SAMPLING AND TRAPPING INSECT POPULATIONS, THE IMPORTANCE OF ENVIRONMENT, INSECTS AND TRADE.

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Abstract

The ultimate success of any strategy for pest control is dependent upon the effectiveness of the methods used for monitoring the presence of pests. The requirements for methods of sampling insect populations in raw and processed foodstuffs are very different from those for measuring insect populations in storage buildings. Even in bulk commodities, methods which are appropriate for static cereal bulks may be ineffective for grain in transit. Sampling may be based on direct methods of inspection of samples and use of traps or by indirect methods which use indicators of insect presence. The behaviour of different species in response to their environment also has a profound influence on the choice of the most suitable method to use.

Much of the recent effort on the development of trapping techniques have resulted in traps enhanced by pheromones or food attractants which are apparently extremely effective for the detection of a wide range of insect pests. However, there has not been a similar amount of work devoted to the interpretation of trap catch and this has sometimes a produced a large gap between the objectives of a laboratory research programme and the real needs of the storage industry. It is clear that unless new and improved traps and sampling methods are introduced together with a strategy for their use in commercial storage practice, the potential benefits of any new techniques will be lost.

Introduction

The ultimate success of any strategy for pest control is dependent upon the methods used for monitoring the presence of pests. Routine treatments with residual insecticides or fumigant gas to obtain certificates or to meet statutary requirements are usually carried out irrespective of infestation levels. Because of this, apart from questioning the desirability of such practices, they need not concern us further. If, however, control strategies are based on reaction to insect presence and success is determined by some assessment of insect kill or survival, then it is essential to understand the limitations of the methods used and the need for intelligent interpretation of data.

The requirement for methods of sampling and trapping insect populations in raw and processed food are very different from those used for measuring insect populations in storage buildings. Even in bulk commodities, methods which are appropriate for large static cereal bulks may be ineffective for detecting insect infestation in grain in transit. This paper will therefore consider insect sampling and trapping methods in relation to the commodity and environment and the eventual interpretation of results.

Sampling

Sampling of commodities by extraction and examination of samples may appear to be relatively simple compared to trapping. However, as the very word 'sampling' implies, only a proportion of the material is removed for examination. Successful determination of insect infestation by interpretation of such samples is dependent upon the frequency and spatial distribution of samples and also the frequency and distribution of insects in the commodity. A further key factor is the efficiency of removal of insects from any samples. Various workers including Johnson [1979], Subramanyam and Harein [1991] and Lippert and Hagstrum [1987] have shown that the success of detection of insects by sampling is proportional to the size of samples taken and that many statutory or recommended sampling frequency levels for grain are below the level which would allow the regular detection of infestation levels as high as 2 insects/kg grain [Wilkin and Fleurat-Lessard In press]. At densities of 20 insects per tonne only 1% of samples taken would be expected to contain insects [Wright 1989]. Insects are under-dispersed or clumped in grain and it is a depressing thought that the detection of anything other than a heavy infestation of grain insects is more a matter of good or bad luck depending upon your commercial viewpoint. Even the detection of insects in samples is fraught with problems and it has proven extremely difficult to devise realistic or meaningful experiments to validate and calibrate such estimates Hagstrum *et al.* [1991],. Most of the preceeding comments relate to relatively simple problems posed by the detection of surface living infestation in grains, when situations dictate that the internal feeders such as grain or rice weevils need to be detected then completely different methods and approaches must be considered [Pinniger *et al.*, 1986, Chambers 1987].

Trapping

Any method which is more effective than proportional removal of samples would seem to be desirable. However, the success of more sensitive methods such as trapping techniques is usually measured by calibration of trap catch against a 'standard' sampling method [Subramanyan and Harein 1991]. In bulk cereals this may be by examination of samples removed by spear or vacuum and the realiability of such a baseline has already been questioned. In smaller scale experiments, infestation may be introduced into bulks at known densities and this may give more credence to the estimation of relative efficacy of traps by comparison of the numbers caught by different methods. Problems may arise because the very fact that insects are introduced into grain may mean that they do not respond to traps in the same way as 'normal' infestations. In addition, the insects may be distributed in a way which reflects their place and method of introduction rather than a natural dispersion [Hagstrum *et al.*, 1991].

Sampling of insects in buildings has always presented more problems than those of sampling bulk commodities. Counts of crawling or settled insects on predetermined areas is only practical when large numbers of insects are present. More usually, insects are much less visible and most of the population is confined to cracks, crevices and other dead spaces. Sampling of residues in harbourages to find insects can be effective and distribution of infestation in a building can be determined in this way. The major limitation to this procedure is that it necessarily destroys the habitat of the insect and is therefore a destructive 'one-off' method. Mark-recapture techniques are frequently used in ecological studies but they seem to be inappropriate for the study of the ecology of storage insects. The author once spent a tedious three hours marking the elytra of 200 grain weevils with white paint before releasing them into a small (100 tonne) grain store. One week later I returned to estimate the population by the frequency of recapture of marked individuals. Of the 30 insects found during an exhaustive inspection only one was marked and this was only found because it had died at the point of release. Other workers may have had more success with this technique but it does not seem to be recorded in the literature.

Physical traps were first devised in an attempt to catch insects in numbers and thereby reduce infestation problems. The first reference to the use of such traps seems to be in the ancient Greek Geoponika, the first handbook of pest control [Beavis 1988]. Together with more elaborate and fanciful schemes can be found the suggestion to place vessels filled with goat grease near and under beds to trap and control bedbugs (*Cimex*) and fleas (*Pulex*).
Sticky traps have been employed over the succeeding 2,000 years in attempts to control flies, moths and other insect pests. Although there are very few examples of traps eliminating or even limiting infestations it is a logical development to use such traps in a far more effective way to detect and monitor smaller populations of flying and crawling insect and use these data to implement successful control measures based on environmental manipulation or use of insecticides.

As with the calibration of traps in bulk cereals, the determination of the efficiency of traps in catching insects in storage buildings is extremely difficult. Any population estimates other than of very heavy infestations will usually be based on destructive sampling techniques which are not repeatable. Thereby lies one of the main advantages of traps in that except at very low levels of infestation or high densities of traps, trapping can proceed over a period of time without the method profoundly influencing the population. In many storage situations it is the sequence of trap catch data which is probably more informative than a one-off result. However, in any assessment of the value or otherwise of traps, the question which must first be answered is whether traps are more effective than existing procedures of inspection or examination of samples. Effectiveness must be defined. A frequently used standard is to compare the relative numbers of insects caught in a given period of time with a standard intensity of inspection and sampling effort. More striking examples often arise when traps detect insects before they are found by conventional means. Early discovery of infestation has been shown by pitfall traps in grain [Cogan and Wakefield 1987], moth traps in warehouses [Cogan and Hartley 1984] and baitbags in grain stores [Pinniger and Wildey 1975]. In some cases this has resulted in early warning which has avoided problems caused by infestation development or failure of fumigation. In other cases, no insects were detected by conventional sampling when insects were regularly being caught in grain pitfall and probe traps. This 'improvement' in insect detection can have conflicting results if guidelines on trap interpretation are not established and this question will be addressed later in the paper after an examination of trap improvements.

Sticky traps

Even though they are the oldest trap concept, there are many improvements to trap design which have been made in recent years. Many of these developments have been related to an increased knowledge of insect behavioural responses to objects and traps. Most effort has been devoted to cockroach traps with varying and sometimes conflicting claims for so called 'essential' design features. Most authors agree that a ramp and overhanging lip is a vital feature to improve trap efficacy and that strong adhesive is essential to retain adult roaches. The value of coloured cartoons of alluring female roaches on traps is questionable entomologically if not commercially. Much less is known about the responses of storage beetles to traps although Wyatt [1989] in his study of responses of *Oryzaephilus surinamensis* and *Tribolium castaneum* to sticky traps concluded than an overhang and lip were critical for storage beetles as well as cockroaches. This trap is now commercially available as a 'window' beetle trap. The value of vertical sticky surfaces on hanging traps for moths has been demonstrated and a vertical adhesive trap is also effective for some flying beetles such as *Lasioderma serricorne* and possibly *Anthrenus sp.* The effect of including food or pheromone attractant lures in sticky traps will be dealt with later in the paper.

The use of water filled bowls acting as pitfall traps also goes back to the times of the Ancient Greeks [Beavis 1988]. The principle of a buried pitfall into which insects blunder and fall has been widely adopted for use in ecological studies and they are particularly effective for active ground beetles [Greenslade 1964]. Pitfall traps were adapted for use on the surface of bulk grain in Germany in the 1960's and this idea has been developed in a number of ways. Firstly on the surface by using a plastic beaker coated with non-stick PTFE suspension (Fluon) to prevent trapped insects escaping [Cogan *et al.*, 1985] and more recently by the development of a "PC" pitfall trap with a perforated cover which allows insects but not grain to enter the trap [Cogan and Pinniger in press]. Although both the "window" trap and the corrugated card Storgard TM traps are sometimes called pitfall traps their facility to trap insects is more influenced by other design and behaviour factors than the pitfall principle.

Perforated probe pitfall traps

Originally conceived by Loschiavo [1975], this type of pitfall which is buried in grain catches insects which drop through small pitfall apertures into the trap. Inserted at various depths in grain this type of trap can be extremely effective and a number of designs have been produced [Barak 1991]. Prevention of insects emerging from the trap can be critical to the success of these and other pitfall traps and the use of an oil trap [Burkholder 1988] or non-stick PTFE coating [Cogan personal communication] has been suggested and shown to improve trap catch retention.

Other Traps

A number of other physical traps do not fall easily into the previous categories. These include electric grid UV light traps, suction moth traps and Storgard TM corrugated pitfall beetle traps. The latter type of trap has recently been developed with an oil-filled boat pitfall specifically for *Trogaderma granarium* [Barak 1989] but this oil also acts as an attractant.

Lures

All of the preceeding trap types will trap insects without lures but most have been shown to be more effective, sometimes by factors of x100, when they are enhanced by a pheromone or food attractant lure. The range of types and value of food pheromone lures has been extensively reviewed by Burkholder and Ma [1985] Chambers [1991], Pinniger and Chambers [1987] and others and the merits of individual lures need not be discussed in detail in this paper. However, it is now worthwhile examining the factors which influence trap catch to see if there are marked differences between traps or common principles which can be applied to all types.

Factors which influence trap catch

As trap catch will be determined by the combined effect of insect behaviour and trap design it is necessary to examine these separately before discussing their interaction. Influences on insect behaviour can be conveniently divided into those which are responses to external stimuli and those which are innate or driven by hormonal triggers within the animal. Of course it is understood that many of the internal responses will in turn have been triggered at some point by an external factor. A simplified diagrammatic scheme of internal and external influences is shown in Fig 1.

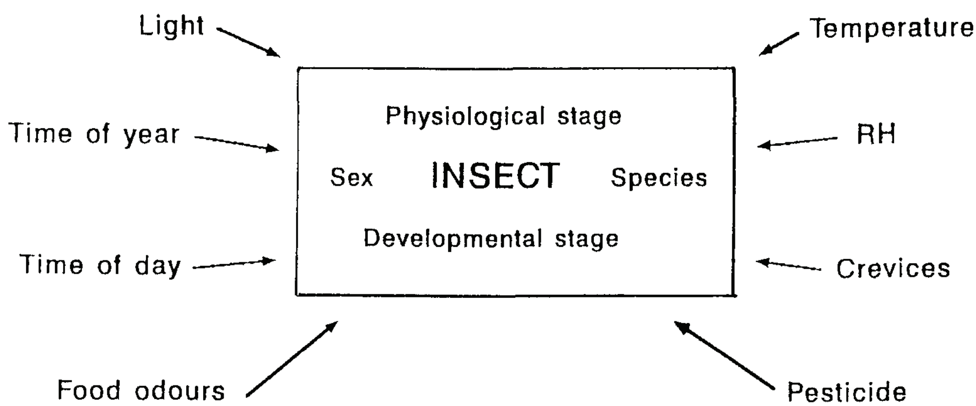

Figure 1. Factors which influence insect behaviour

The interaction between light and temperature on diurnal activity peaks or annual reproductive cycles is well known. This is partly because the enviromental influences are relatively easy to measure. Insect responses to behavioural modifiers such as food odours and cracks and crevices are far more difficult to investigate. Any interpretation of population sampling or trap catch must take into account all of these parameters and perhaps others not mentioned. A major problem arises in that it is relatively easy to measure macro climate of temperature and relative humidity in grain bulk or buildings. However, what the insect is responding to is the micro climate in its immediate vicinity. This sphere of influence could be as small as the difference between adjacent interstitial grain spaces or the changes in temperature, relative humidity, light and food odour as an insect penetrates cracks between bricks. A further external influence which is sometimes overlooked is the response of insects to pesticides applied for their control. The irritant action of natural pyrethrins which will flush cockroaches from harbourages is well documented and the repellancy of certain formulations to storage beetles has been documentated by Wildey [1987]. The effect of some treatments may be to drive insects deeper into harbourages and the eventual effect will be the selection of strains which are genetically different with greater refuge-seeking tendencies. The response of insects to fumigant gases also deserves more consideration. Bell [1987] has shown that insects which are repelled by sublethal doses of fumigant gas may then survive in buildings or in grain bulks.

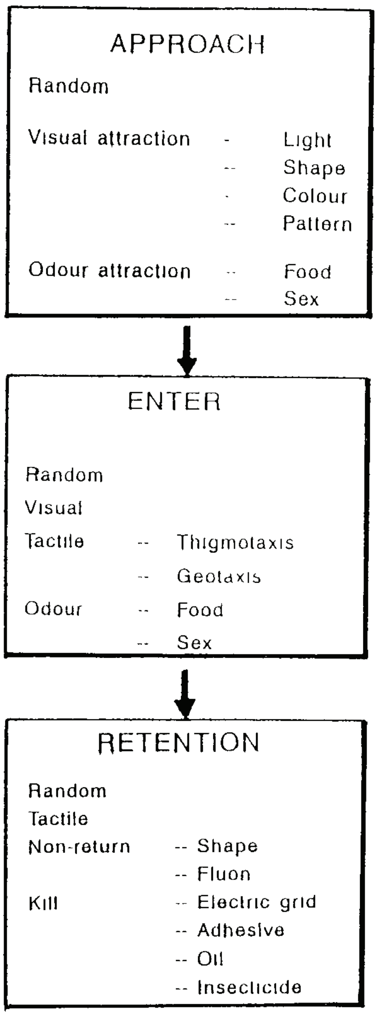

Figure 2. Insect response to traps

The ability to design effective traps depends on consideration of all the above factors and recognition also of the response of the insect to the trap itself. A simple scheme of insect trap interaction is represented in Fig 2. Successful traps range from extremely simple random or blunder traps effective against a wide range of species when used in large numbers or when there are high infestation levels, to complex traps designed to target on one insect species or family. These specific traps can be effective even at very low trap and insect densities. The decision on trap choice and use and the measure of success of trap strategy depends upon the economics of the system and of matching the resultant strategy to this.

Successful trapping strategies

The transition from laboratory experiments and field trials which may show that traps are very effective to the successful use of the trap in commercial practice is the greatest hurdle. This is partly influenced by the commercial factors of trap production, promotion and sale as described by Jones [1987]. It is not sufficient merely to produce an effective trap, it must be accepted by industry that the use of such a trap will be economically justified. Pressure for higher standards results in lower tolerances of insects and this can result in some conflict. Although in a well integrated system the use of traps can raise standards, the immediate effect of adopting traps may be to demonstrate the presence of insects in places and commodities where they were thought to be absent. Therefore the ability to detect insects at decreasing levels of infestation is not necessarily perceived as being beneficial to the food industry.

An unquestioned desire for increased overall sensitivity of insect monitoring systems comes from quarantine and inspection services who wish to exclude insects and prevent them entering countries or facilities. Conflict may result in the chain of food usage from the initial producer to intermediate traders and the eventual processing company. If the system operates on penalties for failure to meet certain standards based on discovery of insects then disagreement may result when one party has a more sensitive system than another. In the absence of sensible guidelines this can lead to dispute which reflects badly on the trap use. What is needed is a strategy for insect trap use and response designed for each trap, species and situation. Although we are obviously a long way from achieving this, there has been encouraging progress in some areas. The pressure for high standards in certain food processes such as confectionary and chocolate manufacture coupled with a desire to reduce pesticide residues from application of blanket control treatments has produced some of the best examples of trap use strategy.

The crucial point is that these systems were not designed and then improved on the system but have been evolved by the companies concerned with additional advice and input from economic entomologists. Many are based on the simplified scheme outlined in Fig 3 which can be modified for different environments and pests [Pinniger 1988].

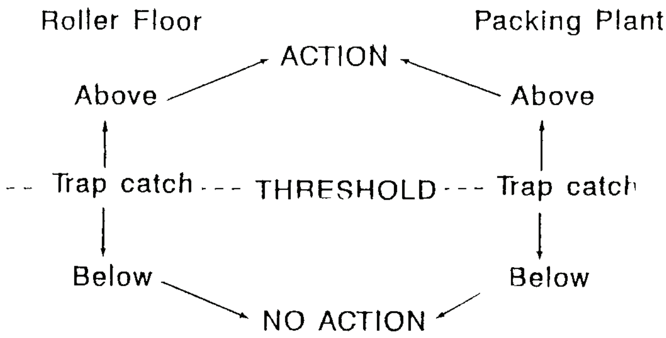

Figure 3. Detection strategy based on response to trap thresholds for two areas in a flour mill.

Thresholds can only be set by experience which reflects the needs of the industry and as stated previously they must be capable of revision upwards or downwards as deemed necessary. The scheme can be adapted for specific environments and storage situations for example strategies for monitoring bulk grain based on reaction to trap catch thresholds are described by Cogan and Wakefield [1987] and Wilkin [1991]. Decisions are taken at certain points depending upon environmental conditions, changing trap catch and fate of the grain and other economic pressures. These strategies can be successfully adopted by different users and for different trap types and commodities with the proviso that there is flexibility and feedback between the advisory entomologist and the user.

Improved trap designs will eventually result in higher standards and reduced pesticide use but only if high priority is given to collaborative development of strategies for trap use in practical storage programmes.

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L'ECHANTILLONNAGE ET LE PIEGEAGE DES POPULATIONS D'INSECTES, L'IMPORTANCE DE L'ENVIRONNEMENT, DES INSECTES ET DES REGLES COMMERCIALES.

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RESUME

Le succès final de toute stratégie de lutte contre les ravageurs dépend de l'efficacité des méthodes utilisées pour surveiller leur présence. Les méthodes d'échantillonnage des populations d'insectes vivant sur les produits alimentaires crus et conditionnés sont très différentes de celles servant à mesurer ces mêmes populations dans les magasins de stockage. Même dans les stocks de vrac, les méthodes appropriées ne sont pas forcément valables vis-à-vis du grain en transit. L'échantillonnage peut être basé sur des méthodes d'inspection d'échantillons et d'utilisation de pièges, ou même être indirectes et utiliser des appareils indiquant la présence d'insectes. Le comportement de nombreuses espèces par rapport à leur environnement influence aussi profondément le choix d'une méthode appropriée.

La plus grande partie des efforts entrepris pour concevoir des techniques de piégeage à la construction de pièges à phéromone ou alimentaires apparemment très efficaces dans la détection d'une large variété d'insectes ravageurs. Cependant, la même somme d'efforts n'a pas été déployée pour comprendre et interpréter le résultat de ces prises, ce qui a quelquefois abouti à créer un fossé entre les objectifs de la recherche en laboratoire et les besoins réels de l'industrie du stockage. Il est clair qu'à moins d'améliorer les méthodes d'échantillonnage, de piégeage, et d'introduire des stratégies nouvelles pour les employer dans la pratique commerciale, les bénéfices potentiels de n'importe quelle technique nouvelle seront perdus.