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Registration of Twelve Sorghum Germplasm Lines Tolerant to Greenbug Feeding Damage

K. D. Kofoid, R. Perumal,* J. C. Reese, and L. R. Campbell

1ABSTRACT

The biotypic diversity of the greenbug [*Schizaphis graminum* (Rondani)] and development of lines with tolerance to greenbug feeding are ongoing concerns of sorghum [*Sorghum bicolor* (L.) Moench.] breeding programs in the United States. The genetic male sterile population KP7B and four germplasm sources (IS 25246, IS 27002, IS 27834, and IS 27903) were used in population improvement for tolerance to greenbug feeding. Differences in tolerance were quantified by estimating the chlorophyll content of leaf tissues using a SPAD chlorophyll meter following a 7-d period of greenbug feeding on leaves. Twelve sorghum germplasm lines KS 121 (Reg. No. GP-718, PI 651584), KS 122 (Reg. No. GP-719, PI 651585), KS 123 (Reg. No. GP-720, PI 651586); KS 124 (Reg. No. GP-721, PI 651587), KS 125 (Reg. No. GP-722, PI 651588), KS 126 (Reg. No. GP-723, PI 651589), KS 127 (Reg. No. GP-724, PI 651590), KS 128 (Reg. No. GP-725, PI 651591), KS 129 (Reg. No. GP-726, PI 651592), KS 130 (Reg. No. GP-727, PI 651593), KS 131 (Reg. No. GP-728, PI 651594), and KS 132 (Reg. No. GP-729, PI 651595) with enhanced tolerance to greenbug feeding were developed and released by the Kansas Agricultural Experiment Station in October 2007. These lines are three-dwarf (dw_1, Dw_2, dw_3, dw_4) in height, photoperiod-insensitive, and possess unique combinations of plant color and tolerance to damage by greenbug biotypes E, I, and K. All 12 lines restore fertility in the A1 cytoplasm system and hence can be used as R-lines in breeding programs to develop new hybrids with greenbug feeding tolerance.

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Abbreviation: GMS, genetic male-sterile.

Greenbug [(*Schizaphis graminum* (Rondani) (Hemiptera: Aphididae)] is the most important insect pest of sorghum [*Sorghum bicolor* (L.) Moench.] in the southern Great Plains of the United States. This pest frequently causes severe crop damage and economic losses in sorghum production fields (Wilde and Tuinstra, 2000). Biotype I is the most widespread and dominant greenbug pest in sorghum and wheat [*Triticum aestivum* L.] fields, and also on many noncultivated grass species (Wu et al., 2007). Although genetic sources of resistance have been developed to minimize greenbug damage, new greenbug biotypes that overcome these sources of

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resistance appear every few years. It has been postulated that the known greenbug biotypes are preadapted opportunists that take advantage of genetically uniform hosts and are clonally prolific on transient sorghum or wheat crops (Porter et al., 1997). This hypothesis suggests that early biotypes, like biotype E, were not replaced by later biotypes; rather, they remain widespread and will damage sorghum production if sorghum hybrids do not have the relevant resistance genes (Wu et al., 2007). We therefore undertook the development of lines with feeding tolerance to greenbug biotypes E, I, and K.

Twelve sorghum germplasm lines KS 121 (Reg. No. GP-718, PI 651584), KS 122 (Reg. No. GP-719, PI 651585), KS 123 (Reg. No. GP-720, PI 651586); KS 124 (Reg. No. GP-721, PI 651587), KS 125 (Reg. No. GP-722, PI 651588), KS 126 (Reg. No. GP-723, PI 651589), KS 127 (Reg. No. GP-724, PI 651590), KS 128 (Reg. No. GP-725, PI 651591), KS 129 (Reg. No. GP-726, PI 651592), KS 130 (Reg. No. GP-727, PI 651593), KS 131 (Reg. No. GP-728, PI 651594), and KS 132 (Reg. No. GP-729, PI 651595) were developed through population improvement for greenbug feeding tolerance and released by the Kansas Agricultural Experiment Station in October 2007.

METHODS

Population Development

New biotypes of the greenbug that overcome sorghum lines with resistance are found every few years. We used a random-mating recurrent selection method to break undesirable linkages and incorporate desirable genes for feeding tolerance into improved genetic backgrounds. Recurrent selection procedures for plant population improvement are generally restricted to cross-pollinated species. To implement a recurrent selection program in sorghum requires techniques that increase natural outcrossing. In this study, the genetic male-sterile (GMS) population KP7B (plant, purple; seed, white; glume, black) was used because GMS lines produce seed on sterile plants by natural outcrossing. All experiments were conducted at Puerto Vallarta, Mexico (winter nursery) and at the Agricultural Research Center, Hays, Kansas (summer). Evaluation for resistance to the biotype E greenbug identified four germplasm sources—IS 25246 (Ethiopia), IS 27002 (India), IS 27834 (Hungary), and IS 27903 (Sierra Leone)—that lived 4–7 d longer than the susceptible check DK 40 (DeKalb) in a flat-screening trial. These lines were grown in the

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winter nursery in 1990–1991, and each line was crossed to at least three GMS plants from the KP7B random-mating population and to elite lines (KS 97, PI 550610, PI 266965, PI 550607, and Cargill 607E). The F_1 plants were grown in the 1991–1992 winter nursery and individual plants were selected. Seed from the selected plants were bulked while seed from the crosses to the elite lines was maintained separately. During the summer 1992 season, photoperiod-insensitive, 3-dwarf plants from both groups were crossed to genetic male-sterile segregates from each family. Random mating was continued for two more generations with selection for plant height and photoperiod insensitivity. In the early 1990s, biotype I greenbug (Harvey et al., 1991) emerged, replacing biotype E greenbug. After the third cycle of random mating, 200 individual S_1 plants were selected, and the progeny were evaluated for damage by biotype I greenbug feeding.

Recurrent Selection

Progeny from each S_1 plant were grown under controlled conditions in a greenhouse. Plants were watered and fertilized as needed to maintain growth and development. When the flag leaf emerged, five plants from each S_1 were tested in each of three replications. A laboratory colony of biotype I greenbugs was obtained from Dr. John Reese, Department of Entomology, Kansas State University, Manhattan. To assess greenbug feeding tolerance, about 80 greenbugs were placed into a 1.6-cm diameter, double-stick, foam, leaf cage on the youngest fully expanded leaf and allowed to feed for 7 d (Deol et al., 1997). Cages were monitored daily and greenbugs were added if necessary to maintain coverage of the entire area. After 7 d, greenbugs were removed, and the chlorophyll content of the infested and nearby noninfested leaf tissue was measured using a SPAD (Minolta Camera Co., Ltd., Japan) chlorophyll meter. Five measurements were made within each site, and the average value was recorded and used to calculate a tolerance index (Girma et al., 1998). For each cycle of selection, 200 S_1 families were tested in experiments using a randomized complete block design with 10 sets of 20 families plus a commercial check, DK40. Data were standardized (SAS Institute, 1987), and the top 20% of families with tolerance to greenbug feeding were selected for recombination. The selected S_1 families were planted in two-row plots in the field at Hays or in the winter nursery. At flowering, GMS plants were identified, open florets were removed, and the panicles were bagged. After the panicle had flowered, the pollen was randomly bulked from at least four other families and used

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for crossing onto each male-sterile panicle. At least five sterile plants were pollinated in each S_1 family. Seeds from these crosses were bulked, and a second cycle of recombination was done by growing the population in a field in isolation where GMS were identified and allowed to pollinate at random. An equal amount of seeds from each male-sterile plant was bulked to form the next cycle for selection. The recombined population was grown and individual fertile plants were randomly chosen for testing. After two cycles of selection using biotype I greenbugs, a new biotype of greenbug (biotype K) was identified (Harvey et al., 1997). Greenbug biotype K was used in two subsequent cycles of selection.

Line Development

After four cycles of selection for greenbug feeding tolerance, the top 40 families were grown and a single fertile plant from each family was self-pollinated. Progeny from these plants were evaluated for tolerance and those that were significantly less damaged (lower tolerance index) than the check hybrid were self-pollinated. After four generations of inbreeding and testing, the 12 best lines were chosen for release. All 12 lines restore fertility (R-lines) in the A1 cytoplasm system. Fertility restoration in other cytoplasmic systems is not known.

CHARACTERISTICS

Agronomic and tolerance index values for the 12 lines and a check hybrid are listed in Table 1. The change in screening from biotype I to biotype K resulted in a slight increase in tolerance index values (data not presented). After two additional cycles of selection, tolerance index values were significantly better than the check hybrid. All 12 lines were evaluated using a randomized block design with three replications in 2008 and 2009 at the Agricultural Research Center, Hays. Agronomic data were collected and averaged over the two environments. The data were analyzed using SAS software and least square means were calculated using PROC MIXED (SAS Institute, 1987). Days to 50% anthesis varied considerably among the lines, with KS 128 being the earliest and KS 130 being the latest. KS 128 and KS 129 plants are tan while the rest of the lines are purple. Seeds are red for all lines except KS 123 and KS 125, which have white seeds. A negligible number of plants may still segregate for male sterility in later generations because of recessive gene expression of the genetic male-sterility system. These germplasm lines provide

new genetic diversity for greenbug feeding tolerance and can be used for trait improvement in other adapted lines to maximize the grain yield potential.

AVAILABILITY

Seed of each of the lines may be obtained from the corresponding author for a period of 5 yr. Seed has been deposited in the National Plant Germplasm System, where it will be available for distributer 5 yr after the date of publication. It is requested that appropriate recognition be given when these lines contribute to a publication or to the development of new breeding lines or germplasm.

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Table 1. Agronomic characteristics of greenbug-tolerant sorghum germplasm lines in trials conducted at the Agricultural Research Center, Hays, KS in 2008 and 2009.

Line	Tolerance index†	Days to anthesis	Plant height	Seed color	Awns‡	Glume color	Plant color
			cm				
KS 121	0.240	76	95	red	–	black	purple
KS 122	0.233	74	75	red	+	black	purple
KS 123	0.233	75	80	white	+	black	purple
KS 124	0.229	66	70	red	+	black	purple
KS 125	0.208	71	80	white	–	mahogany	purple
KS 126	0.204	69	90	red	–	black	purple
KS 127	0.197	78	95	red	–	straw	purple
KS 128	0.194	56	105	red	+	tan	tan
KS 129	0.189	73	80	red	–	sienna	tan
KS 130	0.185	82	85	red	–	black	purple
KS 131	0.161	73	90	red	–	black	purple
KS 132	0.111	65	115	red	+	black	purple
NC^{+} 272	0.384						
LSD (0.05)	0.125	1.5	6.3				

†Tolerance index = (SPAD reading control − SPAD reading greenbug feeding) ÷ SPAD reading control.

‡+, present; −, absent.