–o
100	PI 641810	Colman (Y)	8	3 ± 0.19 g–o
109	PI 642999	Leoti-Peltier	8	3 ± 0.38 g–o
92	PI 535785	N100	8	2.88 ± 0.30 h–p
102	PI 641817	Early Sumac	8	2.88 ± 0.30 h–p
115	PI 653411	M 81E	8	2.88 ± 0.30 h–p
29		(ATx630 × McCurdy Bird off) (tan)	6	2.83 ± 0.31 h–q
99	PI 641807	Atlas	5	2.8 ± 0.37 h–q
50	Sugar Drip		8	2.75 ± 0.25 i–q
97	PI 586541	Tracy	8	2.75 ± 0.16 i–q
104	PI 641834	Planter	8	2.75 ± 0.49 i–q
105	PI 641835	Rex	8	2.75 ± 0.25 i–q
10	Tift MR9120		8	2.63 ± 0.38 j–q
59	PI 145622		8	2.63 ± 0.32 j–q
60	PI 145626		8	2.63 ± 0.46 j–q
62	PI 146890	Sugar Drip, MN 591	8	2.63 ± 0.32 j–q
76	PI 193073		8	2.63 ± 0.26 j–q
116	PI 653616	Wray	8	2.63 ± 0.42 j–q
117	PI 653617	Keller-GRIN	8	2.63 ± 0.42 j–q
24		(ATx630 × McCurdy Bird off)	6	2.5 ± 0.56 k–q
64	PI 152714		8	2.5 ± 0.27 k–q
81	PI 250897		8	2.5 ± 0.27 k–q
101	PI 641815	Early Folger	8	2.5 ± 0.38 k–q
106	PI 641848	Texas Seeded Ribbon	8	2.5 ± 0.33 k–q
107	PI 641862	Collier, MN 715	8	2.5 ± 0.33 k–q
80	PI 201723		7	2.43 ± 0.37 l–q
11	Tift MR9110		8	2.38 ± 0.38 n–q

Table 1. Continued.

Entry	Name	Other Name/Pedigree	*n*	Damage Rating
79	PI 198885		8	2.38 ± 0.26 n–q
82*	PI 250898	MN 4134	8	2.38 ± 0.18 n–q
90	PI 533998	Brawley	8	2.38 ± 0.26 n–q
54*	PI 17548	Red Amber	8	2.25 ± 0.31 o–q
75	PI 183086	IS 12900, MN 2949	8	2.13 ± 0.30 o–q
2*	BTx623		8	2 ± 0.33 pq
77	PI 196583	MN 3080	8	2 ± 0.38 pq
91	PI 535783	N98	8	1.88 ± 0.35 q

* Total number of accessions planted was 117; only 116 were screened, because the seeds for Entry 40 did not germinate. Damage ratings were based on a 1-to-9 scale (1 = no damage, 4 = lost whorl tissue, 9 = completely defoliated). Means followed by the same letter are not significantly different (LSD test, $\alpha = 0.05$). Entries with asterisks were selected and used for the greenhouse experiment.

extensively used as the controls for fall armyworm resistance research under both field and greenhouse conditions (Chen et al. 2009, Ni et al. 2008), were used as the controls for the current experiment. The maize line AB24E (Ni et al. 2008) was used as the susceptible control, while MP708 was used as the resistant control (Ni et al. 2008, Williams et al. 1990). A total of 11 genotypes (i.e., nine sorghum accessions and two maize lines) was used in the greenhouse experiment (Table 2). The seeds of the 11 entries were planted in Promix BX Biofungicide potting mix (Premier Horticulture, Quakertown, PA) in 18-cm-high black plastic pots (bottom diam. 15 cm, top diam. 19 cm). Each pot was planted with two seeds, except for Plant Introduction (PI) 17548 which was planted with four seeds in Trial 2 because a low germination rate had been observed in the first trial. Ten days after emergence, the plants were thinned to one seedling per pot. Plants were grown in a heated greenhouse set at 27°C and fertilized weekly with 1.2 g of 16–4–8. Chelated iron was applied to all plants as needed.

Fall armyworm damage ratings from the greenhouse experiment. All of the plants at the 6- or 8-leaf stage were infested with approximately 10 fall armyworm neonate larvae per plant by mixing the larvae with corncob grits and then dispensing the mixture with a “bazooka”-type dispenser into the whorls of the plants. The artificial infestations for the two trials were conducted on 28 August 2013 and 8 November 2013, respectively. The plants in the two trials were 34 and 46 d old, respectively, when the artificial infestations were conducted. At 7 and 14 d after the infestation, whorl damage of all plants was rated using the rating scale described previously by Ni et al. (2008).

Experimental design and data analysis for the greenhouse experiment. For the greenhouse experiment, after emergence, all of the potted plants were placed in a randomized complete block design with 15 replications as the block factor. The

Table 2. Maize and sorghum lines used to assess the response to fall armyworm feeding at 7 and 14 d postinfestation.

Genotype	Species	Type	Pedigree/Alternate Name
BTx623	Sorghum	Grain	BTx3197 × SC170-6
13	Sorghum	Sweet	
22	Sorghum	Sweet	(A Wheat. × AF28)-6-2-2-2-B
PI 17548	Sorghum	Sweet	Red Amber
PI 147573	Sorghum	Sweet	MN 600
PI 250898	Sorghum	Sweet	MN 4134
GT-IR6	Sorghum	Grain	SGIRL-MR1-SGIRL Exp4
GT-IR7	Sorghum	Grain	SGIRL-MR1-SGIRL Exp4
GT-IR8	Sorghum	Grain	SGIRL Exp4 × SGIRL Exp3

insect damage ratings were analyzed by using the PROC GLIMMIX procedure and the least squares means were separated using the Tukey–Kramer procedure ($\alpha = 0.05$) (SAS Institute 2003). The fall armyworm damage ratings at 7 and 14 d after infestation were analyzed separately, with trial, entry, and trial × entry as fixed effects and replication as a random effect. The damage ratings at 7 and 14 d were also compared using a *t*-test, with two samples assuming unequal variance, in Microsoft Excel 2010 (Microsoft Corp., Redmond, WA). In addition, correlation between the field damage ratings and 7- or 14-d damage ratings after the infestation in the greenhouse experiment was analyzed using a Pearson's correlation coefficient calculator (Stangroom 2014), and a Spearman's rank correlation was completed in Microsoft Excel 2010.

Results and Discussion

Fall armyworm damage ratings from the field nursery. A collection of primarily sweet sorghum accessions were evaluated for fall armyworm damage with two plantings under field conditions in 2009. The damage ratings of fall armyworm natural infestation was significantly different among the 116 accessions evaluated ($F = 3.85$; df = 115, 668; $P < 0.0001$). The average fall armyworm damage ranged from 1.88 ± 0.35 to 4.75 ± 0.37 (Table 1), suggesting that a range of response to fall armyworm feeding exists in the sorghum germplasm collection. Two samples obtained from different sources of 'Brandes' (Entries 7 and 39), 'Dale' (Entries 48 and 113), and 'Bundle King' (Entries 52 and 146) had similar levels of fall armyworm damage (Table 1). Previous studies (Murray et al. 2009) have noted that sweet sorghum cultivars from different sources are often genetically different. Yet, the results from the field screening with natural fall armyworm infestation showed that damage for these cultivars obtained from different sources is similar. Furthermore, the natural field infestation data were also in agreement with a greenhouse study by

Cheng et al. (2013) that found 'N98′ (Entry 91) and PI 196583 (Entry 77) had a low fall armyworm damage rating at 7 d and low larval weight at 10 d. In contrast, the line 'Della' (Entry 94) had a medium range of resistance for the natural fall armyworm damage ratings in the current study, but Della had the lowest fall armyworm damage rating at 14 d and low larval weight after 10 d in the report by Cheng et al. (2013). In addition, four of the six brown midrib (bmr) lines, lines with low lignin, reddish-brown pigmentation of the midrib of the leaves, and improved forage digestibility, were in the top 25 most susceptible entries (i.e., Entries 13, 14, 15, 44, 46, and 47). A relationship of reduced lignin and high level of fall armyworm damage exists. A study examining 42 sorghum conversion lines for fall armyworm damage detected significantly higher average lignin content in the panicles of the lines identified as resistant as compared to lines identified as susceptible (Mousa et al. 1991).

Fall armyworm damage ratings from the greenhouse experiments. Three entries with some of the highest (Entries 13, 22, and 63) or lowest fall armyworm damage ratings (Entries 2, 54, and 82) were selected for the greenhouse experiments. Henceforth, we will use the cultivar or PI name instead of the entry name if an alternative name is available. As determined by a *t*-test, fall armyworm damage ratings were significantly greater at 14 d than at 7 d postinfestation ($t = -6.66236$; df $= 587$; $P < 0.0001$). This is logical as by 14 d the fall armyworm has reached a late larval development stage in which feeding damage is much greater than in the earlier instars of the larval development. Maize susceptible control AB24E had a significantly higher fall armyworm damage rating than the resistant maize line MP708 at both 7 and 14 d after infestation (Fig. 1A, B), indicating the greenhouse conditions we used were sufficient for distinguishing resistant versus susceptible genotypes. At 7 d postinfestation, the sorghum entries BTx623 and PI 147573 had similar levels of fall armyworm damage as compared to the resistant maize line MP708 (Fig. 1A). However, at 14 d, all sorghum lines had similar levels of damage as MP708 (Fig. 1B). The susceptible maize line AB24E had similar damage ratings to all sorghum lines at 7 d, but at 14 d, all sorghum lines had significantly less fall armyworm damage than AB24E (Fig. 1B). This suggests that most sorghum lines did not have the level of resistance as the resistant maize line at 7 d but, by 14 d after the infestation, all sorghum lines tested had a similar level of resistance to MP708. This suggests that the sorghum lines at 14 d may have induced resistance after injury by the fall armyworm. Induced resistance in many plant species is often mediated by salicylic acid, jasmonic acid, or ethylene (Stout et al. 2009). These differing responses to fall armyworm feeding may be due to different mechanism(s) of fall armyworm resistance in sorghum and maize. The mechanism of maize line MP708 to slow fall armyworm larval growth has been extensively characterized and is a multigenic trait (Brooks et al. 2005, 2007) controlled by, but not limited to, a constitutive high level of jasmonic acid and herbivore defense gene transcripts and the accumulation of the maize insect resistant 1-cysteine protease (Mir1-CP) in the whorl within 1 h of larval attack. This protease attacks the midgut of the fall armyworm and impairs the ability to utilize nutrients from its diet. The fall armyworm larvae respond to the toxin by increasing production of proteins involved in peritrophic matrix production and food digestion, enabling some larvae to acquire nutrients and grow on resistant germplasm

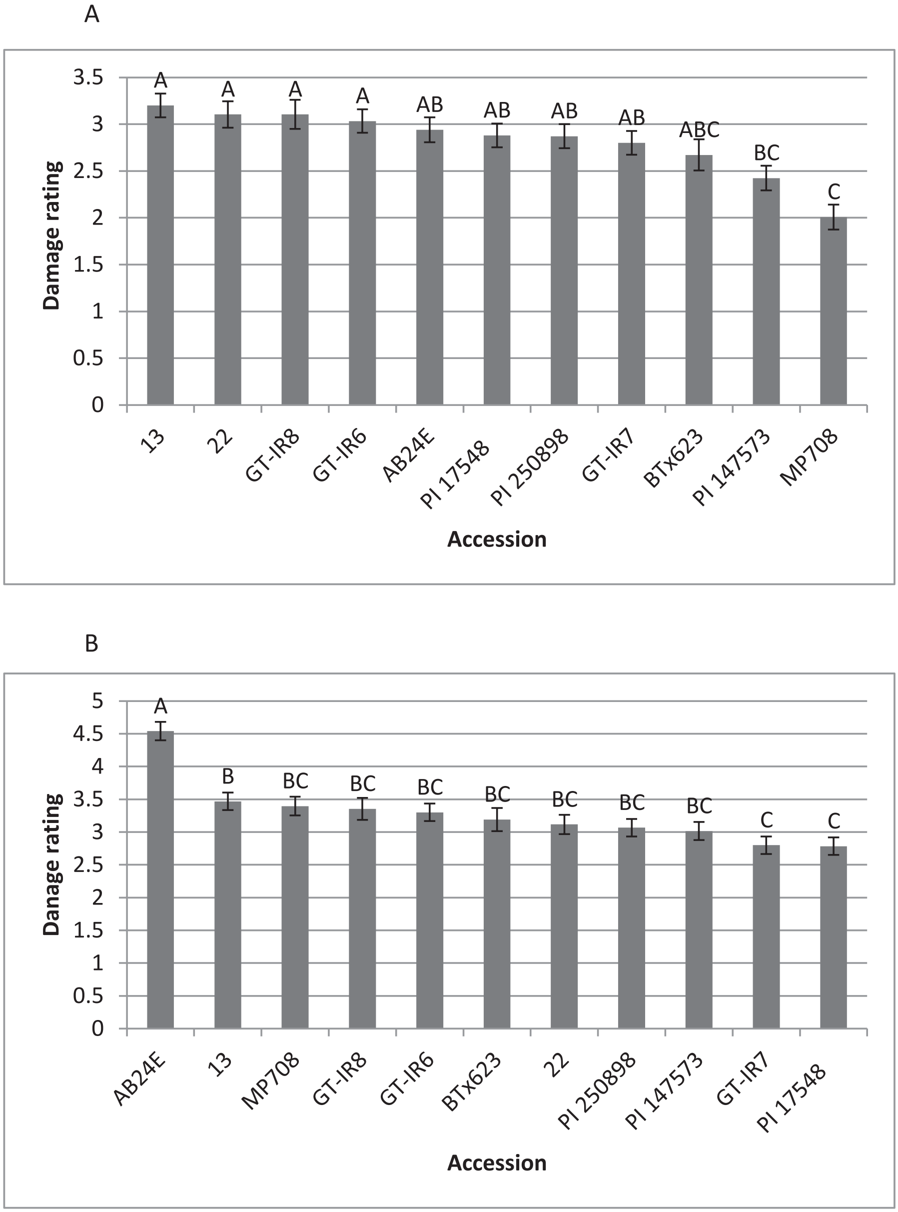

Fig. 1. Greenhouse assessment of fall armyworm damage at (A) 7 d and (B) 14 d after infestation in sorghum and maize lines.

(Fescemyer et al. 2013). To our knowledge, the role of cysteine proteases in the resistance of sorghum to fall armyworm has not been elucidated.

Significant differences among the genotypes for both day ratings exist (7 d: $F = 6.89$; df = 10, 246; $P < 0.0001$; 14 d: $F = 11.71$; df = 10, 248; $P < 0.0001$). For the 7-

d damage rating, there were significant differences between the two trials ($F = 17.76$; df $= 1, 28$; $P = 0.0002$) and genotype $\times$ trial interaction as well ($F = 2.05$; df $= 10, 246$; $P = 0.03$). At 7 d, the average fall armyworm damage rating for Trial 1 was significantly higher than Trial 2 (3.01 ± 0.06 versus 2.63 ± 0.06), which indicates that fall armyworm damage was greater in the first trial than in the second trial. For the sorghum plants at the 7-d rating for both trials, genotype Entries 13 and 22, GT-IR8, and GT-IR6 showed significantly higher fall armyworm damage than PI 147573 (Fig. 1A).

For the 14-d damage ratings, there was not a significant trial effect ($F = 0.62$; df $= 1, 28$; $P = 0.44$), suggesting that fall armyworm damage at 14 d between the two trials was similar, but there was a significant genotype ($F = 11.71$; df $= 10, 248$; $P = <0.0001$) effect, as well as genotype $\times$ trial interaction ($F = 2.20$; df $= 10, 248$; $P = 0.02$). At 14 d after the infestation, sorghum Entry 13 had a significantly higher fall armyworm damage rating than GT-IR7 and PI 17548 in both trials (Fig. 1B). Data from both trials of the greenhouse experiment identified Entry 13 as having the highest damage ratings for all sorghum genotypes. Entry 13 could be a suitable susceptible parent for biparental mapping to understand the mechanisms for fall armyworm resistance.

The GT-IR6, GT-IR7, and GT-IR8 lines were previously created for enhanced fall armyworm and sorghum midge resistance (Widstrom 1998). At 7 d after fall armyworm infestation, these plants showed significantly more damage than resistant maize inbred MP708. At 14 d after the infestation, GT-IR6, GT-IR7, and GT-IR8 had similar levels of fall armyworm damage as resistant corn line MP708, but all sorghum lines tested had a level of resistance equivalent to MP708 (Fig. 1B). At 14 d after infestation, GT-IR7, which had a greater selection for resistance to insects than GT-IR6 (Widstrom 1998), showed significantly less fall armyworm damage than the Entry 13.

More sorghum genotypes flowered in greenhouse Trial 2 than in Trial 1 (Table 3). This difference in flowering is likely due to the difference in day length between the two trials but also Trial 2 plants are 12 d older than Trial 1 plants. Sorghum is a short-day plant and even those plants with recessive alleles for *ma1*, *ma2*, and *ma3* flower later under long days than short days (Pao and Morgan 1986). The day length for Trial 1 at 7 and 14 d was 12 h and 39 min and 12 h and 26 min, respectively, while day length for Trial 2 at 7 and 14 d was 10 h and 30 min and 10 h and 20 min, respectively. The majority of the plants were flowering for PI 17548 and GT-IR6 at 14 d after the infestation in both trials under the greenhouse conditions (Table 2). The relationship of maturity and fall armyworm damage could be further examined.

To determine the correlation of fall armyworm damage caused by the natural infestations in the field with fall armyworm damage from artificially infested plants in the greenhouse, the least-squares means of the damage ratings in the field were analyzed with the damage ratings at 7 and 14 d in the greenhouse, respectively. No significant correlation was observed between natural fall armyworm damage in the field and in the greenhouse at 7 d ($r = 0.083$, $n = 6$, $P = 0.88$) or 14 d ($r = 0.3325$, $n = 6$, $P = 0.52$). Under natural infestation conditions in the field, the female adults may selectively deposit their eggs. However, the current greenhouse experiment was conducted as a “no-choice” test, and all of the plants were artificially infested. The greenhouse experiment excluded oviposition preference of the female adults, which

Table 3. Percentage of plants flowering in the two trials recorded 7 and 14 d after the infestation with fall armyworm neonate larvae.

Genotype	Trial 1—7 d	Trial 1—14 d	Trial 2—7 d	Trial 2—14 d
BTx623	0	0	0	0
Entry 13	0	0	0	13.3
Entry 22	0	0	0	23.1
PI 17548	28.6	73.3	0	60
PI 147573	0	0	38.5	76.9
PI 250898	0	6.7	13.3	33.3
GT-IR6	0	60	53.3	93.3
GT-IR7	0	0	46.7	80
GT-IR8	0	16.7	0	37.5
AB24E	0	0	0	0
MP708	0	0	0	0

is one of the three classic mechanisms of host plant resistance to insects (i.e., nonpreference or antixenosis, antibiosis, and tolerance). The noncorrelation between the field and greenhouse fall armyworm damage rating data suggests that the role of sorghum volatiles in attracting female oviposition under the field conditions should be further examined.

In conclusion, among the sorghum lines evaluated for fall armyworm resistance in a greenhouse experiment, most of the sorghum lines had significantly higher damage ratings than resistant corn line MP708 at 7 d after the infestation. However, at 14 d after the infestation, all of the sorghum lines had a level of resistance that was similar to MP708. For both rating days as well as the two trials, Entry 13 had the highest fall armyworm damage for the sorghum lines tested. This bmr line may serve as a suitable susceptible parent for developing a biparental mapping population.

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