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Damage to Dry Crop Seed by Red Imported Fire Ant (Hymenoptera: Formicidae)

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ABSTRACT Red imported fire ants, *Solenopsis invicta* Buren, have been documented as damaging to planted field crop seed. The seeds are damaged before completion of germination. Five types of field crop seeds [wheat, *Triticum aestivum* L.; corn, *Zea mays* L.; grain sorghum, *Sorghum bicolor* (L.) Moench; cotton, *Gossypium hirsutum* L.; and soybean, *Glycine max* L.] were exposed to red imported fire ants under laboratory conditions to measure damage caused by feeding. The seeds were at an air-dry moisture condition, as typically sown by farmers. Corn, sorghum, and cotton seeds were tested with and without commercial insecticide treatments used on bagged retail-market seeds. Wheat was tested only as untreated seeds and soybean were tested as both inoculated and noninoculated seeds. Our results show that red imported fire ants feed on dry wheat, corn, and sorghum seeds and to a lesser degree on cotton and soybean seeds. Seed treated with an insecticide sustained less damage; however, if dry soil conditions allowed enough time for damage to exceeded 20–30%, as observed for sorghum, then there would still be a substantial risk to seed germination. Untreated wheat seed was the most heavily damaged and yet farmers in the red imported fire ant-infested region of the United States routinely plant untreated wheat seed. Red imported fire ant damage to the seeds of wheat, corn, sorghum, cotton, and soybean may vary from insignificant to severe, depending on exposure time to red imported fire ants, seed type, and whether or not a seed treatment was used.

KEY WORDS *Solenopsis invicta*, insecticide, seed treatments, seed germination

THE RED IMPORTED fire ant, *Solenopsis invicta* Buren, is established in agricultural field crop production areas of 11 states in the United States and in Puerto Rico. More than 112 million hectares of cropland in the United States are infested with red imported fire ants (H. Collins, unpublished data). Infestations are damaging to some crops and the operation of some types of farm machinery and inflict painful stings on farm workers (Lofgren 1986).

In nontilled fields, such as hay meadows or pastures, fire ant infestations are more noticeable because their mounds are visible. Fields that are annually tilled have fewer mounds because of continuous disturbance from conventional tillage practices. Tillage practices for some annual crops include 6 or more passes of various plows, harrows, and cultivators through the upper 10–20 cm of soil. A no-till system only minimally disturbs the soil to shallow depths in localized bands or slots for the application of fertilizers and planting of seed. Drees et al. (1991) stated that no-till and low-till sorghum, *Sorghum bicolor* (L.) Moench, practices allow *S. invicta* densities to increase in planted areas compared with other cultural planting practices.

In 1983, we identified substantial red imported fire ant damage to sorghum and cotton seed in a no-till system at the Temple, TX, Laboratory (unpublished data). Consistent with reports in research publications, extension bulletins, and farm press (Drees et al. 1991, Leonard and Clay 1993, Anonymous 1994), the planted seed were damaged and plant stands diminished most severely when the soil was dry preventing rapid germination.

Lofgren et al. (1961) tested various seeds and other materials for their potential use in toxic baits. Seeds tested included whole corn, *Zea mays* L., soybean, *glycine max* L.; and cottonseed, *Gossypium hirsutum* L., and ground wheat, *Triticum aestivum* L. Their experiments revealed that dry foods or foods that contained a minimum amount of liquid, showed little attractiveness. Drees et al. (1991) found that red imported fire ants damaged dry

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Table 1. Seed type, insecticide and inoculation treatments, varieties, and sizing with sieves

Treatment no.	Seed	Treatment	Variety	Sieve size
1	Wheat	None	McGregor 2180[a]	#8
2	Corn	None	DeKalb DK-656[b]	6.4 mm
3	Corn	Captan and Pirimi-phos-methyl	DeKalb DK-656[b]	6.4 mm
4	Sorghum	None	DeKalb DK-37[b]	#6
5	Sorghum	Captan and Chlorpyri-fos-methyl	DeKalb DK-37[b]	#6
6	Cotton	None	GP 74+[c]	#4
7	Cotton	Thiram and Apron	GP 74+[c]	#4
8	Soybean	None	DeKalb CS-458[b]	#4
9	Soybean	Inoculated with Nitaragin	DeKalb CS-458[b]	#4
10	Control	NA	NA	Grit
11	Wheat (broken)	None	McGregor 2180[a]	NA
12	Corn (broken)	None	DeKalb DK-656[b]	NA
13	Sorghum (broken)	None	DeKalb DK-37[b]	NA
14	Cotton (broken)	None	GP 74+[c]	NA
15	Soybean (broken)	None	DeKalb CS-458[b]	NA

NA, not applicable.
[a] ESCO Seed, McGregor, TX.
[b] DeKalb-Pfizer Genetics, Illiopolis, IL.
[c] G. & P. Seed, Aquilla, TX.

corn and sorghum seed, but water-soaked and germinating seed were damaged at higher rates. Ready and Vinson (1995) screened 96 species and varieties of dry and wet seeds in 28 families for red imported fire ant damage. They found < 5% damage to dry cotton and soybean seeds. Soaking the seed did not increase damage to cotton, soybean, or sorghum, but substantially increased damage to corn and wheat.

The objective of this study was to document the rate of damage to the seed of 5 widely grown crops in red imported fire ant infested regions of the United States.

Materials and Methods

This study was conducted at the USDA–ARS Grassland Soil and Water Research Laboratory at Temple, TX. Cooperation was with the USDA–ARS, Medical and Veterinary Entomology Research Laboratory, Imported Fire Ant and Household Insects Research Unit at Gainesville, FL.

Red imported fire ant colonies were excavated from long-term no-till field plots at Temple, TX. The colonies were floated out of the soil and established in deep trays (52 cm long by 39 cm wide by 13 cm deep) that contained watered dental-plaster cells (150 mm diameter), glass test-tube waterers, and feeding dishes as described by Banks et al. (1981) and Williams (1989). The colonies were maintained in a windowless laboratory at 25°C and a photoperiod of 12:12 (L:D) h. The maintenance feeding diet consisted of dead crickets and a 1:1 dilution of honey and water.

Seeds to be tested were furnished by seed companies (Table 1) both as untreated seeds and as insecticide-treated retail market seeds. Tested seeds were wheat, corn, grain sorghum, cotton, and soybeans; varieties and insecticide treatments are listed with treatment number in Table 1. Seeds were sieved to obtain uniform size, inspected for damaged seed, and sorted into lots of 50 each for the feeding trials. Workers wore latex gloves to avoid leaving any deposits of oils from hands on the seed. Soybean seeds are not usually treated with insecticides, but they are treated with an inoculant before planting. Treatment 9 soybeans were treated with an inoculant (Soybean "S" Culture, The Nitragin Company, Milwaukee, WI) suspended in a solution of sucrose-sweetened drinking soda (Coca-Cola, The Coca-Cola Company, Atlanta, GA). Treatment 10 was a 1:1 by weight mixture of corn grit (crushed Corn Pops, Kellogg USA, Battle Creek, MI) and soy oil. Treatment 10 served as our control food source, which was similar but not identical to the corn grit and soy oil control used by Williams et al. (1991), to confirm that red imported fire ants were present and feeding. Treatments 11–15 were 50 untreated seeds of each crop that had been broken by cutting through individual seeds with hand cutters to eliminate the possibly restrictive barrier of hard seed coats to red imported fire ant feeding.

Feeding trial equipment consisted of 15 separate trays, each provided with a watered cell (Williams 1989), watering tube, and a feeding dish. The dish was a petri dish (100 mm diameter, 15 mm deep) with four 3.2-mm holes drilled into both the sides and a lid allowing access, but preventing removal of seed. Red imported fire ants from a single large colony were subdivided by putting 2,000 workers and some brood in each tray.

Lots of 50 seeds were placed in feeding dishes, weighed to the nearest 0.01 g, and each lot was placed in an individual treatment tray at the start of a feeding trial. Separate lots of 50 seed were weighed and placed in 65°C drying ovens for 24 h to determine the initial dry basis water content.

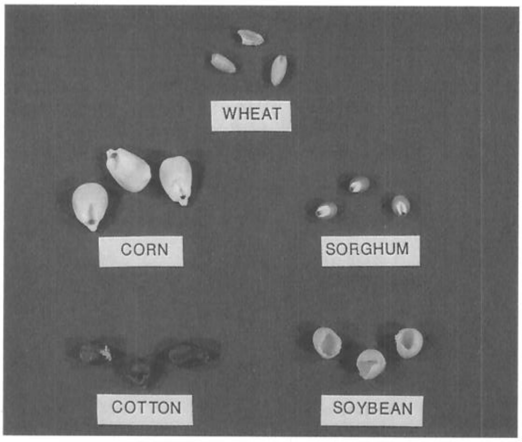

Fig. 1. Dry crop seeds that are visibly damaged after exposure to red imported fire ants.

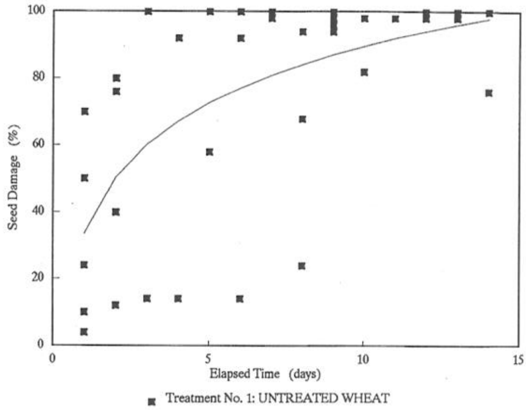

Fig. 2. Visually scored red imported fire ant feeding damage to dry untreated wheat seeds during 14 d of elapsed time; seed damage = 33.54 + 56.02 log(elapsed time), $r2 = 0.40$.

Five other treatment-lots of 50 untreated seed from the 5 seed types were placed in feeding dishes, weighed at the start and termination of each trial (but not offered to the red imported fire ants) to determine any change in seed weight as a result of changes in seed water content during the trial. Seed in treatments 1–9 were inspected for damage at 1- to 3-d intervals during the 14-d duration of each trial. Any seed with marks of red imported fire ant feeding (breaking through the pericarp) were scored as damaged. Broken seed in treatments 10–15 could not be scored for damage and were evaluated by differences between initial and final weights. Final weights were taken for all treatments to determine the amount of seed weight loss caused by feeding. Seeds from treatments 1–9 and water-loss control seed lots were placed on moistened filter paper in covered petri dishes for 6 d after the feeding trial and germination was monitored. The procedure was replicated 5 times, using red imported fire ants from 5 separate colonies.

Data were analyzed by calculation of means, standard deviations, and correlation coefficients using SAS statistical software (SAS Institute 1988) and by regressions to represent trends in data among replications. Seed weight loss means were compared by using the Duncan multiple range test and rates of damage by using Student *t*-test. Regression equations were written on the plotted illustrations.

Results and Discussion

The initial seed water content ranged from 7 to 10.6% dry basis moisture content and may be viewed as typical water contents of seeds at planting. Seed weight changes during the study, indicating seed water content changes, were only ±1–2% so that any substantial weight losses from material in the feeding dishes could be attributed to *S. invicta* feeding damage.

The 5 types of crop seeds were fed upon by red imported fire ants with damage ranging from minor surface scarification to whole seed destruction. The most common mode of seed damage was located at the base of the seed embryo, where the seed was often hollowed-out from removal of the high protein embryo (Fig. 1). This mode of damage was predominate in the wheat, corn, and sorghum seed. The relatively hard-coated cotton and soybean seeds rarely were penetrated by the red imported fire ants; however, if the pericarp was breached, seeds were almost completely eaten. This may have been because both cotton and soybean are high protein oil-seed and provide a more desirable food source for the red imported fire ants than the starchy endosperm of the other types of seeds.

The percentage of seeds with visible damage is plotted against the elapsed feeding time for the red imported fire ants in Figs. 2–5. Although some data are widely separated among replications, regression lines indicate general trends for each treatment. Of all the treatments, the untreated wheat seed had the highest rate of damage with ≈100% damage within 10 d (Fig. 2). Other untreated seeds had approximately double the damage as inflicted on the same seed that was insecticide treated, as typically purchased by farmers (Figs. 3, 4, and 5A). The exception was that inoculated soybean seed was 2–3 times more damaged as compared with noninoculated soybeans (Fig. 5B). The inoculant and sugar-laden drinking soda that was used for a sticker and inoculant activator may have been an attractant or perhaps a softening agent on the seed coat.

In all cases, the red imported fire ant damage to the seed reached stable values within the range of elapsed time from 10 to 15 d (Figs. 2–5). This finding has potential implications for nonirrigated farming wherein planted seeds occasionally remain nongerminated for periods of 10–20 d before rains

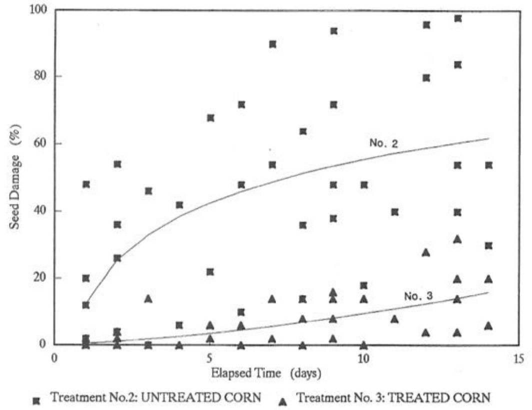

Fig. 3. Red imported fire ant feeding damage to dry untreated corn seeds; seed damage = 12.25 + 43.33 log(elapsed time), $r2$ = 0.32. For dry corn seeds commercially treated with Captan and Piriimiphos-methyl, seed damage = 0.541(elapsed time) + 0.048(elapsed time)^2, r^2 = 0.40.

or migrating soil water are sufficient to support germination and emergence. It is during such periods of slow crop emergence that farmers report seed damage caused by red imported fire ant feeding (Drees et al. 1991). If our data are indicative of field conditions, then growers might expect from 15 to 95% damage to wheat, corn, and sorghum seed during periods of slow germination. Damage will depend on the elapsed time, seed type, and whether or not insecticidal seed treatments were used. Dry cotton and soybean seed appear to be less vulnerable to red imported fire ant feeding, with damage in the range of < 10%. This damage would be difficult to detect and of lesser economic importance.

Specific rates of seed damage for the period up through 10 d, arbitrarily chosen to be the period

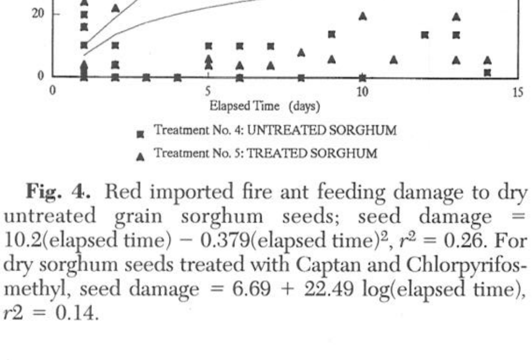

Fig. 4. Red imported fire ant feeding damage to dry untreated grain sorghum seeds; seed damage = 10.2(elapsed time) − 0.379(elapsed time)^2, r^2 = 0.26. For dry sorghum seeds treated with Captan and Chlorpyrifos-methyl, seed damage = 6.69 + 22.49 log(elapsed time), $r2$ = 0.14.

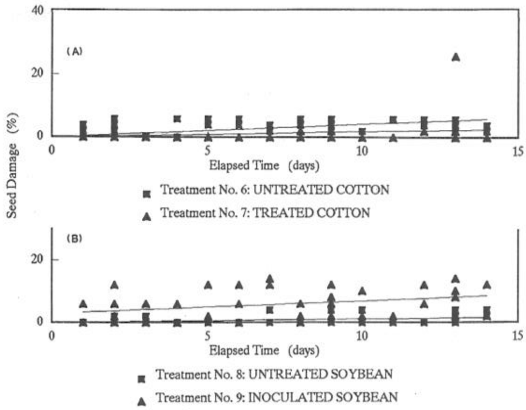

Fig. 5. Red imported fire ant feeding damage to dry untreated cotton seeds; seed damage = 4.39 log(elapsed time), r^2 = 0.05. For dry cotton seeds treated with Thiram and Apron, seed damage = 0.177(elapsed time), r^2 = 0.07. For untreated dry soybean seeds, seed damage = 0.109 (elapsed time), $r2$ = 0.13. For inoculated dry soybean seeds, seed damage = 2.91 + 0.393(elapsed time), r^2 = 0.13.

before the responses leveled, are given in Table 2. Acknowledging that there were large differences in feeding rates among replications, our data indicate that untreated wheat, corn, and sorghum seed with damage rates in the range of 6–11%/d would require germination in 2–3 d to avoid a potential crop stand failure. Treated sorghum seeds could also fall into the potential stand failure group if planted when germination is delayed 10–14 d after planting. They could suffer up to 36% damage. Farmers should use insecticidal seed treatments to hedge against the risk of red imported fire ant-induced wheat, corn, and sorghum seed damage.

Of the 2 methods for assessing seed weight loss, the percentage of weight loss was more highly correlated (r = 0.644, P = 0.0001) with the number of seed damaged than was the quantitative seed weight loss (r = 0.329, P = 0.027). Weight loss data were required for this study because of the

Table 2. Red imported fire ant feeding damage (percentage per day) rates to dry seed during the first 10 d of exposure

Seed	Seed condition	Rate of damage[a]
Wheat	Untreated	11.17a
Corn	Untreated	6.44b
Corn	Treated	0.88d
Sorghum	Untreated	7.14b
Sorghum	Treated	3.31d
Cotton	Untreated	0.54d
Cotton	Treated	0.03e
Soybean	Untreated	0.11e
Soybean	Inoculated	0.85d

Student t-test separations; rates followed by the same letter are similar at $P < 0.05$ ($t_{0.05}$ = 2.01).

[a] Rate is regression coefficient for first 10 d of study, with the regression forced through a zero intercept.

Table 3. Seed weight loss, apparently caused by ant damage/feeding

Seed	Seed weight loss, %		
	Untreated	Treated	Broken untreated
Wheat	7.1c	NA	26.9a
Corn	2.6c	0.49c	3.9c
Sorghum	6.9c	2.3c	20.1b
Cotton	2.0c	0.22c	7.0c
Soybean	0c	3.9c	0.79c
Control	0.58c	0.58c	0.58c

Means with the same letter are not different at the 5% level of significance in the Duncan multiple range test. NA, not applicable.

inclusion of treatments with broken seed wherein damage could not be assessed. Final seed germination was highly correlated with the number of seeds that were visibly damaged ($r = 0.975$, $P = 0.001$). Therefore, final germination would be an adequate index of red imported fire ant damage to whole dry seed.

The red imported fire ants consumed 3–4 times more of the broken sorghum and wheat seed than whole seed, respectively (Table 3). Although the weight losses of other seed lots were not significantly different, the breaking of the seed to reduce mechanical impedance to feeding did tend to increase the percentage of seed weight that was consumed. Some types of broken seeds may be more vulnerable to red imported fire ant feeding, but the data document that appreciable damage can occur to whole seed.

In conclusion, red imported fire ants do feed on dry wheat, corn, and sorghum seed and to some extent on dry cotton and soybean seed, under laboratory conditions. Inspection of the seed for feeding damage was useful to determine the rate of damage during the 14-d test. Final seed germination was highly correlated with damage and would be equally useful for determining the degree of red imported fire ant feeding damage to dry seed. Tested commercial insecticidal treatments did reduce red imported fire ant feeding, but if damage exceeded 20–30%, as seen for treated sorghum, then there would still be a substantial risk of crop stand failure. Untreated wheat seed was the most damaged, and yet farmers in the red imported fire ant infested region of the United States routinely plant untreated wheat seed. These results suggest that wheat should be treated with a repellant or insecticide to reduce the risk of crop stand failure. Red imported fire ant damage to the dry seeds of the 5 crops we tested may vary from insignificant to severe, depending on exposure time, seed type, and seed insecticidal treatment.

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