Pest Control

STORED PRODUCT PEST

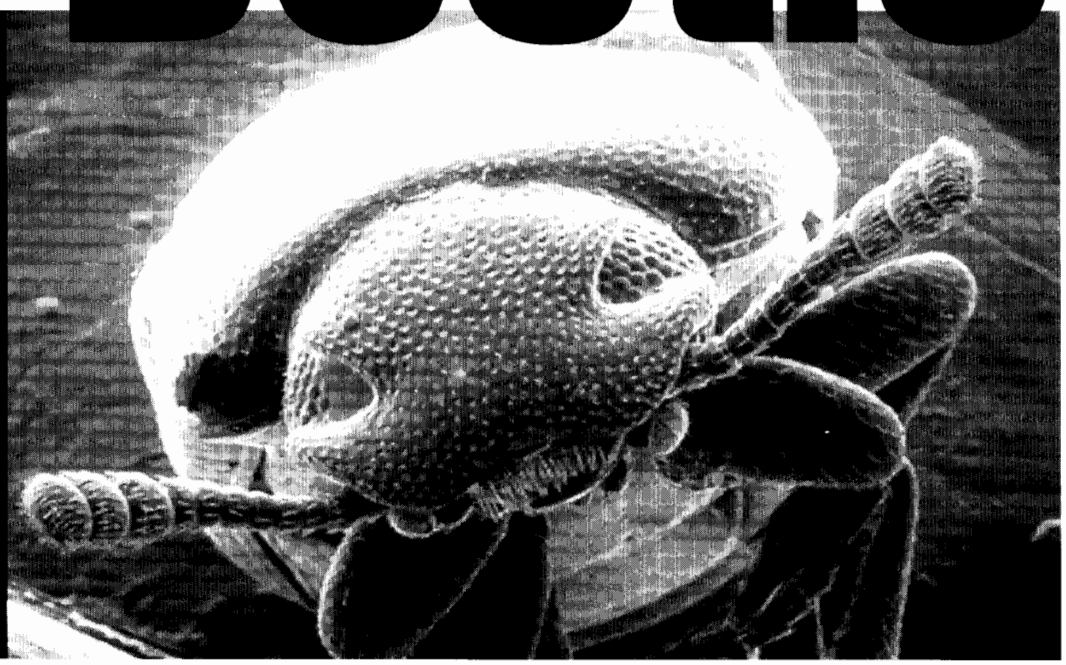
Profile of a Prolific Pest: *Red Flour* Beetle

Common Name:
Red Flour Beetle

Scientific Name:
Tribolium castaneum (Herbst)

Family:
Tenebrionidae

Order:
Coleoptera



Understanding the biology and behavior of this economic pest can lead to breakthroughs in effective control.

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Contributors

The red flour beetle is an economic pest in flour mills. It can also be found in stored raw grains, food warehouses, feed mills, grocery stores and homes.

Red flour beetle adults are small, reddish-brown, 2.3 to 4.4 millimeters long, and 0.97 to 1.26 millimeters wide, with 11-segmented, club-shaped antennae. In the red flour beetle, the three terminal antennal segments are significantly larger than the other antennal segments. However, in a related species—the confused flour beetle, *Tribolium con-*

fusum (Jacquelin duVal)—the antennal segments increase gradually in size from the base to the tip (see Figure 1).

Furthermore, in the red flour beetle adults, the compound eyes extend ventrally, and distance between eyes on the ventral side is equal to the transverse ventral diameter of the eye (see Figure 1). The front and middle pairs of legs have five tarsal segments, while the hind pair has four tarsal segments. The femur of the front pair of legs in males has a hairy puncture on the ventral surface. This aspect is absent in females. The hairy puncture, also referred to as the sex or setiferous patch, is believed to be the site of pheromone production (see Figure 2). Unlike the confused flour beetle, the red flour beetle can fly.

Red flour beetle eggs are oblong and white. They are 0.6 to 0.7 millimeter long and 0.3 to 0.4 millimeter wide. The eggs are tacky, and therefore, eggs laid in flour are covered by finer flour particles.

The larvae are yellowish-white.

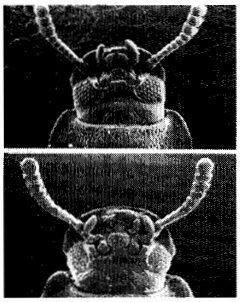

Figure 1: ***A scanning electron micrograph shows the ventral view of the head of a red flour beetle adult (top) and confused flour beetle (bottom). Note the differences in the antennal shape of the red and confused flour beetles, and the distance between the eyes.***

The tenebrionid larvae have a characteristic shape with three pairs of legs. These larvae closely resemble wireworms, or larvae of the click beetles. Therefore, tenebrionid larvae are sometimes called false wireworms.

The red flour beetle larval cuticle is hard (sclerotized) and has a banded appearance with two pointed projections (Urogomphi) at the tip of the ninth abdominal segment. The first through fourth abdominal segments of larva have two hairs (setae) above and two below an imaginary line drawn from the spiracle. The femur of the first pair of legs on the ventral side has three setae.

The first instar is 1.1 millimeters long, and the head capsule width is 0.2 millimeter. Typically, there are between six and seven instars. The instars can be distinguished either by head capsule width measurements or by weight. Larvae that go through six instars tend to develop faster and have a lower body weight than those that go through seven instars.

The individuals that go through seven instars are better able to withstand adverse environmental conditions. Adults emerging from such individuals are less productive, but more resistant to environmental adversity. On the other hand, adults emerging from larvae that go through six instars are more productive and are considered "colonizers."

The pupa is white (naked), about 3.3 to 3.4 millimeters long, 1.1 millimeters wide, and weighs about 2.5 milligrams. External genitalic structures on pupae can be used to separate male and female.

Life History

In nature, the red flour beetle has been reported from bee nests in Hawaii and from acorns in South Africa. However, the beetles were only able to successfully infest acorns with longitudinally split testa (seed coat).

Red flour beetles have been reported from bark habitats in Great Britain, the United States, West Indies and India. The bark habitat provides protection from predators as well as food sources of both plant and animal origin. While natural habitats exist for many stored-product insects, large populations are always associated with manufactured, harvested and/or stored food and feed products.

The red flour beetle is an economic pest because of its association with stored cereal grains, oilseeds, nuts, dried fruits, spices and pulses

Figure 2: ***The sex patch (SP) has fluted setae and secondary reservoirs (SR). The aggregation pheromone is secreted from this site.*** (PHOTO COURTESY OF THE JOURNAL OF CHEMICAL ECOLOGY, 1981, P. 69, FIGURE 1-D)

(legumes). Both larvae and adults feed on seed embryo, grain dust and broken kernels.

Beetles also survive and reproduce on molds, notably *Alternaria, Mucor, Cladosporium, Nigrospora, Absidia, Curvularia* and *Scopulariopsis.* Red flour beetles may often be found in damp or moldy stored grain. When there are too many insects present relative to the available food (that is, under crowded conditions), adults and larvae of red flour beetles tend to be cannibalistic and feed on eggs and pupae of their own species.

These insects develop less effectively on undamaged cereal grains than they do on damaged or broken grains. Kernels damaged by machines during harvesting and handling, or by insects such as the weevils or borers in storage, create an ideal environment for red flour beetle infestation and establishment. Therefore, red flour beetles are considered secondary pests, because of their reduced ability to successfully feed and thrive on undamaged grains.

These insects prefer floury materials and are considered economic pests in flour mills, grocery stores and homes. The production of adults on various food products is variable, and the addition of yeast significantly affects offspring production. Therefore,

yeast is often added to whole-wheat flour when culturing insects in the laboratory.

Red flour beetle adults have a long life span. Under laboratory conditions (18 to 29 degrees Celsius), the average lifespan of male and female beetles is 130 and 198 days, respectively. Some red flour beetle adults have been reported to live for several years. Mating occurs 17 to 26 hours after emergence, and adults are capable of reproduction throughout their life. Eggs are laid by females 10 to 15 days after emergence.

Initially, a female lays between three to five eggs per day for a couple of days at 25 degrees Celsius and 70 percent relative humidity. For the remainder of the female's adult life, two to three eggs per day are laid. A female on average lays 360 eggs

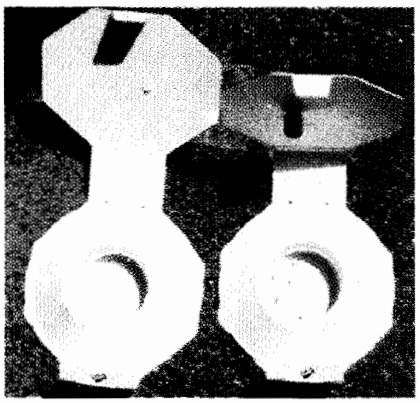

Figure 3: ***Flit-Trak traps are valuable tools for detecting and monitoring red flour beetles. The use of a pheromone lure (right) along with the food attractant (oil) enhances trap catch and detection frequency.***

(with a range of 195 to 569 eggs). Egg-laying typically decreases in females more than 100 days old.

Temperature affects adult longevity and number of eggs laid (see Table 1). At cooler temperatures (20 degrees Celsius and 14 to 16 percent moisture food), adult survival is essentially unaffected, but few or no eggs are laid by the females. At warmer temperatures (27 degrees Celsius to 32 degrees Celsius), adult survival decreases with age of the insects. At these temperatures, females lay a majority of eggs within the first eight weeks.

The egg-to-adult development of the red flour beetle takes 66 days at 22.5 degrees Celsius and 22 days at 37.5 degrees Celsius. The developmental time is shortest at 35 degrees Celsius (see Table 2).

At a given diet moisture level, the percentage of time spent in egg, larval and pupal stages is consistent across a broad range of temperatures (see Table 3). Thus, the time spent in immature stages can be calculated by multiplying the percentage of time spent in egg, larval or pupal stage with the egg-to-adult developmental time.

Adult activity on the surface of the food is the most obvious indicator of an infestation. This usually occurs in laboratory culture jars, and may not occur under field conditions until populations reach high levels. Larval and adult tunnels are common in infested flour, as well as on dusty surfaces in food processing facilities and grain elevators. Tunnels or tracks on dusty surfaces, especially in a flour mill, may indicate red or confused flour beetle presence.

Food infested with red flour beetles for several months may contain all life stages of the insect, cast skins and fecal pellets. The food may also be discolored or tainted with a disagreeable odor, due to benzoquinone compounds, and the quality of foods such as flours and breads may be lowered.

Trapping and Monitoring

Currently, an aggregation pheromone is commercially available as part of a Flit-Trak trap kit. Each kit contains five pheromone lures, a bottle with a food lure (oil), five filter paper disks, five shallow plastic holders and five cardboard enclosures with holes for the lures (see Figure 3). Research has shown that more beetles are attracted to food lure plus pheromone compared with food lure or pheromone alone.

Insects attracted to the food and pheromone lures fall into the shallow receptacle containing the oil. Adults suffocate and die as the oil spreads on the insect's body, clogging the spiracles (the exterior openings of the insect respiratory system).

The efficacy of Flit-Trak traps in capturing red flour beetles has been characterized under laboratory conditions. In general, the traps capture only 20 to 30 percent of the released red flour beetles (about 50 to 100 beetles were released in the experiments).

These traps should not be used in bulk-stored grain, as the food odors from the grain will decrease trap effectiveness. They are best suited for use in homes, food warehouses, flour mills, feed mills, pet stores and gro-

Table 1: **Effects of temperature and relative humidity on fecundity of female red flour beetles**

Relative Humidity	Temperature, degrees Celsius (degrees Fahrenheit)	Mean No. Eggs/Female*
30 %	25.0 (77.0)	84.4
	30.0 (86.0)	186.9
	35.0 (95.0)	413.1
70%	22.5 (72.5)	119.2
	25.0 (77.0)	146.1
	27.5 (81.5)	352.0
	30.0 (86.0)	253.0
	32.5 (90.5)	539.2
	35.0 (98.0)	466.4
	37.5 (105.0)	355.0

*Mean number of eggs laid in seven weeks

Table 2: **Mean egg-to-adult developmental time of red flour beetles at various temperatures***

Temperature, degrees Celsius (degrees Fahrenheit)	Mean Duration Days
22.5 (72.5)	66.4
25.0 (77.0)	41.9
27.5 (81.5)	28.2
30.0 (86.0)	24.3
32.5 (90.5)	19.7
35.0 (95.0)	18.8
37.5 (99.5)	21.7

*Data based on insects reared on wheat flour plus a five percent yeast diet.

cery stores to detect and monitor red or confused flour beetles. The traps can also be used before and after a control treatment (with pesticides or alternatives) to judge the degree and duration of insect control.

Anecdotal reports from users indicate that the Flit-Trak traps with the pheromone plus food bait are effective only short distances. However, it is unclear what that short distance might be. If traps are indeed effective only short distances, it is clearly an advantage. For example, insects captured in traps would indicate an infestation near the trap's vicinity. If visual inspection does not reveal an infestation, then it would be logical to assume that red flour beetles arrived at the trap site from a distance, as the beetles are strong fliers.

Interpreting red flour beetle trap catches is difficult. Furthermore, the absence of insects in traps does not indicate that the area being trapped is insect-free. Sometimes, insects may be present at low levels, but are not attracted to the trap. Therefore, using more traps is always better than using fewer traps when monitoring red flour beetles. Although there is limited information on the "zone of influence" of the Flit-Trak traps, one can still use them to detect and monitor red flour beetles.

The traps may be placed on the floor or under pallets, and off the floor in any convenient location (pallet racks, beams, etc.). Traps should be placed near suspected sources of infestation or foods susceptible to infestation. A grid pattern for trap placement is usually recommended. However, it is not necessary to place traps in a grid pattern as long as trap locations are marked.

There is renewed interest in exploring alternatives to control stored-product insects because of the 1996 Food Quality Protection Act (FQPA), which threatens to cancel organophosphates currently used for stored-product protection. Other factors include resistance development in insects and the increased use of integrated pest management (IPM) practices by the grain and food industry. IPM methods currently being explored for red flour beetle control include the use of diatomaceous earth (DE), heat or a combination of DE and heat. **PC**

Table 3: **Mean percentage of time spent in egg, larval, and pupal stages on less than 12% and more than 12% moisture diets***

Stage	Diets with less than 12% moisture	Diets with more than 12% moisture
Egg	15	11
Larva	66	74
Pupa	19	15

*Data based on insects reared on wheat, wheat flour, millet, and cracked corn. Percentages calculated at 27°C, but are similar for temperatures between 20 and 35°C.

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Flour Beetle Web Sites

Here are a few sites the authors recommend for additional information.

- *http://bru.usgmrl.ksu.edu/beeman/tribolium.html*
- *http://pmo.umext.maine.edu/factsht/flourbtl.htm*
- *http://www.entm.purdue.edu/entomology/ext/targets/e-series/stored.htm*
- *http://www.okstate.edu/OSU_Ag/agedcm4h/pearl/e912/ch13/ch13f15.htm* □