

RESISTANCE TO FALL ARMYWORM IN CONVERTED SORGHUMS

MOUSSA M. DIAWARA
Department of Entomology
University of Georgia
Athens, GA 30602

B. R. WISEMAN
USDA-IBPMRL
Tifton, GA 31793-0748

D. J. ISENHOUR
Department of Entomology
Coastal Plain Exp. Stn.
University of Georgia
Tifton, GA 31793

G. R. LOVELL
USDA-ARS
Experiment, GA

ABSTRACT

Field experiments were conducted in 1988 to evaluate newly converted sorghum, *Sorghum bicolor* (L.) Moench, germplasm for both whorl and panicle resistance to feeding by larvae of the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith). In the whorl-stage resistance study, over 20 and 30 of the entries were significantly more resistant to FAW feeding than the resistant check at 7 and 14 days after infestation, respectively. Significant differences also were found among the entries for the number of FAW larvae that established per panicle 4 days after infestation.

RESUMEN

En 1988 se hicieron experimentos en el campo para evaluar la resistencia del verticilo y de la panícula de nuevos germoplasmas de sorgo, *Sorghum bicolor* (L.) Moench, hacia larvas del gusano cogollero *Spodoptera frugiperda* (J. E. Smith). En el estudio de resistencia del verticilo, más del 20 y 30 de los sorgos fueron significativamente más resistente al gusano cogollero que el patrón resistente, a los 7 y 14 días respectivamente después de la infestación. Se encontraron diferencias significativas entre los sorgos en el número de larvas del gusano cogollero establecidas por panículas, 4 días después de infestadas.

Grain sorghum, *Sorghum bicolor* (L.) Moench, is one of the world's most important food, feed, and fiber crops. The value of sorghum has steadily increased in the United States especially in the southeast over the past two decades (Wiseman & Morrison 1981). The management of insect pests, however, remains a great concern in agricultural systems. Annual loss estimates due to the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), exceed \$300 million in the US (Mitchell 1979). Sparks (1979) reported that farmers in the southeastern United States annually lose between \$30 to 60 million due to the FAW.

One of the best alternatives for controlling insect pests of agricultural crops is to grow insect-resistant cultivars. Painter (1951) defined plant resistance as "the relative

amount of heritable qualities possessed by the plant which influences the ultimate degree of damage done by the insect". The concept of host plant resistance is based on the natural defense mechanisms developed by plant species during their evolution with various herbivorous enemies. The development of resistant germplasm is an important factor for the success of the overall scheme of integrated pest management.

We report here the evaluation of sorghum germplasm for resistance to FAW in the whorl-stage and in the panicle-stage of plant development. The genotypes used in this study were plant introductions that had been converted to day-length-sensitive types (Stephens et al. 1967). Characterization of the potential of new germplasm as sources of pest resistance should be useful for breeding programs.

MATERIALS AND METHODS

The FAW larvae used in this research were reared at the USDA Insect Biology and Population Management Research Laboratory at Tifton, Georgia using the procedures described by Perkins (1979). The sorghum genotypes are originally from different parts of the world including Ethiopia, India, Mexico, Nigeria, Pakistan, Sudan, South America, South Africa, Tanzania, USA, Yemen, and Zimbabwe. The sorghum entries were obtained from the Texas Agricultural Experiment Station at Lubbock after they had been converted to day-length-sensitive types for subtropical use (Stephens et al. 1967). Separate field experiments to determine whorl- and panicle-stage resistance in the converted sorghums to FAW were conducted in 1988 at the Coastal Plain Experiment Station Research Farm at Tifton, Georgia.

Whorl-Stage Resistance Test. The study was conducted on a sandy loam soil (pH ca. 6.4) to which 448 kg ha⁻¹ of 5-10-15 (N-P-K) fertilizer was incorporated prior to sorghum planting. Conventional tillage procedures were employed and plots were irrigated as needed. On May 13, 1988, 340 newly converted sorghums were planted in single rows of 3 m x 76.2 cm. A randomized complete block design with two replications was used. Seeding rate was 5-6 seeds/30.5 cm row. Plants were thinned to a density of 15 to 20 plants per row. A seedling-stage resistant [1821 (CIMMYT)] and susceptible [Huerin] cultivars (Wiseman & Lovell 1988) were used as checks. The sorghums were infested with 2 applications of 25 FAW neonates/plant into the whorl using a mechanical larval dispenser (Wiseman et al. 1980). Applications were made 38 and 39 days after planting. Most of the sorghum lines were in the growth stage (GS) 3 or early GS 4 at time of infestation; but a few were in the GS 5 (Vanderlip & Reeves 1972). Visual insect damage ratings were taken (average of two independent ratings) at 7 and 14 days after infestation (DAI). A 0-9 scale permitted a separation of relative differences in resistance into resistant (0-3), intermediately resistant (4-6), and susceptible (7-9) categories (F. M. Davis, USDA, Mississippi State, MS, personal communication).

Panicle-Stage Resistance Test. A separate planting of the converted sorghum entries for evaluating panicle-stage resistance to feeding by FAW larvae was made on May 16, 1988 using the same procedures as described above. Panicle-stage resistant (Northrup King Savanna 5) and susceptible (Funk H-5245) cultivars (Wiseman et al. 1986) also were included. Prior to the initiation of flowering (between GS 5 and GS 6), the panicle of each plant was infested with ca. 50 FAW neonates using the mechanical larval dispenser. Larvae were maintained on the plant at time of infestation by tightly securing a paper shoot-bag around the base of the panicle just prior to infesting (Wiseman 1989). Establishment/panicle by FAW was determined at 4 DAI. Since germination was not uniform for the different germplasm, counts of larvae were made on 5-15 panicles/entry/replication. Size of the larvae in each panicle was also visually scored as small (<5 mg), medium (6-15 mg), or large (>15 mg) based on weights of several field samples.

Statistical Analysis. Data were subjected to analysis of variance (SAS 1985) and means

were separated at the 5% level using the Waller-Duncan multiple range test (Waller & Duncan 1969). The larval establishment data were transformed to \log_{10} for analysis of variance.

TABLE 1. FALL ARMYWORM LEAF-FEEDING DAMAGE TO CONVERTED SORGHUMS AT 7 AND 14 DAYS AFTER ARTIFICIAL INFESTIONS (DAI), TIFT Co., GA, 1988¹.

Entry	Country of origin	\bar{x} injury rating ²	
		7 DAI	14 DAI
1821 cm (Res. check)	Sudan	5.0 abc	7.0 ab
IS 7565C	Nigeria	6.5 a	5.0 cdef
IS 7757C	Nigeria	6.0 ab	5.0 cdef
IS 3169C	South Africa	5.0 abc	5.0 cdef
IS 12678C	Nigeria	4.5 bc	5.0 cdef
IS 7715C	Nigeria	4.5 bc	4.0 efgh
IS 628C	South America	4.0 c	5.0 cdef
IS 2401C	USA	4.0 c	4.5 defg
IS 7382C	Nigeria	4.0 c	4.5 defg
IS 7438C	Nigeria	4.0 c	4.0 efgh
IS 1333C	Tanzania	4.0 c	4.0 efgh
IS 3612C	Nigeria	4.0 c	4.0 efgh
IS 2246C	India	3.5 cdef	4.5 defg
IS 7367C	Nigeria	3.5 cdef	4.5 defg
IS 3598C	Sudan	3.5 cdef	4.0 efgh
IS 1056C	India	3.5 cdef	4.0 efgh
IS 7498C	Nigeria	3.5 cdef	3.5 fgh
IS 1151C	India	3.0 defg	4.0 efgh
IS 6964C	Sudan	3.0 defg	5.5 bc
IS 3552C	Sudan	3.0 defg	6.5 bc
IS 12679C	Nigeria	3.0 defg	6.5 bc
IS 4023C	India	3.0 defg	7.0 ab
IS 7947C	Nigeria	3.0 defg	3.5 fgh
IS 7399C	Nigeria	3.0 defg	6.0 bc
IS 2177C	India	3.0 defg	8.0 a
IS 7695C	Nigeria	3.0 defg	3.0 gh
IS 7301C	Nigeria	2.5 efgh	3.0 gh
IS 7794C	Nigeria	2.5 efgh	5.5 bc
IS 6962C	Sudan	2.5 efgh	4.5 def
IS 7273C	Nigeria	2.5 efgh	4.0 efgh
IS 7724C	Nigeria	2.0 fgh	3.0 gh
IS 2541C	Sudan	2.0 fgh	5.0 c
IS 12680C	India	2.0 fgh	3.5 fgh
IS 7013C	Sudan	1.5 gh	2.5 h
IS 12633C	Ethiopia	1.5 gh	2.5 h
IS 7444C	Nigeria	1.5 gh	4.0 efgh
IS 12573C	Sudan	1.0 h	4.5 def
IS 6984C	Sudan	1.0 h	3.0 gh
IS 7668C	Nigeria	1.0 h	5.5 bc

¹Ratings followed by the same letter within a column are not significantly different ($P>0.05$; Waller and Duncan's [1969] multiple range test).

²Based on a visual rating scale of 0-9: for rating 7 DAI, 0 = no damage and 9 = many elongated lesions on whorl and furl leaves plus elongated or irregular portions of the furl leaves eaten including basal membrane; for rating 14 DAI, 0 = no damage and 9 = plants almost totally destroyed (F. M. Oavis. USDA, Mississippi State, Miss., personal communication). Visual ratings were made 7 and 14 days after infestation on a plot basis of ca. 15-20 plants/entry with 2 replications.

RESULTS AND DISCUSSION

More than 20 sorghum entries had significantly lower damage ratings than the resistant check at 7 DAI and over 30 entries had significantly less damage than the resistant check at 14 DAI (Table 1). The distribution of the converted sorghum entries based on the leaf-feeding damage for ratings at 7 DAI and 14 DAI is reported in Table 2. Thirty-five entries were rated resistant (<4 rating) to FAW feeding 7 DAI, but only 10 entries maintained that rating 14 DAI. Damage by leaf-feeding did not increase after 7 days on these lines.

More of the sorghum entries were rated susceptible or highly susceptible to FAW leaf-feeding at 14 DAI than at 7 DAI and, thus, a higher frequency of susceptibility was observed at 14 DAI than at 7 DAI (Table 2). However, several damaged entries exhibited tolerance and produced panicles. Also, the early maturing entries grew rapidly through the whorl-stage and FAW larvae did not feed beyond initial establishment as indicated by only pin-hole feeding at 14 DAI.

Significant differences were found among the entries for the number of FAW larvae that established/panicle 4 DAI. However, none of the sorghum introductions had significantly lower larval establishment than the resistant check, and only 3 entries had establishment levels significantly lower than those of the susceptible check (Table 3). Approximately 6 and 15 larvae were counted/panicle on the resistant and susceptible check, respectively. Fourteen entries had establishment levels of <5 larvae/panicle (Tables 3 and 4), while 97 entries had levels of FAW larval establishment of 5-10 per panicle (Table 4). The entries with a larval establishment count between 10 to 15 had the highest frequency. More than 25 larvae/panicle were observed for only 8 entries.

Fewer medium to large larvae were found on panicles of sorghums in which resistance to FAW was a result of non-establishment. In such germplasm as the resistant

TABLE 2. DISTRIBUTION OF DAMAGE RATINGS OF FALL ARMYWORM ON LEAVES OF CONVERTED SORGHUMS AT 7 AND 14 DAYS AFTER ARTIFICIAL INFESTATIONS (DAI), TIFT CO. GA, 1988.

Damage Ratings Class	Distribution of Damage Ratings ¹			
	No. of entries in Class		Frequency of class	
	Rating 7 DAI	Rating 14 DAI	Rating 7 DAI	Rating 14 DAI
0-2	6	0	0.018	0
2-3	7	2	0.021	0.006
3-4	22	8	0.065	0.024
4-5 ²	79	15	0.232	0.044
5-6	126	28	0.371	0.082
6-7 ³	83	57	0.244	0.168
7-8	17	110	0.050	0.324
8-9	0	120	0	0.353
C.V.	18	13		
Total	340			

¹Based on a visual rating scale of 0-9: for rating 7 DAI, 0 = no damage and 9 = many elongated lesions on whorl and furl leaves plus elongated or irregular portions of the furl leaves eaten including basal membrane; for rating 14 DAI, 0 = no damage and 9 = plants almost totally destroyed (F. M. Davis, USDA, Mississippi State, Miss., personal communication). Ratings were made 7 and 14 days after infestation, respectively, on a plot basis of ca. 15-20 plants/entry with 2 replications.

²Class of the resistant check [1821 (CIMMYT)] for rating 7 DAI.

³Class of the resistant check [1821 (CIMMYT)] for rating 14 DAI.

TABLE 3. FALL ARMYWORM LARVAE ESTABLISHMENT/PANICLE OF CONVERTED SORGHUMS AT 4 DAYS AFTER ARTIFICIAL INFESTATIONS, TIFT Co., GA, 1988¹.

Entry	Country of origin	\bar{x} no. of larvae/panicle ²
Funk H-5245 (Suscep. check)	USA ³	15.0 ab
NK Savanna 5 (Res. check)	USA ³	6.0 abcd
IS 7668C	Nigeria	8.5 abcd
IS 7498C	Nigeria	7.0 abcd
IS 1477C	India	4.5 abcd
IS 7595C	Nigeria	4.5 abcd
IS 2549C	Ethiopia	4.5 abcd
IS 6404C	India	4.0 abcd
IS 7518C	Nigeria	4.0 abcd
IS 2508C	Sudan	3.5 abcd
IS 2740C	Uganda	3.5 abcd
IS 2478C	Ethiopia	3.5 abcd
IS 12543C	Ethiopia	3.5 abcd
IS 6411C	India	3.0 abcd
IS 1387C	India	2.5 bcd
IS 530C	Nigeria	2.0 cd
IS 3072C	Sudan	2.0 cd
SC 972C	Sudan	2.0 d

¹Means followed by the same letter are not significantly different ($P>0.05$; Waller & Duncan's [1969] multiple range test).

²Transformed back to actual numbers from log transformations used for analysis of variance. FAW larvae establishment/panicle was counted 4 DAI. Counts were based on 5-15 panicles/entry with 2 replications.

³Commercial industry USA.

TABLE 4. DISTRIBUTION OF FALL ARMYWORM LARVAE ON DEVELOPING PANICLES OF CONVERTED SORGHUMS AT 4 DAYS AFTER ARTIFICIAL INFESTATIONS, TIFT Co., GA, 1988.

No. of larvae/panicle class ¹	No. of entries in class	Frequency of class
0-5	14	0.042
5-10 ²	97	0.289
10-15	118	0.351
15-20 ³	70	0.208
20-25	29	0.086
25-30	3	0.009
30-35	2	0.006
35-40	1	0.003
40-45	1	0.003
45-50	1	0.003
CV	21	
Total	336	

¹FAW larvae establishment/panicle was counted 4 days after infestation. Counts were based on 5-15 panicles/entry with 2 replications.

²Class of the resistant check, NK Savanna 5.

³Class of the susceptible check, Funk H-5245.

TABLE 5. DISTRIBUTION OF FALL ARMYWORM LARVAL SIZE ON DEVELOPING PANICLES OF CONVERTED SORGHUMS AT 4 DAYS AFTER ARTIFICIAL INFESTATIONS, TIFT CO., GA, 1988.

Larva size/panicle class ¹	No. of entries in class	Frequency of class
Small ²	34	0.101
Medium	70	0.208
Large	66	0.196
Small/Medium	55	0.164
Small/Large	19	0.057
Medium/Large ³	77	0.229
Small/Medium/Large	15	0.045
Total	336	

¹FAW larva size for each panicle was determined 4 days after infestation. Classes were defined as follows: Small = <5 mg, Medium = 6-15 mg, Large = >15 mg.

²Class of the resistant check, NK Savanna 5.

³Class of the susceptible check, Funk H-5245.

check (NK Savanna 5), where antibiosis has been reported as the major cause of resistance (Wiseman et al. 1986), the larvae observed/panicle were usually small though sometimes numerous (Tables 4 and 5). Entries such as the susceptible check (Funk H-5245) had a relatively high number of medium to large size larvae/panicle. 'International sorghum (IS) 7498 converted (C)', and 'IS 7668C' showed some degree of both whorl- (ratings of 3.5 and 1.0, respectively) and panicle-stage (7.0 and 8.5 larvae/panicle) resistance.

Visual ratings of whorl damage and counts of the number of FAW larvae that established/panicle provide an indication of both whorl- and panicle-stage resistance in the converted sorghum introductions. However, the more promising entries need to be re-evaluated and the mechanism(s) of resistance need to be investigated in more detail.


ACKNOWLEDGMENTS

The authors thank Johnny Skinner and Charles Mullis for their assistance in this research.

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SEASONAL CHANGES IN BAIT PREFERENCE BY RED IMPORTED FIRE ANT, *SOLENOPSIS INVICTA* (HYMENOPTERA: FORMICIDAE)

MARTIN B. STEIN¹, HARLAN G. THORVILSON, AND JAMES W. JOHNSON
Department of Agronomy, Horticulture, and Entomology
Texas Tech University
Lubbock, Texas 79409

ABSTRACT

Bait stations were established in four different vegetational habitats near Houston, Texas, to attract *Solenopsis invicta* Buren, the red imported fire ant (RIFA). Bait preferences were compared in each habitat for each monthly 24-h sampling period. Foragers located both the high carbohydrate and high protein baits, but greater numbers were recruited to the carbohydrate bait during the sampling periods of the year registering lower temperatures (mean = 17°C). In contrast, when the seasonal temperatures were greater (mean = 25°C), RIFA's were collected in higher numbers on the proteinaceous bait. These findings must be considered when planning a field research project to collect RIFA's.

RESUMEN

Para atraer a la hormiga de fuego roja importada, *Solenopsis invicta* Buren, se establecieron estaciones con cebos en cuatro diferentes habitats vegetacionales en los alrededores de Houston, Texas. Se compararon las preferencias por los cebos en cada habitat para cada período de muestreo (mensual-24 horas). Las forrajeras localizaron tanto los cebos ricos en proteínas como los ricos en carbohidratos, pero mayores números fueron atraídos hacia los cebos de carbohidratos durante los períodos de muestro que registraron temperaturas más bajas (media = 17°C). En contraste, cuando las temperaturas estacionales fueron más alta (media = 25°C), se colectaron mayores números

¹Current address: USDA-ARS, Cropping Systems Research Laboratory, Rt. 3, Box 215, Lubbock, Texas 79401.