Development of pheromone-baited insect traps

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Abstract

An initial step in the development of an effective insect trap is to study the traps currently in use. In this paper the efficiency of several commercially available pheromone traps in capturing adult *Tribolium castaneum* under warehouse conditions is examined. To illustrate the development of an effective trap, the evolution of the Savannah trap from a tennis-ball canister to the final commercial product is discussed.

Introduction

Early detection of pest populations with pheromone-baited traps is one way to reduce our dependence on pesticides. Having identified and synthesised many pheromones, we can now concentrate on the design and development of effective traps to make use of these pheromones. In stored-product environments it is essential that we develop traps that are effective, sensitive, and selective.

The development of effective insect traps must bring together a variety of disciplines. The developer must be, as expected, an entomologist with a strong background in insect behaviour, a video specialist, and a design engineer.

DeCoursey (1931) reported the development of an efficient trap for *Tribolium confusum* Jacquelin du Val. The traps contained no pheromone and consisted of corrugated paper containing various food baits. Flour was often used as the bait and although it was effective as an attractant, it provided no means of killing the insects. In general, food baits do not attract over long distances. Incorporation of insect pheromones has improved the effectiveness of traps. Multilayered corrugated paperboard traps for trapping stored–product insects were designed by Burkholder (1976), Barak and Burkholder (1976, 1985), and Williams et al. (1981). These traps were similar to the DeCoursey trap in that they were constructed of corrugated cardboard and took advantage of insect behaviour by providing a place to hide. The traps incorporated a food attractant, a pheromone bait, and a killing agent. Barak and Burkholder (1985) improved the traps by replacing the insecticide with a plastic pitfall containing an oil bait which served as both a food attractant and a killing agent. A modification of this trap was made by Barak (1989) as an effective trap for *Trogoderma granarium* Everts.

Other factors must be considered when developing traps. It was reported by Barak and Burkholder (1985) and Mullen (1992) that some insect species are hesitant about walking onto a sticky surface. In the development of the trap described by Mullen (1992), as well as other trap types, some glues repelled insects or were not strong enough to capture them. Other considerations are dust resistance, an ability to discourage humans or animals from disturbing the trap, and placement of the traps in such a way that normal warehouse traffic and commodity movement do not affect performance.

Development of the Savannah Trap

The development of the trap initially known as the Savannah trap was an evolution of design. From previous studies of other traps it was determined that an effective trap for *Tribolium* sp. would take into account several aspects of pest behaviour. Because no single pheromone trap would be effective for all species, a compromise between convenience and efficiency is essential. An initial step in trap development was the evaluation of commercially available traps in detecting various Coleoptera in storage environments. This study led to the development of a new trap that incorporated some of the features of previous traps as well as innovations to help eliminate some of their limitations.

The Storgard® trap is a widely used trap that uses a pheromone and oil bait to lure insects into the corrugated paper trap and hopefully into an oil filled pit in the centre. This trap consists of four layers of corrugation with only one layer leading to the oil pit. The result was a trap that attracted the insects, but allowed them to escape. The trap simply provides a dark place for the insects to hide. The Trappit® trap and its improvement, the Window® trap, are constructed of corrugated plastic with a clear window that makes it easy to count the trapped insects. However, close observation with a video camera showed that the beetles entered the trap but hesitated to walk out on the sticky surface. Improvement of the Window® trap eliminated the corrugated plastic and substituted a paperboard ramp. Also studied was the Allure® trap, a box trap which requires insects to walk up a ramp and fall over a sharp edge onto a sticky surface. The Fuji Tribo® trap includes a ramp with a net material suspended over an oil filled pit. All of these traps have design features that needed to be incorporated into a new trap design. The Storgard® trap had a dark place for insects to hide as well as an oil pit that provided a place for a food attractant and a killing agent. The Trappit®, Window®, and Tribo® trap provide an easy way to count the trapped insects, but they are not reusable. The Allure® trap had a long ramp for the insects to climb as well as a sticky surface to trap the insects. The later Window® trap, the Tribo® trap, and the Storgard® trap can only be entered from the ends and insects were often found along the sides of the trap with no way to enter.

As an example of the development of a successful trap, I will trace the steps and considerations made during the design of the Savannah trap. During the evolution of the Savannah trap several designs were developed and tested before the final design was selected. All were of the pitfall type. The earliest was constructed from layers of 1/8" posterboard. Each layer was smaller than the next, creating a pyramid with a series of steps. At the top and in the centre a recessed plastic cup served as the pitfall. The plastic cup contained a small amount of

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wheat–oat oil that acted both as an attractant and as a killing agent. A pheromone–impregnated rubber septum was placed on a small piece of aluminium foil in the centre of the cup. Early tests on the preliminary trap design were conducted in painted wooden chambers 1.2 m square. Chambers were covered with a wooden frame top covered with cloth screen to prevent the insects from escaping but still allow air movement.

Further modifications of the basic design resulted in a trap constructed from Plexiglas®. These round traps were approximately 6 cm in diameter and 1 cm high and were machined so that the 2 cm sides sloped upward at an angle of 35 degrees. At its apex the slope was reversed so that a downward slope of about 45 degrees led to a pit. The pit was constructed from a 2 cm stainless steel cup that was fitted into the trap through a hole that was machined from the base through the top. The longer outer slope was roughened to make a surface for the insects to crawl up, while the shorter inner slope was polished to induce the insects to slide into the pit once they crossed over the apex of the trap. As in the previous design, the pit was filled with an oil bait.

The final experimental trap was constructed from a plastic tennis-ball canister (Fig. 1A). The top 2.5 cm of the can was removed with a band saw. Five 2.5 cm slits were cut in the top part of the canister (Fig. 1B, 1) to form openings through which the insects could enter the trap, and to provide legs to support the top. The concave bottom of the canister was inverted and a 3.0 cm hole (2) was drilled through the centre. As with the Plexiglas® trap, the upward slope was roughened to allow the insects to crawl up and the shorter, steeper downward slope was left smooth to induce insects to slide into the trap. The canister top with the legs (3) was then fastened to the bottom with epoxy glue and pushed down so that the entire trap was about 2.5 cm tall and 6 cm in diameter. The trap was designed so that the canister lid also served as the top of the trap. A hole was made in the centre of the lid to accept the pheromone-impregnated rubber septum (4). This arrangement allowed part of the septum to protrude from the top of the lid as well as into the centre of the trap. Another lid was used as the bottom of the trap (5). This lid was trimmed so that only the minimal vertical surface remained for the insect to climb. The trapping surface at the bottom of the trap was made from a piece of index card cut into a 6 cm circle. The disk was coated with Tangletrap® and was held in place with double stick tape. A fibre disk (6) 2 × 6 mm was with the oil bait and placed on a pin pushed through the top of the trap.

The early cardboard pyramid traps were tested in the painted plywood boxes previously described. The traps were placed into the centre of the chamber and 50 one-week old *T. castaneum* (Herbst) adults were placed in each chamber. Trap catch was recorded after 24 hours. The corrugated paperboard Storgard® flour beetle traps were used as standards for comparison.

Additional tests were conducted in a 19322 m^3 warehouse located at the U.S. Naval Supply Centre in Jacksonville, FL. USA. This series of tests compared the Plexiglas® trap, the Savannah trap, the Storgard® trap, and the Trappit® trap. Traps were placed on the floor near supports and around the walls. Tests were run for 16 weeks. After the first eight weeks the Plexiglas® trap was omitted and the PT 6 Allure® trap was added. Eleven traps of each type were used. The Savannah traps used the Storgard® rubber septa lure. Initially, 1650 two-week old adult *T. castaneum* adults were released every other week from 36 release points scattered around the warehouse. Insects were counted and removed from the traps before each release. Lures and traps were replaced every eight weeks, resulting in two replications over time.

Similar tests were conducted in smaller rooms at the Savannah laboratory. These tests were conducted in 15 × 5.6 × 1.7 m rooms. These tests compared the Savannah, Storgard®, and the Trappit® traps. Two traps of each type were placed around the perimeter of the room. The Storgard® septum lure was used in the Savannah trap. One thousand two-week-old unsexed *T. castaneum* adults were released at various points throughout the exposure room. Counts were made at 24-hour intervals for 72 hours. When possible, captured insects were removed from the traps after counting. Because of its construction, captured insects could not be removed from the Trappit® trap. Only insects that were actually entrapped in the trap were counted. Insects that were in the trap but were not entrapped were returned to the exposure room. At the end of each test the room was cleaned to remove insects that remained between replications. Traps were moved to different locations in the room between replications. Lures and traps were replaced monthly. Each test was replicated 16 times.

The Savannah trap was tested to see if it would capture other stored-product species. It was tested against the maize weevil, *Sitophilus zeamais* Motschulsky, in a small shed which had contained maize. The shed was completely emptied of all maize residues, swept, and the seams were caulked. No pheromone was used and the only attractant was an oily bait made from ground maize extracted with pentane. In other tests the

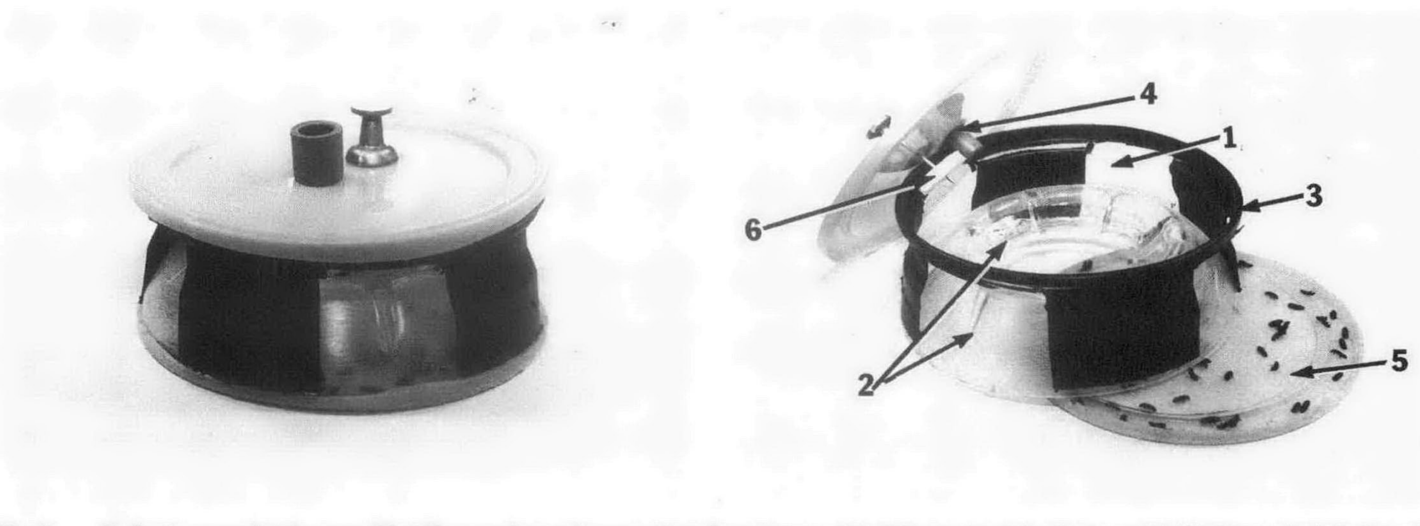

Fig. 1. Left: the completely assembled Savannah trap (support legs have been painted for contrast in photograph). Right: exploded view of the trap showing: (1) entrance slits, (2) concave bottom assembly with 3.0 cm opening, (3) top assembly with support legs, (4) pheromone-impregnated rubber septa, (5) base with sticky bottom, (6) fibre bait pad.

trap was baited with four types of lures for the cigarette beetle, *Lasioderma serricorne* (Fab.). These were the Serrico® lure (Fuji Flavor LTD, Tokyo, Japan), Lasiolure® (der B.A.T. Cigarettenfabriken, GmbH), and the Trécé® lure at 10.0 mg and 1.0 mg loads (Trécé, Salinas, CA). Tests were conducted in 15 ×15.6 m×1.7 m exposure rooms at the Savannah laboratory. Traps were placed in the four corners of the rooms and 250 one-week-old unsexed adults were released every Tuesday and Friday. Counts were made every three days and the rooms were cleaned between releases to remove uncaptured insects. A total of 16 replications was completed using the same lure.

Data were analysed by the GLM procedure of the Statistical Analysis System (SAS Institute 1987).

After 24 hours most of the *T. castaneum* released in the chambers were captured in both cardboard pyramid trap and the Storgard® trap. Although more beetles entered the Storgard® trap, only a few were actually captured in the oil filled pit, indicating that the beetles were attracted to the trap but did not enter the pit. In additional tests, beetles entered unbaited traps almost as readily as baited ones, indicating that the beetles were seeking harbourage. This phenomenon occurred repeatedly in small chamber tests.

The results of the warehouse tests using the Savannah trap, the Storgard® trap, the Trappit® trap, the Allure® trap and the Plexiglas® trap are presented in Figure 2. The Allure® trap was tested for eight weeks and the Trappit® and Storgard® traps for 16 weeks (two replications). The Plexiglas® trap was effective but because the trap was not covered, it was fouled with filth and raided by rodents, and insect numbers were often estimated by counting insect fragments. Data for this trap are not included. The data presented are the mean number of insects trapped at each count. The Savannah trap was more effective than all traps tested and both the Savannah trap and the Storgard® were more effective than either the Allure® or the Trappit® (P>0.001).

In the small warehouse tests the Savannah trap was compared with the Storgard® trap and the Trappit® trap (Fig. 3). In all replications the Savannah trap captured more *T. castaneum* adults than either of the other traps (P>0.0001). The number of insects trapped by the Storgard® and Trappit® traps did not differ significantly. However, the Storgard® trap attracted almost as many insects as did the Savannah trap, the difference being that the Storgard® trap did not entrap the insects and the insects could leave the trap once they entered. Because both traps used the same rubber septum lure impregnated with R,R and R,S of 4,8-dimethyl decanal, the difference in trap catch can be attributed only to trap efficiency. Using only a food lure made from a pentane extract of dried maize, three Savannah traps captured a total of 450 maize weevils in 10 days in an empty warehouse. Cigarette beetle adults were caught when the trap was baited with the Lasio®, Serrico®, and Trécé® lures. Although no statistical difference was found the trap was equally effective when tested with various lures for the cigarette beetle.

The final trap design is shown in Figure 4 and was the result of consultation with a design engineer and a mold maker. The design is such that it can be made in the most economical way possible. It is vacuum molded from one sheet of plastic. This allows several traps to be made at one time and the mold is considerably cheaper than an injection mold. The surface of the mold produces the rough outer climbing surface as well as the smooth surface needed in the cup to prevent escape. The outer cover of the trap is made from a coated paperboard. This coating not only provides a printing surface, but prevents curling. Holes are punched in the top to hold the pheromone lures.

The Savannah trap meets all the requirements of an effective trap as stated by Barak and Burkholder (1985). It is versatile in that it is effective against a wide variety of species. It is made of plastic and is durable, with replaceable parts. Unlike the Storgard® trap, it is practically escape-proof. Trap capture can be increased by removing obstructions near the pheromone dispenser (Tingle and Mitchell 1979). The design of the Savannah trap allows the pheromone dispenser to protrude through the top, thus providing an unobstructed pathway for the pheromone to disperse. Incorporation of an appropriate bait enhances the effect of the pheromone by providing a short distance attractant. This is especially important in a warehouse environment where there is little air movement to effect pheromone dispersal (Mankin et al. 1980). Molecules of pheromone disperse slowly in a closed environment and under some conditions they stick to absorbent surfaces which can then act as secondary pheromone emitters. This makes it difficult for insects to locate traps over long distances and as a result they tend to be attracted to the nearest trap (Vick et al. 1990). Proper use of pheromone traps will allow warehouse workers to locate patch infestations of insects that often occur in stored-product environments. Early detection of infestation will provide the warehouse workers more latitude in choosing the most effective control procedure.

The Savannah trap is now patented and is being marketed as the FLIT–TRAK M^2® by Trécé of Salinas, CA.

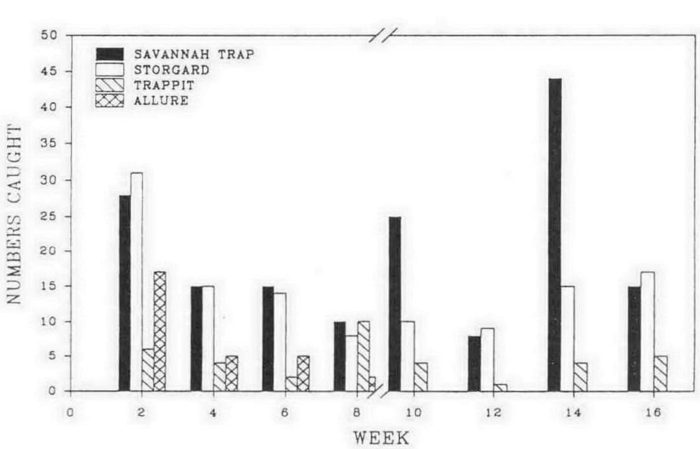

Fig. 2. Large warehouse test comparing four *T. castaneum* traps; lures and traps were replaced every eight weeks.

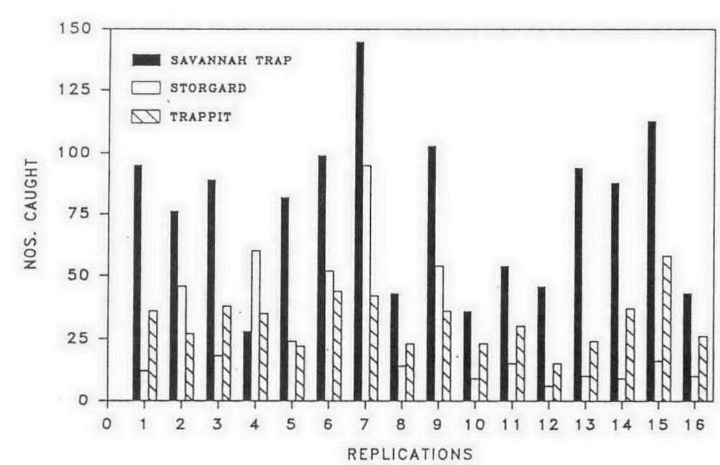

Fig. 3. Small warehouse test comparing the Savannah trap, the Storgard® trap, and the Trappit® trap for *T. castaneum*. Lures and traps were replaced monthly; each test used two traps and was replicated 16 times.

Fig. 4. The commercial product known as the FLIT–TRAK M^2® as produced by Trécé of Salinas, CA, USA.

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