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Hull characteristics as related to susceptibility of different varieties of rough rice to *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae)☆

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Abstract

Rhyzopertha dominica (F.), an important pest of stored grains, causes economic damage to rough rice through physical damage to the kernel, resulting in reductions in grain quality. In this test, 28 varieties of commercial rough rice (10 long grain, 11 medium grain, and 7 short grain) were examined for solid, split and cracked hulls, hull thickness, and adult emergence from neonate *R. dominica* introduced on each individual variety. The percentage of solid hulls ranged from 55.5% on Koshihikari variety to 92.8% on Akita variety, and the percentages of cracked and split hulls were correlated with increased susceptibility. The Dobie index for progeny production showed Wells, Jupiter, and Pirogue varieties as the most tolerant to *R. dominica*, while Rico and Francis were the most susceptible. The hull thickness of rough rice varied among varieties, but the tolerant varieties appeared to have thicker hulls than the susceptible varieties. There was no difference among rice types (long-, medium-, or short grain) regarding tolerance or susceptibility to *R. dominica*. Results show that the characteristics of the rough rice hull are important for conferring susceptibility of individual varieties to *R. dominica*.

Keywords: *Rhyzopertha dominica*; Dobie index; Rough rice; Bioassay; Host plant resistance

1. Introduction

Since 1911, about 140 varieties of rice have been released in the United States of America (USA), with improved characteristics for agronomic production, field tolerance to insects and diseases, milling and baking quality, and industrial cooking preferences (Moldenhauer et al., 2004). Rice is categorized as long-, short-, or medium grain, and different varieties of each type have been created through demands of the milling industry and end-use consumers. There are two major rice-producing regions in the USA—the Gulf Coast region and the Sacramento Valley of California (Moldenhauer et al., 2004). More than 70% of the long grain rice is produced in the Gulf Coast region, medium grains are produced in both areas, and short grain rice is almost exclusively grown in California (Childs, 2004).

Rhyzopertha dominica (F.), the lesser grain borer, is an important pest of most stored raw grains, including rough rice. The developing larva feeds inside grain kernels, and can cause weight loss and damage to the germ and endosperm in wheat (Gundu Rao and Wilbur, 1957; Campbell and Sinha, 1976). Weight loss from individual kernels has also been reported with different varieties of triticale, a wheat-rye hybrid (Baker et al., 1991), and in rice infested with *R. dominica* (Nigam et al., 1977). Several methods have been used to assess varietal resistance of various grains to stored-product insects (Breese, 1960; Cogburn, 1977; Cogburn and Bollich, 1990; Baker et al., 1991; Toews et al., 2000; Throne et al., 2000; Watts and Dunkel, 2003), including feeding damage as measured by frass production (Baker et al., 1991), and biological

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parameters such as developmental rate, fecundity, hatch rate, and longevity of adult insects (Singh et al., 1986; Dobie and Kilminster, 1978).

Rice is generally stored as rough rice, and the hull may offer some protection from stored-product insects such as *R. dominica*. Other potential internal insect pests of rough rice include *Sitotroga cerealella* (Olivier), the Angoumois grain moth; *Sitophilus oryzae* (L.), the rice weevil; and *Sitophilus zeamais* Motschulsky, the maize weevil. Some of the properties of the rice grain, such as tightness of the hull, kernel hardness, and chemical composition of the kernel (Juliano, 1981; Breese, 1960; Cogburn, 1974; Cogburn et al., 1983) were found to confer some level of tolerance to stored-product insects. Many new varieties of rice have been developed in recent years, but there have been few assessments of varietal susceptibility or tolerance to *R. dominica*. Varietal tolerance in different stored commodities has been advocated for inclusion into management programs for insect pests (Throne et al., 2000). Therefore, the objectives of this test were to: (1) assess varieties of rough rice for susceptibility to *R. dominica* and (2) determine if specific characteristics of the rice hull confer susceptibility or tolerance to *R. dominica*.

2. Materials and methods

2.1. Classification of rice kernels

A total of 28 current commercial varieties were obtained from the University of Arkansas, Louisiana State University, the USDA in Beaumont, TX, Lundberg Family Farms, Richvale CA, and the Butte County Rice Growers Association, Richvale, CA. All rice obtained was from the 2004 crop year; however, some of these varieties were commercially grown, while others were from limited production maintained for seed stock. When rice samples arrived at the USDA-ARS Grain Marketing and Production Research Center (GMPRC) in Manhattan, KS, they were immediately placed in cold storage at about 4 °C. Before being used in tests, rice was removed from the cold room, cleaned using a #12 sieve, and tempered to 14% moisture content (m.c.).

Each variety lot was sampled to determine the number of solid, cracked, and split hulls; the procedure for this enumeration was modified from Cogburn et al. (1983). The rice hull is composed of the palea and lemma (Champagne et al., 2004), which was used to classify kernels as follows: solid hulls, with palea and lemma intact and no space between them; split hulls, with spaces in the longitudinal seam of the kernels between the palea and lemma; and cracked hulls, with the palea and lemma cracked longitudinally but not in the seam or transversely.

Twenty grams of each variety were sampled, and 100 kernels were inspected under a microscope and grains classified as having solid, split, or cracked hulls. Ten separate replicates were evaluated for each variety (10 separate 20-g lots). The number of solid, split, and cracked hulls was calculated for each variety, and the data were analyzed using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS Institute, 2001) to identify differences among varieties. The Bonferroni (Dunn) *t*-test was used to account for experiment-wise error rate and to separate means for the percentage of solid, split, and cracked hulls in each variety.

2.2. Insect bioassays

Rhyzopertha dominica adults, reared on rough rice of the long grain variety Francis at 28 °C and 68% relative humidity (r.h.), were obtained from colonies maintained at the GMPRC. Voucher specimens of *R. dominica* from these colonies were previously deposited in the Kansas State University Museum of Entomological and Prairie Arthropod Research under Lot no. 162. Two-week-old adults were obtained from these colonies, placed in a 0.95-L jar with approx. 200 g of rough rice, and held for 2 days at 28 °C and 68% r.h. Rice kernels and adults were then sieved with #12 and 35 sieves. The kernels remained on top of the #12 sieve, the adults fell through and were trapped by the #35 sieve, and eggs and frass were collected in a solid pan underneath the #35 sieve. Eggs were incubated at the same conditions until they hatched.

Four separate replicates of 20 g aliquots of each variety were placed in separate 29-mL plastic vials, and 10 neonates were added to each vial. The four replicates were established at 3-day intervals. All vials were maintained at 32 °C in plastic boxes with NaCl solution to maintain 75% r.h. (Greenspan, 1977). Temperature and r.h. were monitored during the experiment using HOBO data recorders (Onset Computer, Pocasset, MA). Adult emergence was monitored daily beginning 20 days after the initiation of a replicate by pouring the contents of the individual vials into a pan and collecting the adults. The number of adults and development time of each individual adult was recorded until emergence was complete (no emerged adults for 7 days). All emerged adults were transferred to a new vial, which contained the same variety of rice (one of the 28) on which they were reared. These vials were also maintained at 32 °C and 75% r.h. Two weeks after the first adult was placed in the vial, the rice was sifted as described previously, and eggs were collected and counted. This process was repeated at 3 and 4 weeks, and then the parental adults were killed by placing them in alcohol, and sexed by examination of male and female genitalia (Potter, 1935).

The number of emerged adults and median developmental times were averaged and mean differences determined as described for kernel analysis, using Bonferroni correction to account for experiment-wise error. The Dobie index (Dobie, 1974; Dobie and Kilminster, 1978) was also calculated for each variety as $(\log_e F)/D \times 100$, where F is the number of F_1 adults emerging from the original 10 neonates in each vial and D is the median development time of those 10 larvae. A higher Dobie index indicates a