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Review of Pheromone-Baited Sticky Traps for Detection of Stored-Product Insects

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ABSTRACT: Sticky traps are highly useful for the detection of low-level insect populations which are otherwise difficult to detect in processed commodity storages. Even where insect populations may be moderately high, as in the storage of unprocessed agricultural commodities, they are useful for making management decisions on insecticidal treatments and safe storage periods. These traps enable warehousemen to locate infestations and take corrective action while the infestations are still small and before they spread to other commodities. Recently, these traps have been used to demonstrate monitoring of feral populations of stored-product insects in some climatic areas of the world. Feral populations likely serve as reservoirs of insects for infestation of stored commodities, a possibility of much significance for storage management.

The development of pheromone-baited sticky traps has resulted in insect detection in stored products which is much more sensitive and selective than detection tools previously available. In this review we first discuss some of the factors known to influence the operation of these traps, and then present some examples of their practical usage.

Depending on the type and quantity of volatiles emitted from the pheromone bait, a sticky trap selectively captures insects of a small number of species by attraction and interception. Much of the recent entomological literature on sticky traps deals with the pheromone baits used for attraction. However, the sticky "traps" long-used by spiders depend only upon interception except for the bola spider, which uses a pheromone mimic (Stowe et al., 1987). The most efficient spider webs for catching insects are low-visibility orb webs or low-maintenance sheet webs (Rypstra, 1982). Entomologists generally have used high-maintenance coated surfaces that must be renewed or replaced often.

The attraction of insects to a pheromone-baited trap is influenced by a number of meteorological, physical, and behavioral factors, including the pheromone composition and emission rate (Mankin et al., 1980; David et al., 1983; Helland, 1983; Sabelis and Schippers, 1984; Perry and Wall, 1984). Some of the meteorological factors apply uniquely to the closed environments in which stored products usually are found. In the absence of wind, pheromone disperses by a slow process of molecular diffusion rather than the rapid process of convective diffusion (Mankin et al., 1980). The pheromone molecules travel slowly in an enclosed

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environment and, particularly under cool or dry conditions, they tend to plate onto adsorbent surfaces. When the temperature or humidity rises, the adsorbent surfaces then can act as secondary pheromone emitters. As a result, the pheromone becomes distributed in patches rather than well-defined plumes, and insects find it more difficult to locate traps over long distances. This effect can be beneficial for entomologists in search of patchy infestations, because most insects will be captured in the trap nearest to where they emerge.

In general, insects that emit a multicomponent pheromone blend are attracted in greater numbers to sources that emit the full blend rather than one or two components (e.g., Baker and Cardé, 1979; Linn et al., 1987). Blend ratio is highly significant for some insects (Kawasaki, 1986). For others, the presence or absence of a component is more important than the precise ratio (e.g., Mankin et al., 1983).

Sometimes, pheromones from two or more species (the Angoumois grain moth, *Sitotroga cerealella* (Olivier), and Indianmeal moth, *Plodia interpunctella* (Hubner), for example) may be released from the same trap without significant reduction of attractiveness for any species, which simplifies insect surveillance for species that often occur together (Vick et al., 1979). Also, several species may be attracted to a pheromone component common to them as occurs with the Indianmeal moth, Mediterranean flour moth, *Anagasta kuehniella* (Zeller), almond moth, *Ephestia cautella* (Walker), tobacco moth, *E. elutella* (Hubner), and raisin moth, *E. figulilella* Gregson (Vick et al., 1979, 1981). Several of these species have secondary components which when combined with the common component create a more powerful attractant, but add a degree of species specificity that reduces the usefulness of the pheromone as a general attractant (Sower et al., 1974; Krasnoff et al., 1984). The complete pheromone blend of the species should be used when maximum sensitivity is required for that species (Soderstrom et al., 1980; Krasnoff et al., 1984).

Aside from pheromone blend composition, the emission rate is probably the most important factor in the attraction of insects to a pheromone source. Early investigators determined that for many species the capture rate fell off rapidly for pheromone emission rates an order of magnitude above or below the rate for optimal capture (Sharma et al., 1971; Yonce et al., 1976; Tatsuki et al., 1979; Vick et al.,1979; Baker and Roelofs, 1981). It is difficult to control the emission rate accurately for long periods under field conditions, and much effort has been devoted to development of optimal substrates (e.g., Campion et al., 1978; Hendricks et al., 1987). Also, it is important that the substrate not promote the breakdown of the pheromone into an inactive or inhibitory substance (e.g., Ramaswamy and Cardé, 1982; Vrkoc et al., 1988).

The shape, and to a lesser extent size, of the trapping surface, may affect efficiency for capturing attracted insects, in part due to influence of trap size and shape on pheromone dispersal (Lewis and Macaulay, 1976; Angerilli and McLean, 1984) and to search-image cues (Gross et al., 1983; Levinson and Hoppe, 1983) and color cues (Prokopy and Hauschild, 1979; Timmons and Potter, 1981; Niemeyer, 1985). The size of the dispenser is less important than the emission rate (Macaulay and Lewis, 1977). In general, the rate of trap capture is increased by removing obstructions near the pheromone dispenser (Tingle and Mitchell, 1979), and increasing the trapping surface (Lewis and Macaulay, 1976). These effects are strongly influenced, however, by the orientational cues preferred by an insect species. The Indianmeal moth and almond moth, for example, prefer targets with vertical configurations that resemble tree trunks (Levinson and Hoppe, 1983).

Because trapping is strongly influenced by emission rate and orientational cues, the development of a useful trapping system for any species is still somewhat of a process of trial and error. Numerous types of traps have been used to capture various stored-product insect species. Some are markedly superior for one species or another (Vick et al., 1979; Leos-Martinez et al., 1987; Ahmad, 1987). In most cases, however, warehousemen have struck a compromise between convenience and efficacy, and chosen the commercially available trap most appropriate for them.

Pheromone-baited sticky traps have been used to monitor pest populations in several situations. Records of weekly trap catches have revealed fluctuations in insect populations in warehouses storing raw agricultural commodities. Knowledge of such fluctuations has been useful for timing insecticidal treatments and determining the efficacy of the treatments (Reichmuth et al., 1976, 1978; Vick et al., 1981; Buchelos and Levinson, 1985). Sticky traps also have been used widely in food processing plants and processed-food warehouses (Hoppe and Levinson, 1979; Vick et al., 1986).

Ultimately, one of the most far-reaching benefits of pheromone-baited traps for stored-product entomology has been the discovery of feral populations of stored-product insects in field situations where they had not previously been detected. Before the use of the combine harvester, grain was cut by hand or binder and tied into bundles or "shocks" which were left in the field to dry before the grain was threshed and stored. Drying grain in this condition offered a favorable environment for storage insects and "field infestation" was a major problem (Cotton, 1956). These field insects were thought to originate from nearby granaries (Stockel, 1971). The advent of combine harvesting was believed to have eliminated field infestation or to have reduced it significantly.

Subsequent use of pheromone-baited sticky traps demonstrated, however, that the Angoumois grain moth was not only abundant near infested storages but also occurred in several types of environments remote from storages or grain fields (Cogburn and Vick, 1981; Vick et al., 1987). Cogburn (unpubl. data) found that early in the year feral populations of Angoumois grain moth were evenly distributed over wide areas of southeast Texas, regardless of whether the land was in pasture or planted to rice, other grains, or soybeans. However, when the grain produced heads and began to mature, a sudden, dramatic increase in trap catches occurred at sites in or near grain fields (Vick et al., 1987; Cogburn, unpubl. data). Although virtually nothing is known about these insect populations, it is clear that free-living Angoumois grain moths may be a significant reservoir for infestation of grain ripening in the field and stored in granaries.

Pheromone-baited sticky traps were used to demonstrate also that lesser grain borers, *Rhyzopertha dominica* (F.), are ubiquitous in almost all types of environments in southeast Texas. They are particularly abundant in grain handling areas such as around mills, commercial storages and farm bins. Cogburn has accumulated data on grain borer distributions over several years and will publish these results in greater detail elsewhere. We present a brief summary here.

The lesser grain borer is the most destructive insect of stored rice in the USA and seems to be increasing in importance in other grains. A pheromone was developed for this species (Williams et al., 1981) and proved effective in natural environments (Cogburn et al., 1984). From March to December each year, this species can be caught in pheromone-baited traps in cultivated fields, pasturelands and even in woodlands. Local abundance seems to depend on undetermined factors. Two similar sites often yield vastly different numbers of insects.

Unexpected populations of lesser grain borers in forests were first discovered in a woodland between 2 small towns about 15 miles south of Beaumont, Texas. The insects were detected in small numbers in August when the traps were first deployed and low-level captures accrued for several weeks. In September, a ca. 10-fold increase in insects captured occurred and captures remained high until cold weather reduced and then eliminated trap captures. The following year, lesser grain borers appeared in the traps in March and were caught at low levels throughout the spring and summer. In the early fall, a trend almost identical to that of the previous year was recorded. Although this particular woodland was near intensified agriculture, grain storages and human habitations (ca. 3 km) the population trends for 2 consecutive years suggested that the insects were indigenous to the woodland and were not migrants from grain production or storage areas.

More intensive trapping over 3 years in other areas produced similar results. Insects collected with the aid of pheromone-baited live traps from the study sites were less sensitive to organo-phosphate insecticides than were laboratory-reared insects with no history of insecticide exposure, but were more sensitive than insects from commercial grain storages. This suggests that these populations were indigenous to the woodlands, although, with some degree of genetic exchange with storage populations.

The growing knowledge of these feral populations has forced warehouse personnel to re-evaluate their sanitation procedures. Feral insects presumably are capable of infesting storages, so relying only on cleaning and treating the storage bins, with no effect to exclude insects that can fly into the bin, may be unsuccessful in maintaining the stored commodity insect-free.

In summary, pheromone-baited traps are an important part of our defenses against stored-product insects in marketing channels. Although this technique has been in use for many years, refinements in design and methodology are frequently described in the literature. Below are several research areas needing more effort: (1) development of baits tailored for different insect densities and the different insect tolerances associated with processed vs. unprocessed commodities; (2) experimental validation of mathematically-derived pheromone dispersal and trap placement parameters in warehouses, particularly in regard to attractive distance and effect of aisles and stacked commodities on pheromone dispersal; (3) determination of whether the use of pheromones inside buildings will attract insects into buildings and how this might be affected by pheromone bait composition and strength; (4) determination of relationships between trap catch, insect population level and insect-caused damage, and how these relationships are affected by changes in population levels; and (5) measurement of fluctuations in feral population of the most important stored-product insects and determination of their significance to the control of stored-product insects.

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