The use of multiple trapping methods to assess population size: an evaluation

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Abstract

A biological control test in six 1500 bushel metal bins of shelled maize provided an opportunity to compare the accuracy of several trapping methods in determining population numbers of three storage pests and their parasites. The species sampled were the maize weevil, *Sitophilus zeamais*, the red flour beetle, *Tribolium castaneum*, and the Indianmeal moth, *Plodia interpunctella*. Trapping methods included vacuum sampling and probe (pitfall) trapping at 15 points throughout the grain mass, corrugated cardboard refuge traps at the grain surface and pheromone flight traps using a mark–release–recapture method, The results of each of these methods will be compared at different population densities.

Introduction

It is now generally accepted that for the detection of insect populations in bulk grain, traps are much more effective than conventional sampling techniques (Wilkin 1991). This is particularly true for low density or very aggregated populations of insects in large bulks of stored grain. The fact that traps can remain in place for considerable periods of time is probably their major advantage. The greatest disadvantage is that insect trap catch is not easily translatable into meaningful population estimates (Hagstrum et al. 1991). The number of insects caught in a trap is very dependent on the size and behaviour of each species and on a number of environmental variables (Cuperus et al. 1991). The most useful type of trap for detecting insects in bulk grain is the pitfall type of probe trap that is available in a number of modifications (White et al. 1991). These traps are a very sensitive indicator of the presence of insect infestation in bulk grain if they are placed in a number of locations throughout the grain bulk and left for several to many days. Although the estimation of absolute population numbers from probe trap catches may be imprecise, the comparison of the effectiveness of various treatments in similar conditions can be relatively accurate if the number of traps is adequate. In this paper we will discuss the use of correlated vacuum samples and grain probe catches and moth flight traps to assess the effectiveness of an integrated biological control regimen in bins of stored maize.

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Methods and Materials

In order to conduct a test of biological control in stored shelled maize, six 1500 corrugated metal bins were constructed. Bins were circular, 2.75 m in diameter × 4.57 m in height, resting on a flat concrete foundation. The roof of each bin had a centre opening of 0.9 m for grain loading, an access door near the periphery, and three screened air vents for aeration. Bins were equipped with raised perforated metal drying floors, and 0.46 m vane axial fans with 2.0 hp motors. Each bin also had a permanently installed horizontal under-bin unloading auger with a dedicated 3/4 hp motor. All bin seams, joints and small openings were sealed during bin construction and again after bin completion or after bin filling. Bins were instrumented with thermocouples at nine locations in the grain mass and one in the headspace above the grain. Temperature measurements were recorded hourly from each location.

About 1025 bu of shelled maize (Pioneer 3320) from the 1992 crop was loaded into each of the bins between 13 October and 26 October 1992 and then levelled. A number of random samples were taken from the grain stream during the loading of each bin, and the moisture content and infestation levels were determined. Because live insects were detected, all bins were sealed, openings were taped and the bins were fumigated with methyl bromide in January and again in February. Bins were sampled and refumigated if any live insects were detected, until no live insects were detected in any of the bins.

The bins were aerated after each fumigation and for additional periods in order to dry the maize down to a grain moisture content of less than 15% so that the grain would keep for a year without spoilage (Mills 1992). Bins were aerated 18–23 December 1992, 22–25 and 28–29 January and 2 February for a total aeration time of 110 hours.

Bins were sampled at five-week intervals using a Probe-A-Vac® pneumatic grain sampler. Fifteen 4-L samples were aspirated from each bin on each sampling date. The surface of the grain in each bin was divided into five quadrats of equal area (ca 2 m^2) with one round area in the centre and four truncated wedges aligned with the four compass points (N,E,S,W). The grain was then divided into three layers: bottom (0–1.1 m), middle (1.1–2.2 m), and top (2.2–3.3 m). On each sampling date a spot was chosen at random on each surface quadrat, marked with a surveyor's flag, and using the vacuum sampler a 4-L sample was aspirated from each of the three layers to yield 15 samples per bin. These samples were immediately placed in labelled jars, returned to the laboratory and sifted to remove all of the living and dead insects. The insects were then separated from the debris, identified, counted and discarded, and the debris was returned to the samples. The samples were then incubated for four weeks at 30 ± °C and about 70% r.h., and the samples were sifted at two and four weeks to count any insects that emerged during the four-week incubation period. Samples were then frozen and discarded, and jars were cleaned before the next sampling date. Each sample was briefly placed in a Motomco 919 Auto-

matic Moisture Tester® to determine the grain moisture content.

The day following the vacuum sampling, Trappit® grain probe traps were placed in each of the 15 locations from which vacuum samples had been taken. These traps are clear acrylic tubes (370 mm × 27 mm dia.) with a large number of small holes through which the insects pass before they fall down a funnel into a specimen tube enclosed in the bottom of the trap. These traps were left in place for five days and then retrieved using a cord tied to the top of each trap. The traps were removed to the laboratory, where the contents of each was removed, separated into species and all insects both alive and dead were counted. Samples were collected at five-week intervals for the duration of the test.

In addition, mark-recapture flight traps were developed to monitor population levels of the Indianmeal moth, *Plodia interpunctella* (Hübner). Marking was accomplished by marking stations, otherwise identical to sticky traps in structure and lure but modified to mark and release adults back to the population. One trap and one marking station were placed into each bin, suspended on a line about 1.5 m above the grain surface, and traps were retrieved and replaced at regular intervals. Moths caught in the pheromone baited sticky traps were assayed with a shortwave ultraviolet light to determine if they were unmarked or marked with a fluorescent powder from the marking station. The moth population could then be estimated using formulas described by Wileyto et al. (1994) and Wileyto in these proceedings.

Bins disinfested by fumigation were reinfested intentionally by releasing known numbers of pest insects into each bin on a set schedule. Three pest species were released on February 11 1993: 500 unsexed adults of *Sitophilus zeamais* Motschulsky, 100 unsexed adults of *Tribolium castaneum* (Herbst), and 25 pairs of *P. interpunctella* per bin. At five-week intervals throughout the test, smaller numbers of the three pest species were added to each bin to simulate natural immigration. Numbers used per bin were 50 *S. zeamais*, 10 *T. castaneum* and five pairs of *P. interpunctella*, and these were introduced four times.

Bins were assigned randomly to either a check treatment or to a biological control treatment. Pests were added to all six bins, but the biological control agents were added only to the three biological control bins. To establish a population of the predatory warehouse pirate bug, *Xylocoris flavipes* Reuter, 200 adult bugs were released weekly starting on February 18 1993, and continuing through the test period. Starting on March 11, 1993, and weekly thereafter, 1000 adult *Anisopteromalus calandrae* (Howard) (a parasite of *Sitophilus* weevils) and 200 adult *Bracon hebetor* Say (a parasite of pyralid moths) were released into the three designated bins.

Results

Unfortunately the test was late getting started because of technical problems, and the grain temperatures were low when the test started. Just before the start of releases on February 4 1993, the average grain temperatures were very close to 8°C in the six bins. Temperatures warmed about 4.5°C per month, reaching 30°C by the start of July.

In the southeastern United States, maize is harvested in the early fall at a fairly high moisture content, and typically dried to some extent before storage. The maize received for this test had already been cleaned and dried, but the moisture content was still 15.5%. This is above the recommended moisture content for long-term storage of maize (Mills 1992) and the maize was further dried using the aeration fans on the bins. Bins were aerated during three periods: 18–23 December 1992 for 50 hours; 22–24 January 1993 for 42 hours; and 28 January –2 February 1993 for 18 hours. Thus, aeration totaled 110 hours and average grain moisture content was reduced to 14.0% (Fig. 1). Maize moisture content varied only slightly throughout the course of the test (Fig. 1).

Fifteen vacuum samples (4 L) were used to assess the absolute density of insects in each bin and to compare this to the results from the trap catches. Beetle populations were compared, primarily between the vacuum samples and the pitfall probe trap samples. A comparison of results from these two methods for the maize weevil, *S. zeamais*, (Fig. 2) showed very similar population abundance and nearly identical population trends. Early in the year while grain temperatures were low, both techniques indicated low population numbers until about the middle of May. At that time both methods indicated that maize weevil populations started to increase through July. Slight decreases occurred by August, perhaps because of high populations of the parasitoid, *A. calandrae*, in both check and treatment bins by that time. In general, a five-day sampling period for the pitfall probe traps yielded slightly higher numbers of maize weevils than did the vacuum samples (Fig. 2). Overall, the population trends for *S. zeamais* in check bins and biological control bins were very similar, but there was a tendency for more weevils to be present in the check bins. In general, weevil populations remained low in all bins during the course of this test.

Tribolium castaneum populations exhibited different growth curves than the ones for *S. zeamais* (Fig. 3). No *T. castaneum* were detected before May 19, 1993, but their populations increased very rapidly to a high at the end of the test. The pitfall probe traps proved to be a more sensitive monitoring method for *T. castaneum* than the vacuum probe samples (Fig. 3). Although population curves were similar using both methods, the pitfall traps always caught more *Tribolium* adults than were contained in 4 L samples of grain. This difference was accentuated later in the year as grain temperatures increased to over 30°C. In general, both sampling techniques showed that there were fewer adult *T. castaneum* in the biological control bins than in the check bins.

Flat grain beetles, *Cryptolestes* spp., were not introduced into the test bins of this experiment, but several nearby sources of these insects were present. Although bins were tightly sealed, eventually they were all infested by *Cryptolestes* spp. These small active pests were first detected by the pitfall probe traps in March (Fig. 4) and it was not until July when populations had increased significantly that they were found in the vacuum samples. In all cases, the pitfall traps showed significantly more *Cryptolestes* than the vacuum samples. As with *Tribolium*, the greatest differences between the two methods were at the end of the test when temperatures were greatest. No parasitoid was added to control *Cryptolestes* spp. but *X. flavipes* is a very effective predator of these pests (Brower and Press 1992). The vacuum samples showed more *Cryptolestes* adults in the check bins than in the biological control treatment bins, but the pitfall traps did not show any consistent difference between the two treatments (Fig. 4).

Most parasitoids and the predator, *X. flavipes*, are small and fragile and were very poorly represented in vacuum samples of grain. When host populations are low, as in our test, very few parasitoids emerge from incubated grain samples. However, the pitfall probe traps proved to be very good at sampling the small active parasitoids and predators used in this experiment. In fact, the pitfall traps not only documented the spread of the maize weevil parasitoid, *A. calandrae*, into the check bins (Fig. 5) but they also showed that the parasitoid increased rapidly on the larger host populations present in the check bins and actually exceeded the number of parasitoids in the release bins. After this peak of parasitoid density was reached on July 23, 1993 (Fig. 5), the abundance of the host

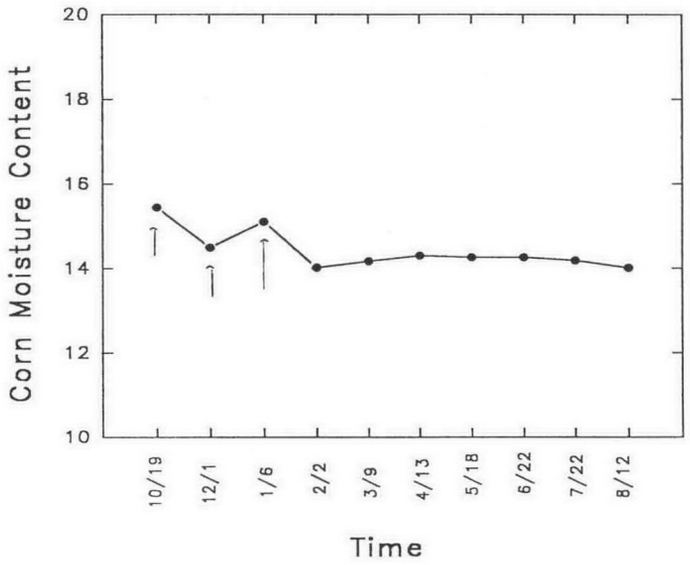

Fig. 1. Average grain moisture content from October 1992 –August 1993. Points are the average for the six bins with 15 moisture determinations per bin. Arrows indicate periods of aeration.

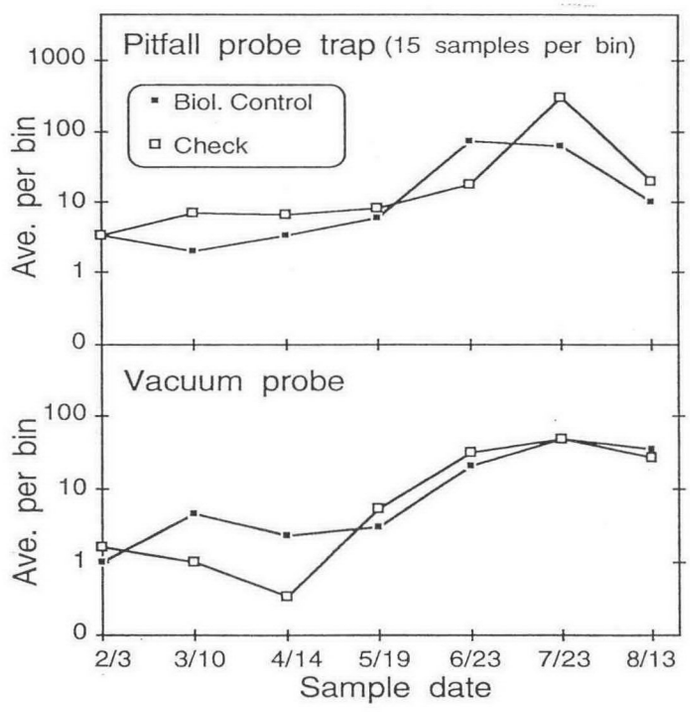

Fig. 2. Comparison of number of adult *S. zeamais* obtained by two different sampling methods. Each point represents the average number of insects in three bins as determined from 15 samples/bin.

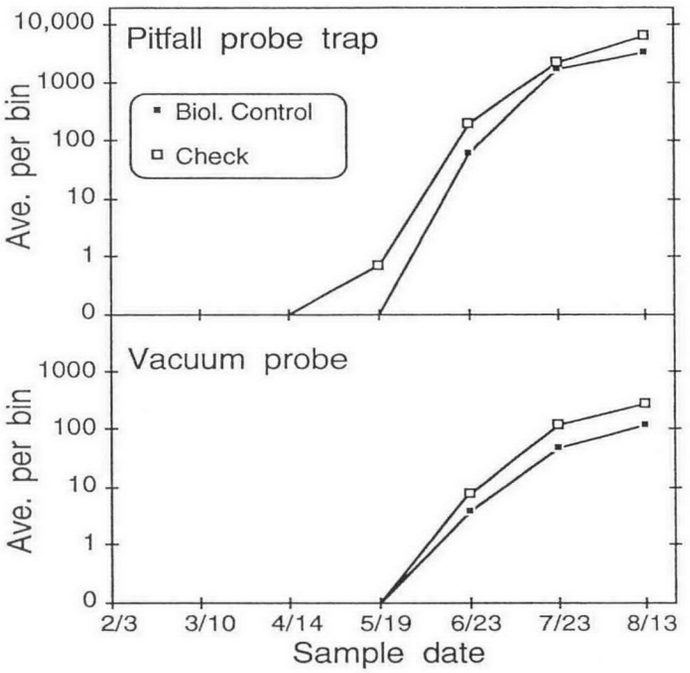

Fig. 3. Number of adult *Tribolium* spp. in pitfall traps and probe samples. Points are averages of total number of insects in three bins as determined by 15 samples/bin

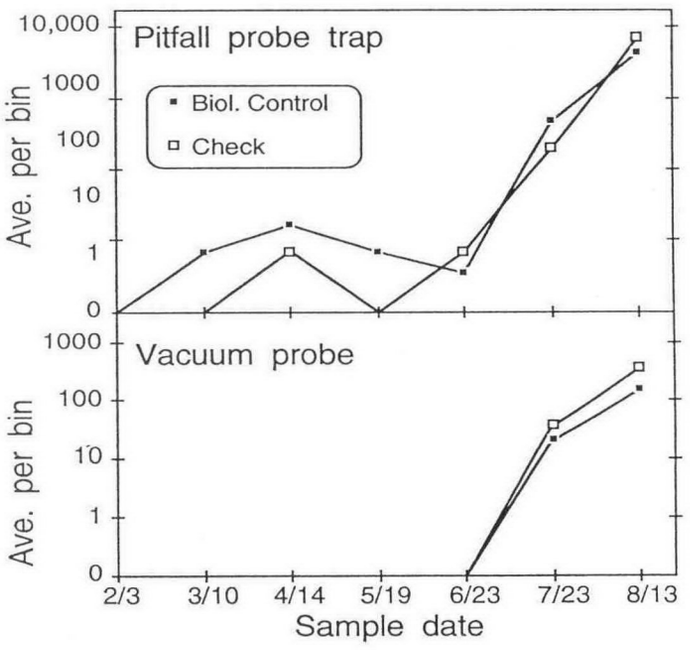

Fig. 4. Number of adult *Cryptolestes* spp. in pitfall traps and probe samples. Points are averages of total number of insects in three bins as determined by 15 samples/bin.

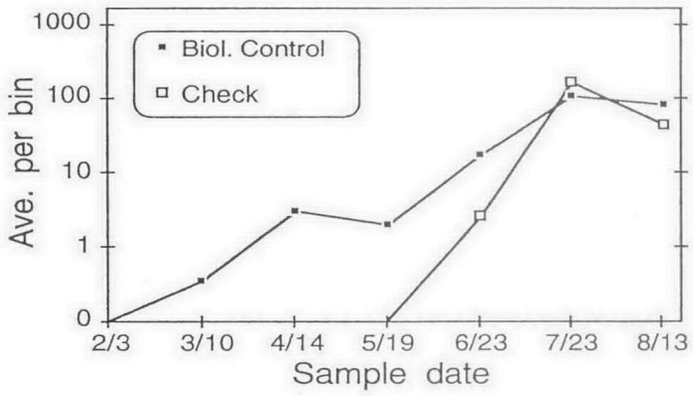

Fig. 5. Number of live parasitoids (*Anisopteromalus calandrae*) recorded in pitfall probe traps. Points represent averages of three bins with 15 samples/bin.

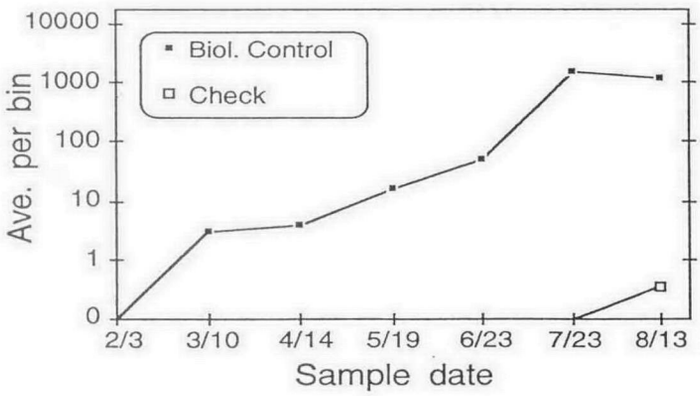

Fig. 6. Number of live predators (*Xylocoris flavipes*) recovered in pitfall probe traps. Points represent averages of three bins with 15 samples/bin.

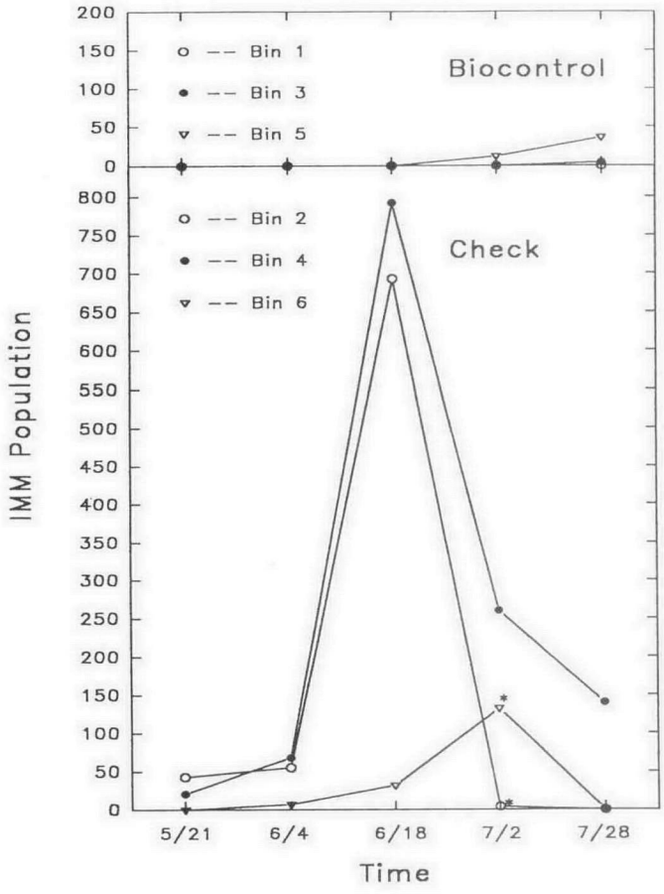

Fig. 7. Estimates of total adult *Plodia interpunctella* (IMM) populations in each of six bins (three treatment and three check) as calculated from mark-release-recapture data (see text for description of technique).

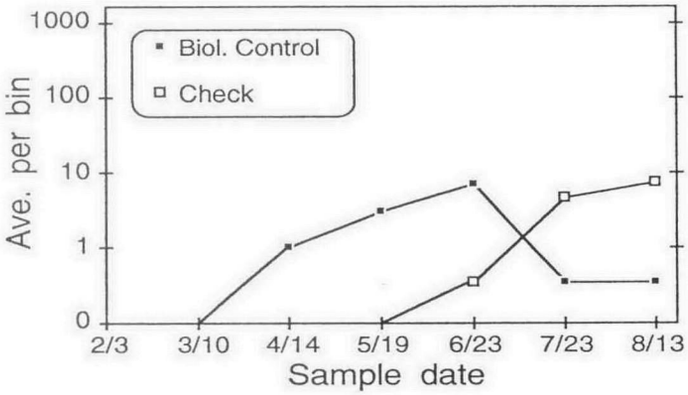

Fig. 8. Number of live *Bracon hebetor* recovered in pitfall probe traps in both biological control and treatment bins.

populations in the check bins declined (Fig. 2). This is probably the first use of pitfall grain probe traps to monitor parasitoid population abundance. In addition, these traps caught significant numbers of the predator, *X. flavipes* (Fig. 6). This bug is typically apterous or brachypterous and does not fly, and so it did not appear in check bins until August 13th and then in very low numbers. In contrast, it appeared in traps in the release bins early in the test and in increasing numbers through most of the test period (Fig. 6). In fact, such large numbers were caught during the last two months of the test (about 1000/bin) that it was feared this removal might decrease the effectiveness of this predator. In any case, this demonstrated that pitfall traps are an effective sampling tool for *X. flavipes* and probably also a good collecting technique for this species.

Standard grain sampling techniques are very poor for estimating moth populations, especially the pyralid pests such as *Plodia* sp. and *Ephestia* spp. This proved to be true in our case since both vacuum samples and probe pitfall traps indicated few to no adult *P. interpunctella* present. A *Plodia* larval sampling technique using corrugated cardboard rolls within 0.5 m metal cylinders inserted into the grain as larval refuge and pupation sites on the grain surface also proved to be negative. However, the pheromone baited flight traps used in the mark–release–recapture technique proved well suited to determining moth population abundance. Using estimating techniques described by Wileyto (these proceedings), the total moth population in each bin was calculated for a number of sampling dates and is shown in Figure 7. *Plodia interpunctella* populations in the biological control bins remained very small throughout the course of this test. In contrast, the adult populations in the check bins increased to over 125 in one bin and to 700–800 in the other two bins (Fig. 7). *Plodia interpunctella* populations peaked in mid-June and then declined precipitously to zero in two of the three bins by late July. Coincidentally with this abrupt decline in abundance was the presence and rapid increase in a specific parasitoid population.

Bracon hebetor is a parasitoid of the pyralid moths associated with stored products and, released into the treatment bins, significant populations are present during the period from April to June (Fig. 8). Few hosts were present in treatment bins during this period but large host populations were present in adjacent check bins (Fig. 7). Visual observations and probe trap catches showed that *B. hebetor* invaded the three check bins during May and June and these populations increased rapidly to outnumber the populations in the treatment bins that still were receiving weekly releases of *B. hebetor* (Fig. 8). The abrupt decline in moth abundance apparently resulted from the actions of these parasitoid populations.

Discussion

The determination of insect abundance in large bulks of grain has always been a difficult problem but one of great importance. Direct sampling methods such as grain triers and vacuum sampling are difficult, time consuming, and sometimes impractical, but the only way to get an absolute estimate of population density. To avoid some of the above problems, many types of insect traps have recently been developed. These are often much more effective at detecting low density insect populations than direct samples, and under some conditions they may catch large numbers of insects. However, environmental conditions greatly affect trap efficiency in most cases (Cuperus et al. 1991), and relating trap catch to absolute population density has proved to be very difficult (Barak and Harein 1982, Lippert and Hagstrum 1987). Thus, the present experiment was designed to sample 15 locations in each of six grain bins having different numbers of insects, by both vacuum samples and probe pitfall traps and to compare these results. This is the first report of those efforts.

Trends of pest populations were very similar using the two different techniques; however, the indication of absolute population size was not well correlated. Species that are more sedentary such as the maize weevil showed a much closer correspondence between the two methods than did highly mobile species such as the flat grain beetles. Environmental conditions seemed to affect the movement of highly mobile species more than they affected more sedentary ones. This study confirmed findings of others (Barak and Harein 1982; Lippert and Hagstrum 1987) that traps are a more sensitive detection method for low density insect populations. This study is perhaps the first to demonstrate the utility of pitfall probe traps for the detection and estimation of relative abundance of biological control agents. It appears that because effective beneficials are usually highly mobile, they are caught by pitfall traps very efficiently.

Differences in insect pest abundance between check bins and biological control bins were modest but usually demonstrable in this first year of the test. However, sampling and trapping techniques provided enough information to suggest improvements that might increase the degree of control attainable, and some of these changes have now been implemented.

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